University of Southampton

Faculty of Environmental and Life Sciences

School of Health Sciences

Exercise Management for People with
Hand Osteoarthritis: A Mixed Methods Multistrand Study

by

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Abstract

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People living with hand osteoarthritis (OA) often experience challenges with performing daily functional tasks due to pain and joint stiffness. Exercises are frequently recommended for hand OA; however, their effects on pain and hand function remain uncertain. Research to determine the optimal exercise programme beneficial for this patient population was warranted. The aim of this PhD was to develop an exercise programme to improve hand pain, function, and quality of life in people with hand OA.

Using mixed methods multistrand research, the aim was addressed in three phases through five studies. Phase-1 comprised two reviews: (1) a systematic review of eight clinical practice guidelines and consensus recommendations on hand OA to provide evidence on contemporary recommended exercises and (2) a scoping review of 33 records to provide evidence on existing hand OA exercises, their development, prescription and adherence strategies. Phase-2 comprised two studies: (1) a qualitative analysis study to understand the views of 10 hand OA patients on an existing hand OA exercise programme and (2) a before and after study to investigate the proof of concept of a rapid-force hand exercise protocol, adapted from the lower limbs, in the hand of 8 healthy volunteers. Findings from Phases 1 and 2 were consolidated in Phase-3, which involved developing a novel hand OA exercise programme, which was tested in 18 adults with hand OA in a proof of concept mixed methods study (Phase-3). Quantitative data were analysed with SPSS statistics and qualitative data with NVivo software using inductive thematic analysis.

The systematic review provided evidence to support the use of strengthening, stretching and joint mobility exercises for hand OA management (Phase-1). These recommendations informed the synthesis of six frequently used exercises from the scoping review: “making O sign”, “making a fist”, finger and thumb stretch, grip strengthening, pinch strengthening, and thumb extension and abduction with elastic band. Based on suggestions from patients in the qualitative study (Phase-2), thumb extension and abduction with elastic bands were excluded from the summary of exercise recommendations due to challenges with pain and difficulty in performing the exercise activity. Findings from the proof of concept study showed positive trends towards the use of rapid-force exercises in the hand which were found to be tolerable and feasible in healthy volunteers. The rapid-force element was combined with the five recommended exercises to develop the Rapid-force Hand Osteoarthritis Exercise (Rapid-HOE) programme. The evidence-based Rapid-HOE programme was found to be feasible, tolerable, and acceptable. This novel programme demonstrated potential for successfully improving hand pain, function, and quality of life in people living hand OA. This thesis has advanced the field of hand OA management and provides a sound basis for a randomised controlled trial to examine the efficacy of the Rapid-HOE programme.

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Research Thesis: Declaration of Authorship

Print name: Beatrice Efua Amoke Sankah

Title of thesis: Exercise Management for People with Hand Osteoarthritis: A Mixed Methods Multistrand Study

I declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

I confirm that:

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Sankah BEA, Stokes M and Adams J (2019) Exercise programs for the management of people with hand osteoarthritis: a scoping review protocol (Protocol)*. JBI Database System Rev Implement Rep* 17 (4): 461-469

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Sankah B, Stokes M, Adams J (2017) Recommendations for exercises in hand osteoarthritis: a systematic review of clinical practice guidelines. PROSPERO 2018 CRD42018086440 Available from: http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42018086440

Signature: ....Date:........................

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Definitions and Abbreviations

Definitions

Confidence interval .... A range of estimated values within which the population parameter of interest lies.

Development .... The process of planning, implementing, and evaluating coordinated set of exercises designed to enhance the wellbeing and prevent or reduce the health limitations of people with hand OA.

Guidelines....................... Written statements developed systematically with the aim of assisting clinicians and patients to decide on the optimal health care for a specific clinical circumstance (WHO 1999)

Intra-rater reliability .... It reflects the variation of data measured by 1 rater across 2 or more trials.

Map .... A process of summarizing the evidence (Levac *et al.*, 2010)

Prescription...................... A written directive which constitutes the components and administration of any exercise program employed in the management of people with hand OA

Primary Studies .... Research conducted first-hand to obtain data

Rapid-force .... Ability to increase the force generated by a muscle as quickly as possible during rapid voluntary contractions from low or resting levels (Maffiuletti *et al.*, 2016).

Rate of rise of force .... It is the capacity to produce maximal voluntary activation in the early phase of explosive (rapid-force) contractions (i.e. first 50 - 75 microseconds) (Maffiuletti *et al.*, 2016).

Reliability .... Extent to which measurements can be replicated. It also reflects the extent of correlation and agreement between measurements (Koo and Li, 2016)

Secondary studies .... Research method that involves the use of already existing data, where these data are summarised and collated to increase the overall research effectiveness

Test-retest reliability......... It reflects the variation in measurements taken by an instrument on the same subject under the same conditions. It is generally indicative of reliability in situations when raters are not involved or rater effect is neglectable, such as self-report survey instrument.

Abbreviations

ACR................................American College of Rheumatology

ACSM..............................American College of Sports Medicine

AGREE............................Appraisal of Guidelines, Research and Evaluation

AIMS...............................Arthritis Impact Measurement Scale

AMED..............................Allied and Complimentary Medicine Database

BMI ....Body Mass Index

CDC................................Centre for Disease Control and Prevention

CINAHL ....Cumulative Index to Nursing and Allied Health Literature

CMC ....Carpometacarpal joints

COREQ ....Consolidated Criteria for Reporting Qualitative Research

CRD................................Centre for Reviews and Dissemination

DIP ....Distal interphalangeal

EBP ....Evidence based practice

EPPI ....Evidence for Policy and Practice Information Centre

EULAR ....European League Against Rheumatism

FCR................................Flexor Carpi radialis

FIHOA ....Functional Index for Hand Osteoarthritis

GCP................................Good Clinical Practice

GIN.................................Guidelines International Network

GoR................................Grade of recommendations

GRADE ....Grading of Recommendations Assessment, Development and Evaluation

GRIPP ....Guidance for Reporting Involvement of Patients and Public

IRAS ....Integrated Research Application System

ISRCTN ....International Standard Randomized Controlled Trials Number Registry

JBI..................................Joanna Briggs Institute

MCP ....Metacarpophalangeal joints

Definitions and Abbreviations

MEDLINE .... Medical Literature Analysis and Retrieval System Online

MRC .... Medical Research Council

NGC .... National Guideline Clearing House

NHMRC .... National Health and Medical Research Council

NHS .... National Health Service

NICE .... National Institute for Health and Care Excellence

NIHR .... National Institute for Health Research

OARSI .... Osteoarthritis Research Society International

OCTRU .... Oxford Clinical Trial Research Unit

OMERACT .... Outcome Measurements in Rheumatology

OTTER II .... Osteoarthritis of the Thumb Base Therapy Trial II

PEDro .... Physiotherapy Evidence Database

PhD .... Doctor of Philosophy

PIP .... Proximal interphalangeal

PoC .... Proof of Concept

PRISMA .... Preferred Reporting Items for Systematic Review and Meta-Analysis

PSFS .... Patient Specific Functional Scale

PPI .... Patient Public Involvement

QoL .... Quality of life

ROM .... Range of motion

SIGN .... Scottish Intercollegiate Guidelines Network

SRQR .... Standards for Reporting Qualitative Research

WHO .... World Health Organisation

Chapter 1 Introduction and PhD Overview

1.1 Introduction

This chapter introduces the overall PhD research. It discusses the rationale for the PhD study as well as the overall aim. Subsequently, a brief overview of the PhD research studies is also discussed. The chapter concludes with a discussion on the structure of the PhD.

1.2 Rationale for the PhD study

Hand Osteoarthritis (OA) is a common adult joint disorder with higher prevalence in women (92.3%) than men (89.9%) (Kodama *et al.*, 2016). According to the Centre for Disease Control and Prevention (CDC), age is a common risk factor (CDC2017). Although reported to affect adults of all ages, an increase in incidence is seen after 45 years. With the global aging population, the prevalence of OA is expected to rise. People with hand OA often experience pain, finger joint stiffness, reduced grip strength and limited hand function (Kwok *et al.*, 2011). Following the International Classification of Function, Disability and Health (ICF) framework (WHO2001), the impact of hand OA can be clearly identified in relation to reduced activity performance and restricted societal participation (Kjeken *et al.*, 2005). The CDC therefore highlights the need for further research to evaluate current and emerging evidence-based interventions to lessen the burden of the disease and improve the quality of life (QoL) of people living with OA (CDC2017). A preliminary review of literature revealed that many pharmacological and non-pharmacologic treatment interventions are used in the management of hand OA and exercises are among those frequently recommended. For example, the National Institute for Health and Care Excellence (NICE) and European League Against Rheumatism (EULAR) recommend the use of low impact physical activity, self-management and joint protection strategies, among others, as a core part of hand OA management (Zhang *et al.*, 2007; National Clinical Guideline Centre (UK), 2014). Despite these recommendations, guidelines are often criticised for aggregating their evidence from underpowered studies and expert opinion.

In the light of questioning the quality of research evidence that informs guideline recommendations, the magnitude of the effects of these recommended exercises have also been questioned, as researchers disagree on their benefits in this patient population.

Whilst some authors reported that existing exercises failed to improve performance-based measures such as handgrip strength and dexterity (Østerås *et al.*, 2014a), others documented moderate to high exercise effectiveness in improving pain (p=0.02), grip strength (p<0.001) and daily functional tasks (p=0.001) (Hennig *et al.*, 2015). A Cochrane review and meta-analysis to substantiate the evidence evaluated the harms and benefits of exercises in hand OA and concluded that low-quality evidence showed small beneficial effects of exercise on hand pain, function and finger joint stiffness with no harmful effects (Osteras *et al.*, 2017). However, the reviewers acknowledged their clinically debateable findings due to small effect size of the studies reviewed (-0.28, 95% CI -0.58 to 0.02 for hand function) and therefore recommended the need for further studies to determine the optimal exercise programme and dosage of these exercises for people with hand OA.

Premised on this Cochrane review, a robust evidence synthesis leading to the development of an optimal exercise programme for the management of people living with hand OA was therefore timely and warranted.

1.3 PhD Overall Aim

The overall aim of this PhD was to develop an optimal exercise programme to improve pain, hand function and QoL in people living with hand OA.

1.4 Brief Overview of PhD Research

The above aim was addressed in three phases through five studies (both primary and secondary research studies) using the mixed methods multistrand study design as outlined in Figure 1-1. Two studies were conducted in Phase-1; a systematic and a scoping review to identify the gaps in literature and synthesize exercise recommendations regarding existing hand OA exercise programmes. In Phase-2, two studies were conducted; a qualitative analysis study to ascertain patient experiences with existing hand OA exercises and a proof of concept study to explore the feasibility of the emerging exercise strengthening concept of rapid-force for use in the hand. Findings from Phases 1 and 2 were combined to develop a novel hand exercise programme which was tested in people with hand OA to establish its proof of concept and feasibility in Phase-3.

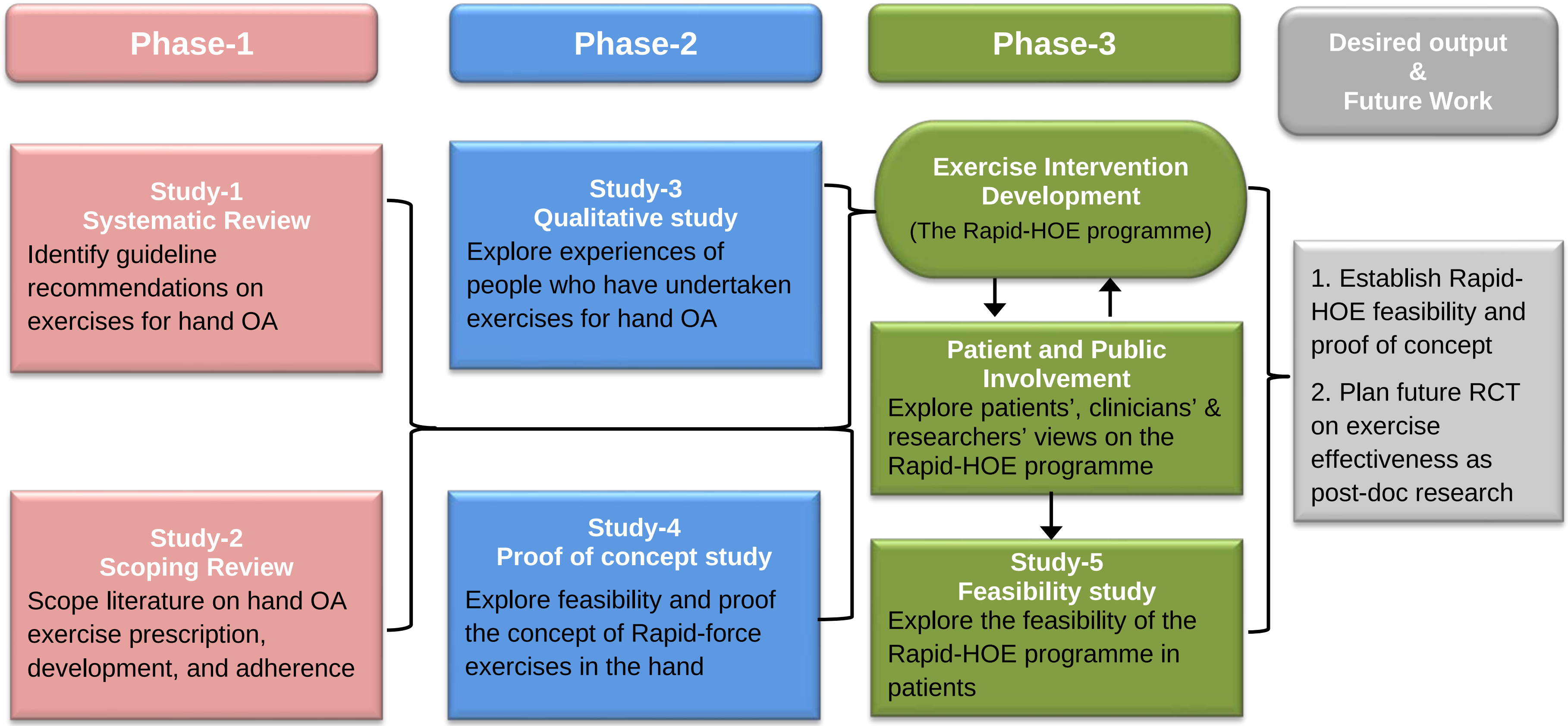

Figure 1-1: PhD Research Overview

1.5 Structure of the PhD

This PhD thesis is structured around ten chapters as illustrated in Figure 1-2. The thesis is introduced in chapter 1 (introduction and overview of the PhD) where the rationale, aim, brief overview and the structure of the PhD research are outlined. In Chapter 2 (overview of Hand OA), a snapshot of evidence regarding hand OA pertinent to the overall research aim was discussed. More specifically, evidence on the description, nature, epidemiology, and overview of hand muscles were reviewed and discussed. The methodology and methods employed within the PhD are discussed in Chapter 3. Here, methodological considerations underpinning this PhD research, the philosophical assumptions, and the choice to use the Mixed Methods research as a methodology and a method within this PhD were discussed. The above three chapters summed up the introductory chapters within the PhD, the succeeding six chapters presented the primary and secondary research studies conducted within this PhD to address the overall PhD aim.

Of the six chapters, two (Chapters 4 and 5) discuss the two secondary research studies conducted within this PhD: a systematic and a scoping review. Chapter 4 describes the systematic review conducted with an aim to identify available clinical practice guidelines and consensus recommendations on hand exercise interventions for hand OA management. Chapter 5 describes the scoping review to identify the gaps and recommendations regarding the development and prescription of hand OA exercise as well as the adherence strategies used with these exercises. Findings from both reviews were combined with that of the next two chapters (Chapter 6 and Chapter 7) to inform the development of a hand OA exercise programme for people with hand OA in Chapter 8.

The next two chapters discuss two of the three primary research studies conducted within this PhD: qualitative and proof of concept studies. Chapter 6 describes the qualitative study which explored the perspectives of hand OA patients regarding an existing hand OA exercise programme to seek a deeper understanding of addressing the overall research aim. Chapter 7 describes a quantitative study to explore the feasibility and prove the concept of rapid-force exercises in the hand of healthy volunteers. This study was based on the need to explore other strength training concepts, suitable for inclusion in hand OA exercises due to mixed reports on the benefits of existing strength training programmes.

Relevant findings from all four preceding studies previously mentioned (chapters 4-7) were synthesized to produce an exercise programme; the Rapid-Hand Osteoarthritis Exercise (Rapid-HOE) programme, which was reported in Chapter 8.

This chapter was presented in two sections; the first describes the evidence-based development of the Rapid-HOE programme and the second; the Patient Public Involvement (PPI) activity conducted as part of the exercise development process to explore views of relevant stakeholders' on the developed Rapid-HOE programme. The Rapid-HOE programme was modified based on relevant information from the PPI activity and the proof of concept study, and feasibility of the revised version were investigated in adults with hand OA using an explanatory mixed methods study design. Findings from this study, the third of the primary studies conducted within this PhD were reported in Chapter 9.

The PhD concludes in Chapter 10 where the summary of all the research studies conducted within the PhD and the main discussion points generated were briefly discussed. Also discussed are the strengths and limitations, implications of the research findings and recommendations for future practice and research.

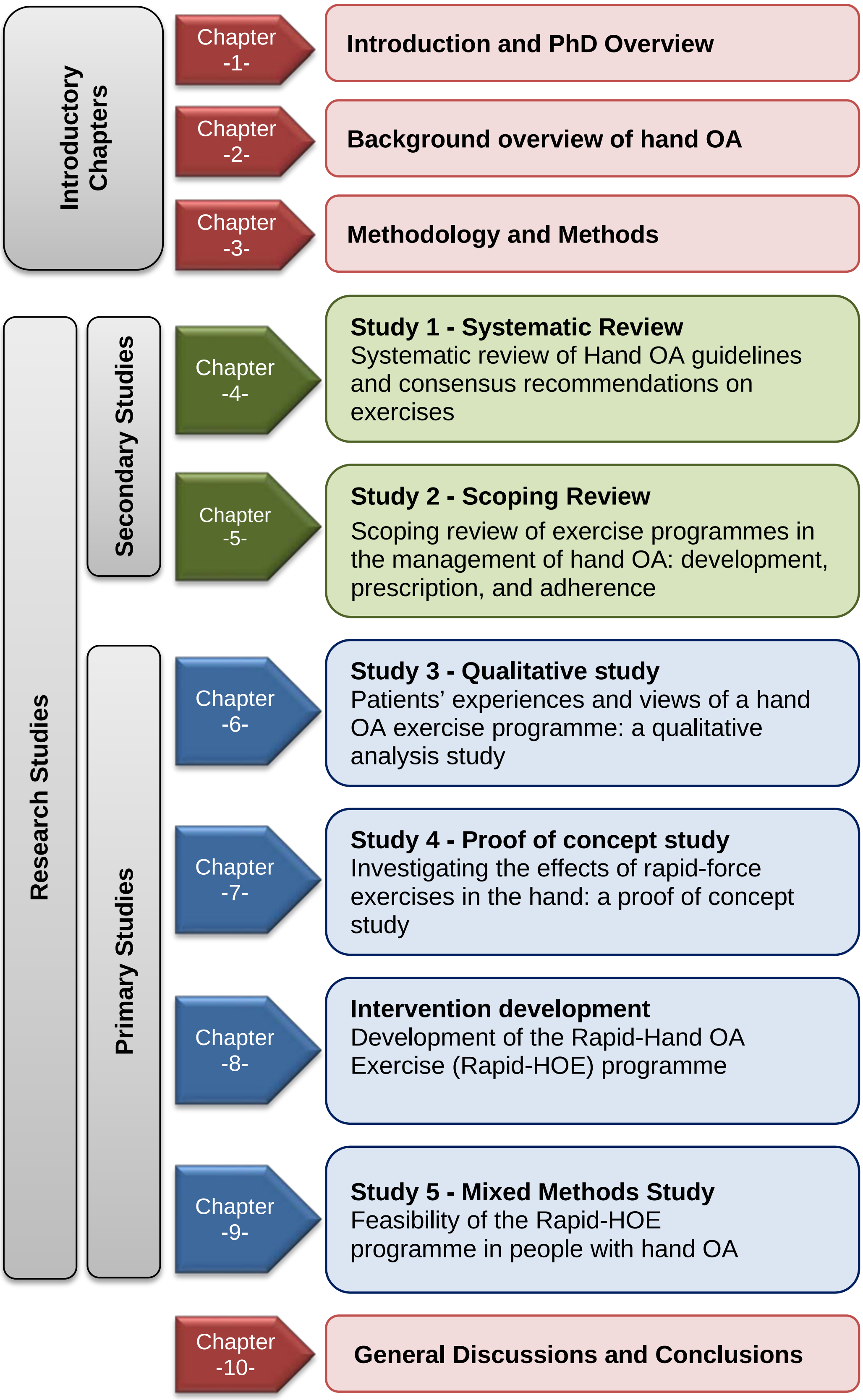

Figure 1-2: PhD thesis structure

Chapter 2 Background Overview of Hand OA

2.1 Introduction

This chapter provides a snapshot of evidence regarding hand OA pertinent to the overall research aim. Within this section, the description, nature, and epidemiology of the disease are discussed. The chapter concludes with a brief discussion on some muscles involved in hand movements.

2.2 Description and Nature of Hand OA

Hand OA is a common condition associated with pain and disability in the hand (see Figure 2-1). Pathologically, it is described as the gradual damage of articular cartilage linked to the degradation of the subchondral bone, joint borders, and periarticular structures of hand joints (De Oliveira *et al.*, 2011; Beasley, 2012). Radiographically, hand OA is characterised by the narrowing, erosion and malalignment of any hand joint with the presence of osteophytes (i.e. abnormal bone growth) (Altman *et al.*, 1990). Symptomatically, hand OA is generally described as the presence of pain, aches or stiffness in any hand joint with radiographic OA (Haugen *et al.*, 2011).

Figure 2-1: Example of hand OA presentations.

Images provided with permission from individuals living with hand OA.

The ACR in their seminal paper (Altman *et al.*, 1990) and widely used definition, described hand OA as any hand with the clinical presentation of tenderness, soft tissue swelling, joint deformity and hard tissue enlargement in two or more hand joints. The authors define these hard tissue enlargements as an increase in the normal structure about interphalangeal joints because of hard tissue or bony enlargement. The distal interphalangeal joints bony enlargements are called Heberden's Nodes and those of the proximal interphalangeal joints are Bouchard's nodes (see Figure 2-2).

Within literature, hand OA is also described as a systemic disease due to its association with OA at other sites. Indeed, available evidence shows that the presence of hand OA greatly increases the tendency for the development and progression of both knee and hip OA and in some cases, atherosclerosis. Individuals showing such disease pattern and relationship are often described as having a "generalized osteoarthritis" (Jonsson *et al.*, 2011). Generally, the joints of the hand normally affected are the distal interphalangeal (DIP) joints, proximal interphalangeal (PIP) joints and the carpometacarpal joints of the thumb (CMC1) (De Oliveira *et al.*, 2011; Beasley, 2012). Amongst these, the DIPs (35%) and the CMC1 joints (21%) are most commonly affected (Bertozzi *et al.*, 2015); the wrist and metacarpophalangeal joints are less often involved (Jonsson, 2017).

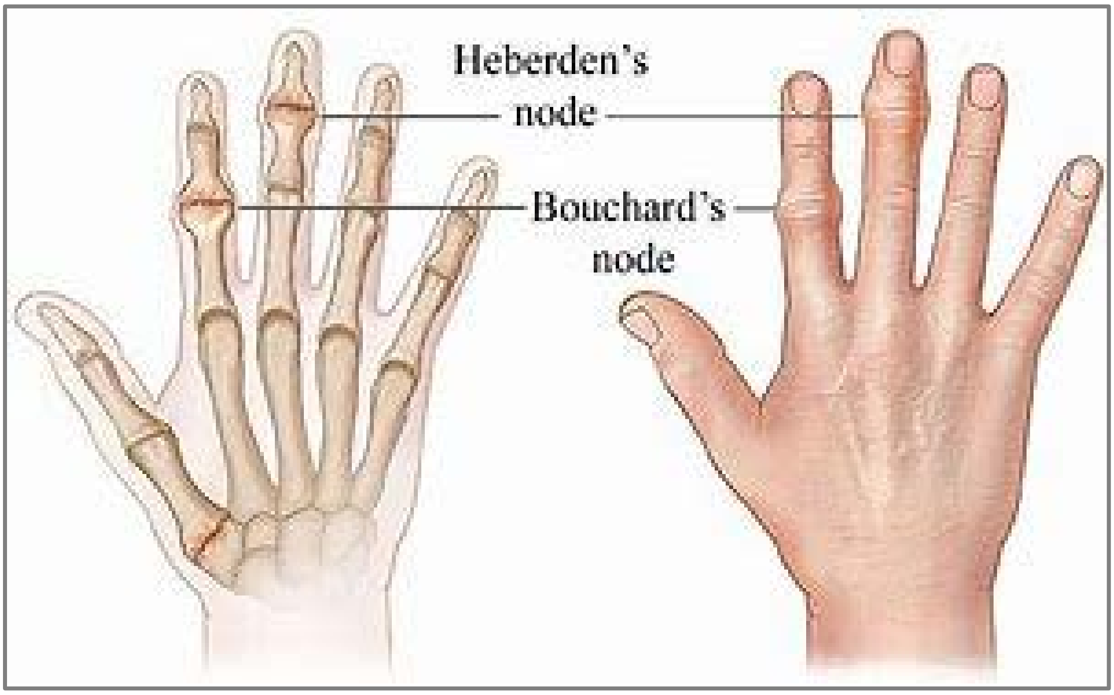

Figure 2-2: Image of a hand with hand OA showing Heberden and Bouchard's nodes.

Hand image reproduced with permission from Drugline.com (http://drugline.org/medic/term/heberden-node/)

2.3 Epidemiology

2.3.1 Prevalence and Incidence of hand OA

The prevalence of OA varies according to the definition of OA, the specific joints involved and sometimes, the characteristics of the study population (Zhang *et al.*, 2010). For example, regarding the definition, the prevalence of erosive and symptomatic OA have been reported to be much higher in women than men (9.9% vs 3.3% and 15.9% vs 8.2%) (Haugen *et al.*, 2011). The prevalence of photographic hand OA in the DIP, PIP and CMC1 joints diagnosed using digital photography was similarly found to be higher in women with marked increase in incidence after the age of 50 (Jonsson, 2017). Regarding specific joint involvement and population characteristics, age-standardised prevalence of hand OA was reported to be modestly higher in women (44.2%) than men (37.7%) (Haugen *et al.*, 2011).

2.3.2 Pattern and distribution of hand OA

The pattern of hand joints affected with hand OA varies in terms of the joint or joint groups affected. It is reported that whilst radiographic, symptomatic and erosive OA phenotype of the DIP, PIP and metacarpophalangeal (MCP) joints are more symmetrical in presentation, that of the CMC1 joint is more commonly seen in the left hand (Haugen *et al.*, 2011). Additionally, the distribution of hand OA is also described in terms of the age the disease development starts and gender. For example, the development of DIP joint OA starts at a younger age compared to PIP and CMC joints OA. In addition, DIP joint OA is reported to show a higher occurrence in females between 55 and 69 years with less marked gender difference after 70 years. Contrarily, PIP joint OA is less common than DIP joint OA and although it starts at an older age, its shows similar patterns of high female prevalence between of 60 and 70 years after which a fairly equal gender prevalence is noted (Jonsson, 2017). Unlike both the DIP and PIP joint OA, CMC1 joint OA is markedly common in females throughout life and its prevalence only increases in males after 75 years (Jonsson, 2017). Finally, photographic hand OA phenotype of the DIP, PIP and CMC1 joints have demonstrated a tendency towards a more right-sided involvement (Jonsson *et al.*, 2012).

2.3.3 Risk factors of Hand OA

It is globally recognised that the number of people with symptomatic hand OA is likely to rise due to the aging population and the obesity epidemic (Haugen *et al.*, 2011).

OA has a multi-factorial aetiology and can be considered the product of an interplay between systemic and local factors.

Examples of these factors are aging, gender, overweight and obesity, repetitive use of joints (occupation), bone density, muscle weakness, and joint laxity (Zhang *et al.*, 2010). Age is one of the strongest risk factors for hand OA. According to some researchers, the rise in prevalence of hand OA with age is perhaps the results of cumulative exposure to different risk factors and the poor coping mechanism of the joints to biological changes such as poor proprioception, weak supportive muscles and cartilage thinning (Zhang *et al.*, 2010). The female gender is another major risk factor for hand OA and from epidemiological studies, not only are women likely to have OA but they tend to develop more severe symptoms compared to men. Additionally, hand OA is also reported to be rife in women during menopause, which suggests the potential correlation between hormonal factors and the disease development (Zhang *et al.*, 2010). Also identified as a major risk factor for hand OA is obesity, as being overweight or obese increases the risk of developing the disease (Grotle *et al.*, 2008; Visser *et al.*, 2014). A population-based study reported that the incidence of general OA including hand OA increases with increasing body mass index (BMI) (Reyes *et al.*, 2016). Although, the level of evidence was moderate, a systematic review concluded that the development of hand OA is associated with weight or BMI, however further high-quality studies are needed to explain the role of weight in hand OA development as this was not clear within the literature reviewed (Yusuf *et al.*, 2010). Finally, occupation is also a recognised risk factor particularly with those that require the repetitive use of the hand (Zhang *et al.*, 2010). For example, workers whose job role requires the use of repeated pincer grip have been reported to develop DIP joint OA than those with job demands that require power grip (Zhang *et al.*, 2010).

2.3.4 Impact of Hand OA

Individuals with hand OA often experience hand pain, finger joint stiffness and reduced grip strength, which invariably impacts hand function, reduces work activity and limits societal participation (Kjeken *et al.*, 2005; Kwok *et al.*, 2011). According to the CDC (CDC 2017), about 43% of those diagnosed with hand OA report challenges with functional abilities and hand-related activity limitations. These challenges result in weaknesses and disabilities, which often interferes with the work output of most people living with the disease, with associated socioeconomic cost to both patients and society (CDC 2017). Regarding activity limitations and occupations, some of the common challenges generally reported are problems with managing household chores, functional mobility, personal care, and leisure activities.

More specifically, people living with hand OA also report that hand activities that involve considerable gripping and twisting of the hands such as wringing clothes and opening jars and bottles are most problematic for them (Kjeken *et al.*, 2005). Research has shown that people with hand OA have decreased HRQoL (Slatkowsky-Christensen *et al.*, 2007) and the common hand OA symptoms of pain, stiffness, and decreased hand function also largely contribute to negatively impact the QoL of people living with the disease (Kloppenburg *et al.*, 2018).

Based on the above discussed prevalence rate and socioeconomic burden of hand OA, the disease has been globally recognized as a public health concern, which warrants further enquiries into their evidenced-based management strategies to lessen the burden of the disease (CDC 2017).

2.3.5 Management of Hand OA

Hand OA is classified as a heterogeneous and chronic disease with a variety of signs and symptoms, which therefore warrants the use of a combination of different treatment strategies for its management (Kloppenburg *et al.*, 2018). The evidence-based EULAR recommendations for hand OA advised that hand OA management should primarily aim to control the symptoms and optimise hand function to maximise activity, participation and QoL of individuals living with the disease (Kloppenburg *et al.*, 2018). The optimal management of hand OA should therefore be approached from a multidisciplinary dimension using non-pharmacological approaches and sometimes pharmacological options where necessary (Kloppenburg *et al.*, 2018). Recommended evidence-based non-pharmacological approaches are education and training in ergonomic principles, pacing of activities, orthoses, assistive devices, and exercises. These interventions should be based on individual patients' preferences and on shared decision-making between the patients and the healthcare professionals delivering the interventions (Kjeken *et al.*, 2011; Osteras *et al.*, 2017; Kloppenburg *et al.*, 2018). Amongst the interventions above, exercises are frequently recommended either as single interventions or in combination with other approaches due to the beneficial effects in improving hand OA symptoms such as hand pain, grip strength, joint stiffness and limited function (National Clinical Guideline Centre (UK), 2014; Hennig *et al.*, 2015). Despite such reports, an RCT that evaluated the clinical effectiveness of an exercise programme in people with hand OA reported that whilst the exercises were well-tolerated within the population studied, only small gains in self-reported functional measures (i.e. hand pain, stiffness and disease activity) were recorded, and not the performance-based measures (i.e. hand grip strength or dexterity) (Østerås *et al.*, 2014a).

Premised on such mixed reports within the literature, a Cochrane review (Osteras *et al.*, 2017) that assessed the benefits and harms of exercises compared with other interventions employed for hand OA reported that low-quality evidence showed minimal beneficial effects of exercise on hand pain, function and finger joint stiffness, with few and non-severe adverse events. The reviewers however debated whether the estimated effects of the exercises found were clinically meaningful as the beneficial effects were only immediate after the intervention and not sustained at follow up. Recommendations for further research to ascertain the optimal exercise programme and the dosage of this exercise programme beneficial and sustainable within this patient population were made (Osteras *et al.*, 2017).

2.4 Overview of hand muscles

2.4.1 Thenar muscles

The thenar muscles are three short muscles located at the base of the thumb which produce a bulge known as the Thenar Eminence (see Figure 2-3) (Palastanga *et al.*, 2012). The thenar muscles are innervated by the median nerve and its function is to control the fine movements of the thumb including gripping, grasping, and pinching. The three thenar muscles are opponens pollicis, abductor pollicis brevis and flexor pollicis muscles (see section 2.4.1.1 - 2.4.1.3).

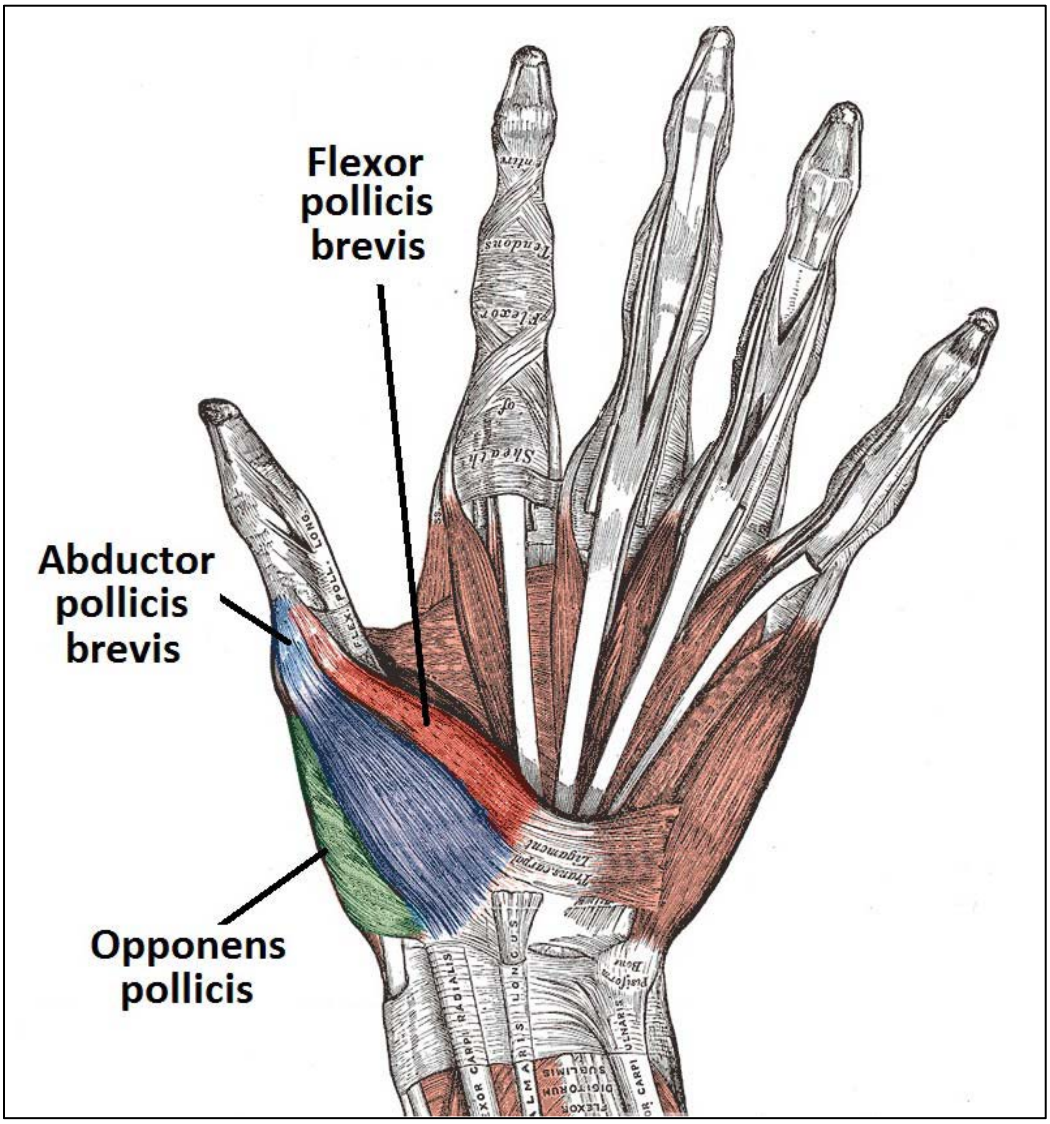

Figure 2-3: Palmer view of the Thenar muscles.

Reproduced with permission from TeachMeSeries Ltd. (2021).

2.4.1.1 Opponens pollicis

The opponens pollicis muscle is the largest of the thenar muscles and lies underneath the other two thenar muscles (see Figure 2-3). It originates from the tubercle of the trapezium, and the associated flexor retinaculum and inserts into the lateral margin of the first metacarpal bone. The action of the opponens pollicis muscle is to oppose the thumb by medially rotating and flexing the trapezium (Palastanga *et al.*, 2012).

2.4.1.2 Abductor pollicis brevis

The abductor pollicis brevis muscle is found anteriorly to the opponens pollicis and proximal to the flexor pollicis brevis (see Figure 2-3). It originates from the tubercles of the scaphoid, trapezium, and associated flexor retinaculum, and attaches to the lateral side of proximal phalanx of the thumb. The action of the abductor pollicis brevis muscle is to abduct the thumb (Palastanga *et al.*, 2012).

2.4.1.3 Flexor Pollicis Brevis

The flexor pollicis brevis muscle originates from the tubercle of the trapezium and from the associated flexor retinaculum and attaches to the base of the proximal phalanx of the thumb. It is largely innervated by the median nerve, but its deep head is innervated by the deep branch of the ulnar nerve. The action of the flexor pollicis brevis muscle is to flex the MCP and CMC joint of the thumb, and medially rotate the thumb (Palastanga *et al.*, 2012).

2.4.2 Flexor carpi radialis

The Flexor Carpi Radialis (FCR) muscle is found in the palmer aspect of the forearm and the most superficial of all the eight muscles found in that region (Figure 2-4). It is innervated by the medium nerve and situated alongside the palmaris longus, pronator teres, and flexor carpi ulnaris (Palastanga *et al.*, 2012). The FCR muscle originates from the medial epicondyle of the humerus via the common flexor tendon and inserts onto the palmer surfaces of the bases of second and third metacarpal bone (Palastanga *et al.*, 2012). The primary action of the FCR muscle is to work with the palmaris longus and flexor carpi ulnaris to flex the wrist. It also abducts the wrist and often described as the muscle used in waving the hand laterally toward the thumb side. The FCR muscle also assists with hand gripping (contracts in the forearm to pull the wrist forward anteriorly) and flexion of the forearm at the elbow.

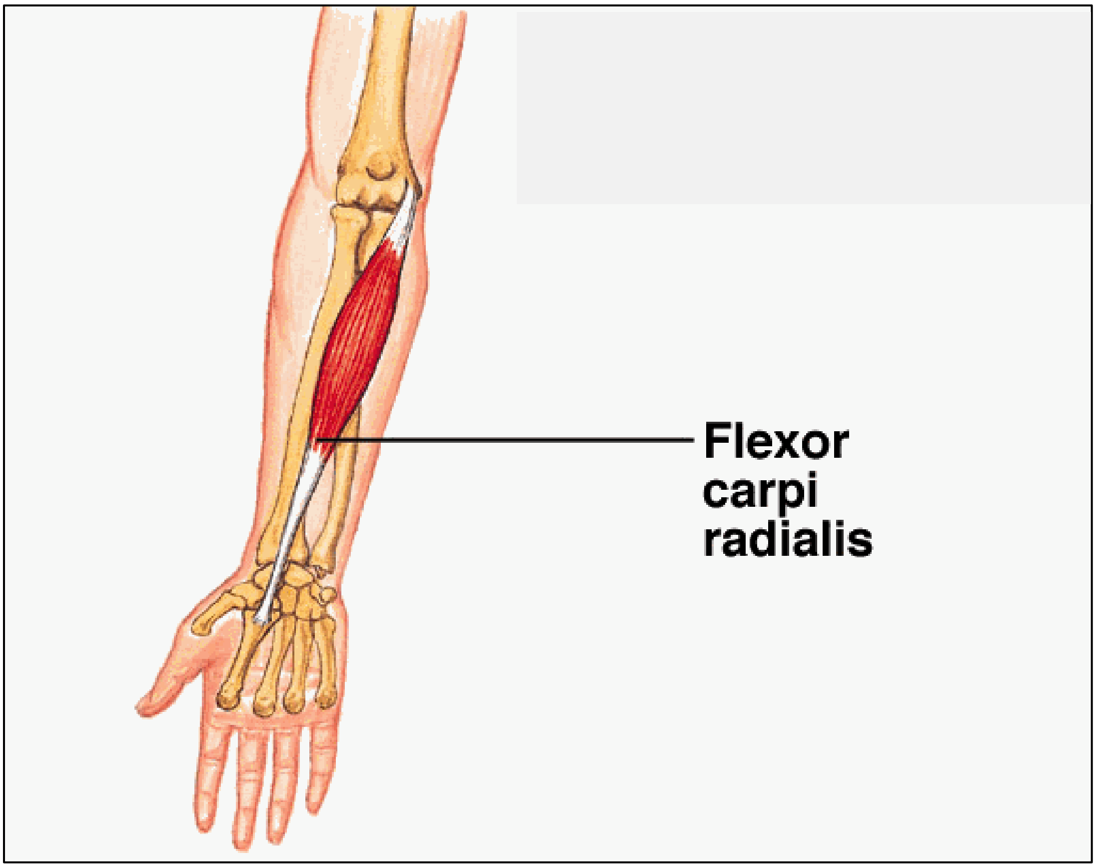

Figure 2-4: Palmer view of the FCR Muscle muscles.

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In summary, the action of the thenar and FCR muscles, their actions and contribution to the research focus is presented below (Table 2-1).

Table 2-1: Action of the thenar and FCR muscles and its contribution to the PhD research

Gross action	Individual actions	Contribution to research focus
Thenar Muscle Actions		
Controls fine Thumb motor movements	Abduct the thumb	N/A
	Oppose the thumb	Pinch grip action
	Flex the MCP joint	
Flexor Carpi Radialis		
Flex the wrist	Abducts the wrist	Hand grip action
Support hand gripping	Flexion forearm at elbow	

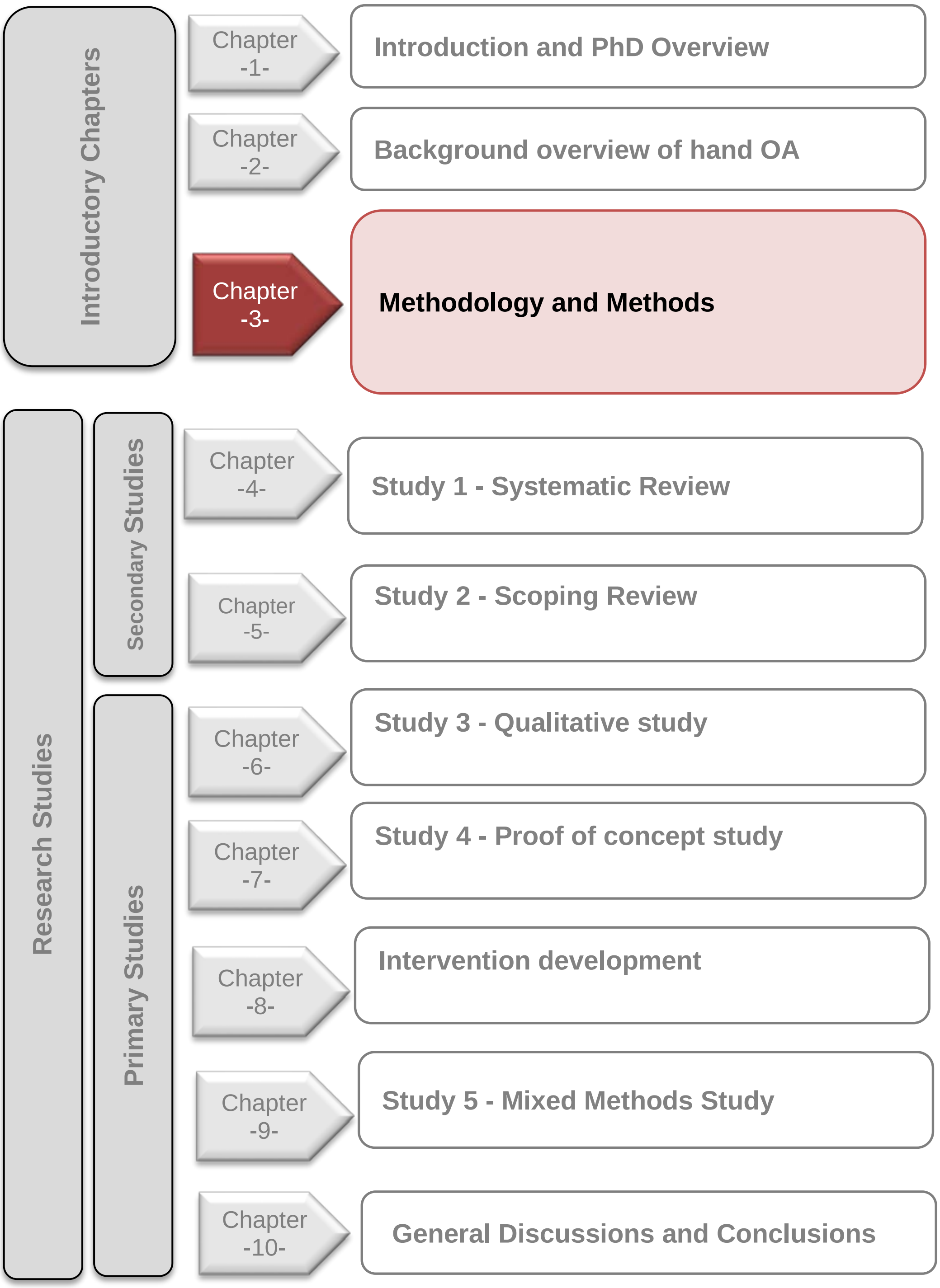
2.5 Research Gap

From the above background overview, the PhD researcher agrees with previous researchers that hand OA is indeed a public health concern due to its high prevalence, associated risk factors and impact on daily lives. Thus, the need to investigate and understand its epidemiology, diagnosis and management is justified. Amongst these three, the management of hand OA is therefore the focus of this PhD research.

2.6 Summary

This chapter has presented a brief overview of evidence regarding the description and epidemiology of hand OA as well as the muscles involved in hand and pinch grip activities. The next chapter discusses the research methodology underpinning the overall PhD research.

Location in thesis



Chapter 3 Methodology and Methods

3.1 Introduction

This chapter discusses the methodological considerations underpinning the PhD research. In this section, the philosophical assumptions, and the choice to use Mixed Methods research as a methodology and a method for the overall PhD research are discussed.

3.2 Broad Philosophical Assumptions in Health Research

The choice of an appropriate research method; be it quantitative, qualitative or mixed methods research is dependent on the research question being asked as well as the societal views, beliefs or philosophy of the researcher (Creswell *et al.*, 2018; Polit *et al.*, 2018). Researchers are therefore advised to situate their research in a selected paradigm that reflects their beliefs on the nature of reality and knowledge creation (Doyle *et al.*, 2016). Morgan (2007) defines a research paradigm as a system of beliefs and practices that influence how researchers choose the research questions they wish to study, and the methods employed to study them. Paradigms are therefore viewed by experts as a guide that researchers can use to ground their research (Shannon-Baker, 2016). The major paradigms that underpin health research are discussed below.

Positivism or Postpositivism is viewed as the first and dominant philosophical paradigm underpinning quantitative research (Bowling, 2009). It is described as the reflection of cultural views based on rationale and science (Polgar *et al.*, 2013; Polit *et al.*, 2018). Positivism is founded on objectivity. As such, quantitative research utilises data collection protocols, specified standardised operating procedures and analyses to reduce bias and generalise research outcomes to a wider population (Polit *et al.*, 2018). However, the positivism paradigm is sometimes flawed with limitations of lack of consideration of diverse human behaviour complexities, the quantification of non-numerical phenomena and the inflexibility of foresight in data collection and analysis. Premised on these limitations, Constructivism, a research paradigm key to qualitative research was developed. Contrary to positivism, constructivism seeks an in-depth understanding of a phenomenon formed through participants and their subjective views (Denzin *et al.*, 2011). Within this paradigm, flexible data collection and analytical approaches are used concurrently to develop evidence-based theories (Polgar *et al.*, 2013). However, the sampling approaches used invariably minimise the generalisability of qualitative research findings to the wider population (Polit *et al.*, 2018).

Some researchers argue that real life phenomena are multifaceted and complex, and indeed, the use of either qualitative or quantitative research alone are insufficient in answering some research questions (Creswell *et al.*, 2018). Some quantitative researchers are reported to have evolved to a point to recognise the role that qualitative research can play in quantitative studies and vice versa (Creswell *et al.*, 2018). To this end, Creswell *et al.* (2018) concluded that the complexity of some research problems calls for answers beyond simple numbers in the quantitative sense or words in the qualitative domain. The recognition of what both approaches add to address the complexities of health-related research problems heralded the evolution of Mixed Methods research in the late 1980s (Creswell *et al.*, 2018). To some researchers, it is the “third research paradigm” (Johnson *et al.*, 2007) or the “Third methodological movement” (Tashakkori and Teddlie 2010).

Described as an intellectual and practical synthesis based on qualitative and quantitative research, mixed methods research provides new ways to answer research questions and generate insights where the use of a single enquiry would be insufficient. It recognizes the importance of traditional quantitative and qualitative research but also offers a powerful third choice that often provides the most informative, balanced and useful results (Johnson *et al.*, 2007). Within mixed methods, the limitations of one study design is offset by the strengths of another and the combination of both methods provides a more complete understanding of a research problem than either approach by itself (Creswell *et al.*, 2018). Finally, mixed methods research helps researchers, particularly students using the approach to develop broader research toolkits and skillsets to address research questions, become productive members of research teams and enhance their ability to teach using multiple methods (Creswell *et al.*, 2018).

Having briefly reviewed the three broad paradigms that underpin health research, it was first apparent that to address the research question within this PhD (“what is the optimal hand exercise programme for people living with hand OA?”), the use of multiple research approaches as identified with the mixed methods research paradigm was needed. Secondly, it was also identified that the research question posed is complex, and as asserted by Creswell *et al.* (2018), the ideal and intuitive way of addressing such problems which reflects real life situations is by mixed methods research. Thirdly, when a need exists to develop, implement, and evaluate a programme, the mixed methods research is suitable as it affords researchers the opportunity to connect several studies to address study aims. With the overall aim of this PhD to develop and propose an exercise intervention for people living with hand OA, the PhD researcher recognised that the mixed methods research approach was the most suitable.

Premised on the above three points, the choice of mixed methods research as the methodological paradigm for this PhD was made.

3.3 The Mixed Methods Research Methodology

Creswell *et al.* (2018) articulated that researchers with an aim to conduct mixed methods research, in addition to identifying whether the research methodology is best suited for the research question must also understand the history, how it has evolved, and the current interest in it. In this section, the historical foundations and philosophical assumptions that underpin mixed methods research as a methodology is briefly discussed. Subsequently, the stance of the PhD researcher in the use of the approach is also discussed.

3.3.1 Development of Mixed Methods Research

Historically, the descriptions of mixed methods research have evolved to advance the notion that two forms of data, methods, research designs or philosophies are combined. Over the years, this research method has been called “hybrid” research (Ragin *et al.*, 2004), “combined research” (Crewell, 1994), “Mixed Research” (Onwuegbuzie, 2012) and “Mixed Methods Research” (Tashakkori *et al.*, 2010; Hesse-Biber *et al.*, 2015). Mixed methods research has been defined as “a type of research in which a researcher or team of researchers combines elements of qualitative and quantitative approaches for the purpose of breadth and depth of understanding and corroboration”. Several other definitions exist with different perspectives on what is being mixed with sometimes ambivalent views on what the research method includes (Johnson *et al.*, 2007; Tashakkori *et al.*, 2007; Lund, 2012; Creswell *et al.*, 2018). Premised on this, seminal mixed methods researchers; Creswell *et al.* (2018) who have pioneered the dialogue on this research approach provided a definition gleaned from several years of experience in teaching, conducting and publishing mixed methods research. According to the authors, mixed methods is a research in which the researcher:

- Collects and analyses both qualitative and quantitative data rigorously in response to research questions and hypotheses
- Mixes the two forms of data and their results
- Organizes the procedure into specific research designs that provide logic and procedure for conducting the study
- Frame these procedures within theory and philosophy (Creswell *et al.*, 2018)

This framework provided useful itemized steps to guide the design, conduct and reporting of this mixed methods PhD research.

3.3.2 Worldviews in Mixed Methods Research

In addition to knowing the historical foundations, literature articulates the importance of researchers in identifying and understanding the philosophical assumptions that underpin their chosen research methodology. These assumptions are described as worldviews and in mixed methods research, researchers are expected to bring to their research a worldview that informs their study (Creswell *et al.*, 2018). Within the mixed methods landscape, several worldviews are recognized, however four are typically identified as the most useful to inform and provide sound philosophical orientation to mixed methods research. These worldviews are Postpositivism, Constructivism, Transformatism and Pragmatism. According to literature, these worldviews differ in several ways such as: i) what is considered real in the world (ontology); ii) how we gain knowledge of what we know (epistemology); iii) the role value plays in research (axiology); iv) the process of conducting research (methodology); and finally the v) language of research (rhetoric) (Hesse-Biber *et al.*, 2015; Creswell *et al.*, 2018).

Positivism and constructivism have already been described in section 3.2, and here the transformative and pragmatic worldviews will be explained. The transformative worldview is pivoted on the need for social justice, the pursuit of human rights (Mertens, 2010) and the integration of value-based goals (Shannon-Baker, 2016) to improve the social world and for individuals to feel less marginalized (Creswell *et al.*, 2018). Although the PhD researcher seeks to produce evidence to enhance the QoL of hand OA patients, she acknowledges that the intended patient population are not marginalized in society as would be the case for a justification to adopt the transformative worldview.

The Pragmatic worldview is a set of ideas focussed on the consequences of research, the primary importance of the research question and the use of multiple methods of data collection to inform the problem under study (Creswell *et al.*, 2018). Philosophically, whilst this worldview recognizes the differences between the quantitative (positivism) and qualitative (constructivism) research methods, it also acknowledges that these methods are equivalent and both work to advance knowledge production (Doyle *et al.*, 2016). Practically, this worldview aims to find a middle ground between previously entrenched philosophical dogmas such as the quantitative and qualitative purists (Johnson and Onwuegbuzie, 2004) and by so doing, affords researchers the freedom to choose workable methods which best answers their research question.

As an emerging researcher, the PhD researcher appreciates the logic, beliefs and arguments of both positivist and constructivist worldviews. Additionally, the researcher also values the objective and subjective knowledge both worldviews advance and their role in health research.

As a clinical physiotherapist, the PhD researcher recognizes the importance of seeking the subjective views of patients (Constructivism) as well as the objective summary of assessed outcomes (Positivism) to make informed clinical judgements (Pragmatism). This is real life practice and indeed, clinically, a combination of approaches is needed and is what works. According to Creswell *et al.* (2018), the use of such real life phenomena oriented towards "what works" reflects the philosophical foundations of the pragmatic worldview, hence its choice to guide this PhD research. It is also noteworthy that the pragmatic worldview is recognized as the optimal worldview for mixed methods research and is largely embraced by most mixed methodologists (Feilzer, 2010; Tashakkori *et al.*, 2010; Creswell *et al.*, 2018).

Guided by pragmatic worldview, the PhD researcher therefore sought to produce evidence to enhance hand exercise management by combining the strengths of the positivist and constructivist worldviews to achieve a balance between subjectivity and objectivity throughout the PhD research.

3.4 Choice of Mixed Methods Research Design

Literature articulates that although mixed methods research is often thought of as a methodology or paradigm alongside quantitative or qualitative research, it is also considered as a research method (Creswell *et al.*, 2018) and within this PhD, it was adopted in both capacities. Having identified and discussed the appropriate research paradigm and worldview underpinning ones' chosen research methodology, researchers are also encouraged to choose a suitable mixed method research design that best answers their research question. From the literature, a plethora of research designs describing different methods were identified, however three core designs premised on their ability to provide useful frameworks for mixed methods research are recommended (Tashakkori *et al.*, 2010; Doyle *et al.*, 2016; Creswell *et al.*, 2018). These are the convergent, explanatory sequential and exploratory sequential mixed methods research design.

The convergent design is a one phase design, which involves a simultaneous concurrent collection of both qualitative and quantitative data followed by the combination of the data sources in the interpretation phase of the research (Creswell et al., 2018). Its intent is to obtain different yet complementary data on the same topic to better understand the research problem. The explanatory sequential design is a two phase design in which the researcher conducts a quantitative phase and follows up on specific results with a qualitative phase to help explain the quantitative results in more depth (Doyle et al., 2016).

Finally, the exploratory sequential design is a three-phase design in which the researcher collects and analyses qualitative data and then follows up with a development phase of translating the data into an approach or tool that is then tested quantitatively. Amongst these three core designs, perhaps the exploratory sequential design would have been suitable to address the PhD aim (i.e. develop an exercise intervention) based on its recommendations as the best design for developing new interventions (Creswell et al., 2018). However, it was recognized that the intended approach to be used in this PhD although similar differs slightly from the exploratory mixed methods design. Unlike the exploratory sequential design which begins with a qualitative phase, this PhD research requires both qualitative and quantitative studies as would be the case in a convergent design to feed into a development phase (exercise intervention development) and then a testing phase, as would be the case for the second and third phases of an exploratory design. Whilst the complexity of the above description lessened the confidence to use the exploratory design, the PhD researcher also recognized that other studies which feeds into the above described plan to address the PhD aim (i.e. studies 1, 2 and 5) (see Figure 1-1) additionally makes the PhD research even more complex.

Several complex mixed methods designs are available but a description of the proposed PhD study aligns with one; the Mixed Methods Evaluation design (Creswell *et al.*, 2018). Also referred to as Mixed Methods Multistrand design (Nastasi *et al.*, 2015) (the preferred name used within this PhD thesis), this complex mixed methods design includes a broad range of applied research approaches within numerous phases with different goals to address a research problem (Creswell *et al.*, 2018). Below are the typical phases in a mixed methods multistrand design:

1. Phase-1: The need for assessment phase
2. Phase-2: Theory development and adaptation phase
3. Phase-3: Programme development and testing phase and
4. Phase-4: Assessment of programme impact through outcomes and processes phase.

The first three phases will be conducted within the time limits for this PhD research, the last phase will be explored during the post-doc period. Below in Figure 3-1, the multiple phases of the multistrand design to be conducted within the PhD is described.

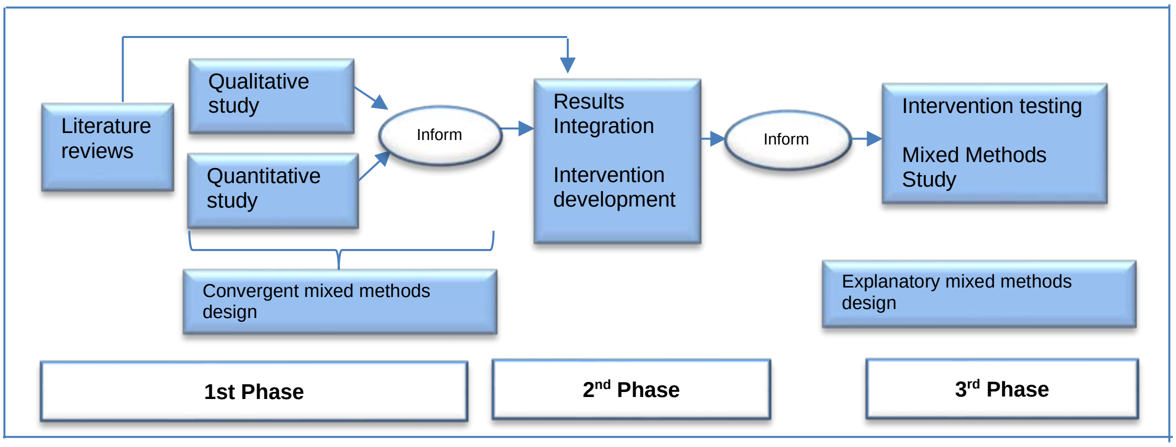
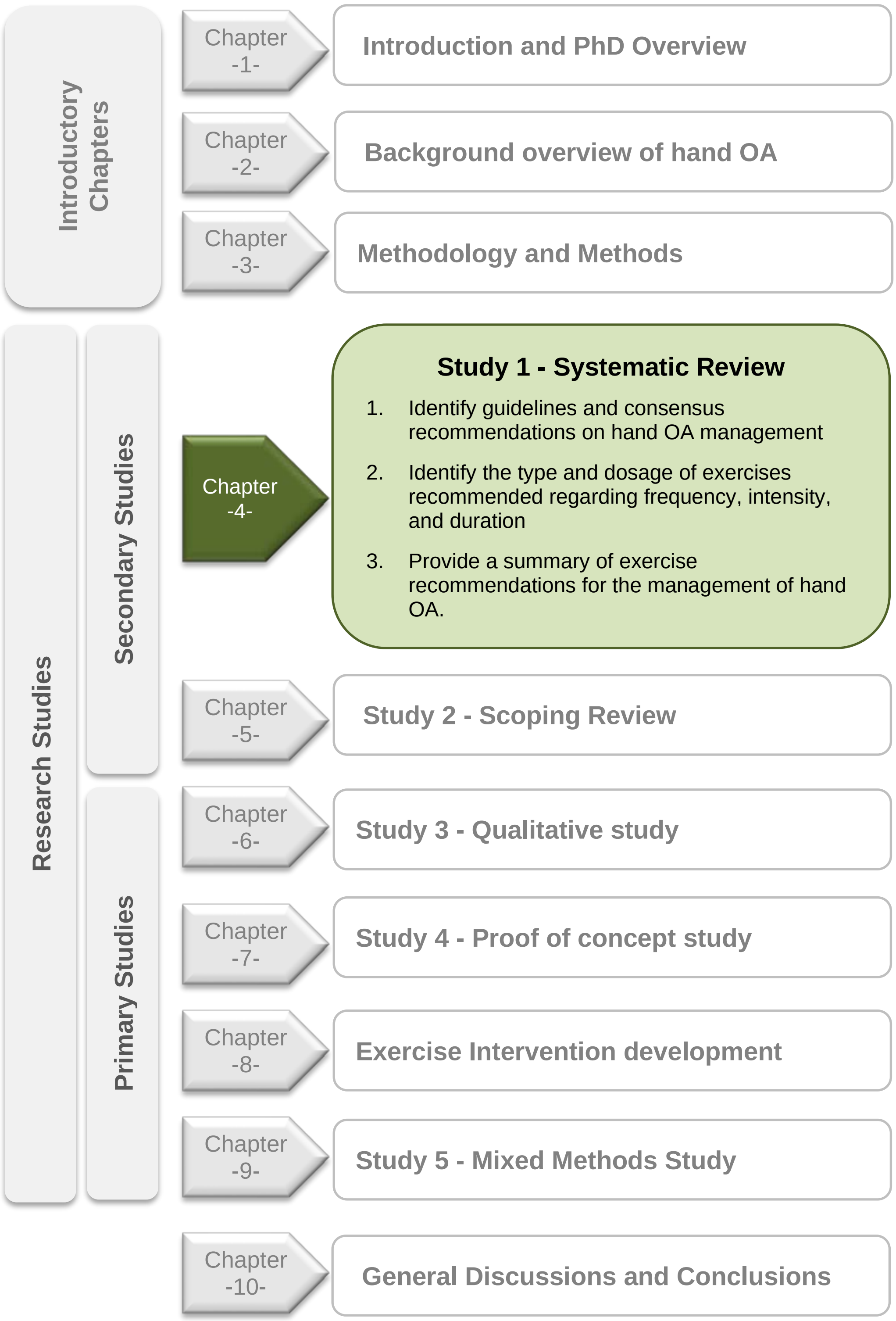


Figure 3-1: Description of PhD research as a Mixed Method Multistrand Design

3.5 Summary

This chapter has discussed the methodological considerations underpinning the PhD research and the rationale to use Mixed Methods Research both as a methodology and a research design. The next five chapters present the multiple studies that make up the mixed methods multistrand design and their relevance in addressing the PhD aim.

Location in thesis



Chapter 4 Study 1 - Systematic Review of Hand OA Clinical Practice Guidelines and Consensus Recommendations on exercises

4.1 Introduction

This chapter describes a systematic review conducted with an overall aim to identify available clinical practice guidelines and consensus recommendations on hand exercise interventions for hand OA management (see Figure 4-1). This review was driven by the questions: “what are the recommended hand exercise interventions for hand OA management” and “what are the type and dosage of these exercises recommended for implementation by clinicians in practice?” The protocol (Sankah *et al.*, 2018b) and review report (Sankah *et al.*, 2019b) for this systematic review have been published.

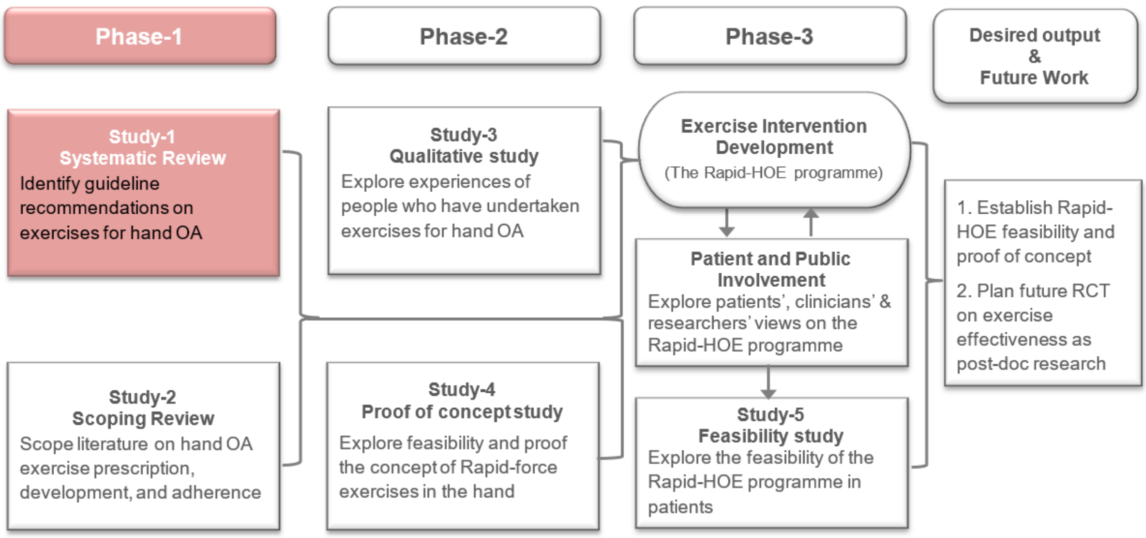


Figure 4-1: Systematic review location within the overall PhD research

4.2 Background

In the management of hand OA, several rehabilitation interventions, such as self-management strategies, joint protection interventions, low impact physical activity and muscle strength training exercises are reported as effective in managing general symptomatic OA (Conaghan *et al.*, 2008; Dziedzic *et al.*, 2015; Centre for Disease Control and Prevention, 2017). Amongst these, substantial evidence supports the recommendation of exercises (Hochberg *et al.*, 2012; Larmer *et al.*, 2014).

Despite the acknowledged benefits of exercise, agreement is lacking on its specific benefits for people with hand OA (Nelson *et al.*, 2014; Magni *et al.*, 2017; Osteras *et al.*, 2017) . Whilst some authors have criticized exercise for having minimal or no beneficial effect on hand muscle strength and range of motion (ROM) (Østerås *et al.*, 2014a), others report moderate to high effectiveness in improving pain, daily activity performance and grip strength (Hennig *et al.*, 2015). As previously mentioned (see section 1.2), a recent Cochrane review concluded that exercises are beneficial for improving hand pain, finger joint stiffness and hand function, with no adverse effects (Osteras *et al.*, 2017). The Cochrane review also highlighted the lack of consensus among researchers on the type and the content of exercise interventions most beneficial for this patient population. Currently, there is no clear indication or agreement of an optimal exercise intervention effective for people with hand OA.

Following an evidence-based perspective, such enquiries can only be made from credible sources that have considered and synthesized findings from the best available evidence, expert opinion, and patient preferences. From the literature, clinical practice guidelines, referred to as “Guidelines” from here, are recognized as the only valuable source for such synthesized evidence (Feder *et al.*, 1999; Graham *et al.*, 2011). Guidelines are the appropriate evidenced-based information source to aid health professionals in their clinical decision making (Scottish Intercollegiate Guidelines Network, 2017). A few systematic reviews of guidelines on OA are available (Pencharz *et al.*, 2002; Larmer *et al.*, 2014; Nelson *et al.*, 2014) however, none has specifically focused on providing a summary of exercise recommendations for hand OA. The present systematic review is important because addresses the question of whether hand exercises are indeed recommended as current best practice for hand OA management based on the established reports of its effectiveness. It will provide a summary of hand exercise recommendations for hand OA management to inform future research questions on the clinical applicability of these exercises. The specific objectives of this systematic review were to:

1. Identify guidelines and consensus recommendations on hand OA management to ascertain whether hand exercises are recommended as part of best practice
2. Identify the type and dosage of exercises recommended regarding frequency, intensity, and duration
3. Provide a summary of exercise recommendations for the management of hand OA.

4.3 Methods

4.3.1 Methodology

The recommended Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) approach was followed in the conduct of this systematic review (see Appendix A.1) (Liberati *et al.*, 2009; Moher *et al.*, 2009). The present systematic review protocol was published (Sankah *et al.*, 2018b) and its details registered on PROSPERO (https://www.crd.york.ac.uk/PROSPERO/display_record.php?RecordID=86440).

4.3.2 Eligibility criteria

This systematic review considered guidelines and evidence-based recommendations on any exercise intervention targeted at the hand for the management of hand OA (see Table 4-1).

Table 4-1: Inclusion and Exclusion Criteria

PICO	Inclusion criteria	Exclusion criteria
Population	1. Adults (aged >18yrs) with hand OA 2. Males and females	1. Rheumatoid arthritis or inflammatory arthritis 2. Children with hand OA
Intervention	Any exercise targeted at the hand or the upper limb	Other interventions e.g. electrical stimulation, continuous passive motion
Comparator	1. Other physical management of hand OA (Larmer *et al.*, 2014) 2. No treatment	
Outcome	1. Guideline Content 2. Quality of Guidelines 3. Strength of guideline recommendations	
Study type	1. Clinical Practice Guidelines 2. Consensus statements 3. Evidence-based recommendations, summaries, or reports 4. Best Clinical Practice 5. Guidelines published as books	1. Patient information booklets 2. Health information leaflets 3. Guideline for patients, duplicate guidelines, editorials, etc. 4.Overviews

4.3.3 Information sources

The following databases and grey literature sources were searched from January 1997 to December 2017 to provide all and the presumed available guidelines published on hand OA (see Table 4-2).

Table 4-2: Information Sources

Published Data sources (1997-2017)	Grey Literature sources	
	Data sources that index Guidelines	**Organizational websites**
AMED	Epistemonikos	African League of Associations for Rheumatology
CINAHL	Evidence for Policy and Practice Information Centre (EPPI-centre)	Agency for healthcare Research and Quality
Cochrane Library	National electronic library for health	AGREE collaboration
MEDLINE	National Guideline Clearing House	American College of Rheumatology
PEDro	NICE Evidence search	Arthritis Research UK
Web of Science and	TRIP clinical search engine	Canadian Institute of Health Research
JBI Database		Chinese Guideline Clearing House
		EULAR
		Guidelines International Network
		Kings Fund
		National Health and Medical Research Council (NHMRC)
		OARSI
		SIGN
		WHO

JBI: Joana Briggs Institute; NICE: National Institute for Health and Care Excellence WHO: World Health Organization; SIGN: Scottish Intercollegiate Guidelines Network

4.3.4 Search

Prior to the commencement of this systematic review, an initial search of existing reviews was conducted in Cochrane Library, Joana Briggs Institute (JBI) and Prospero databases. This search was conducted to avoid the duplication of potential review evidence and to ensure that no current systematic review existed on this review topic (Centre for Reviews and Dissemination, 2009).

With an aim to identify all available guidelines on exercise interventions for the management of hand OA, the comprehensive 3-step search approach recommended by JBI was adopted (Aromataris E *et al.*, 2017).

A preliminary limited search of CINAHL was undertaken using the identified keywords and subject headings. This initial search was performed: (1) to scope and ascertain the existing literature for quantity, quality and available records relevant to the review question; (2) analyse the text words contained in the titles, abstracts and index terms used to describe the available records to identify additional word variants for the main search; and (3) pilot the developed search strategy. With further advice from a librarian, the initial search strategy was refined to develop a more focused and comprehensive strategy which was used in the present systematic review as recommended in literature (Centre for Reviews and Dissemination, 2009; Booth *et al.*, 2016). Using the refined search strategy developed, the second and main literature search of this review was conducted in all identified published databases (Appendix A.2.1 - A.2.6) and grey literature sources. Records published in the English language between January 1997 and December 2017 were applied as limiters. The third and final step was the search of citations, bibliographies, and reference list of all included guidelines to achieve a more comprehensive search.

4.3.5 Study selection

All records identified were managed with Endnote X8 (Clarivate Analytics, PA, USA) and screened for initial eligibility. All titles and abstracts were screened against the broad inclusion and exclusion criteria by the researcher (BS) and independently verified by the primary supervisor (MS). Full text articles were screened against the detailed inclusion and exclusion criteria independently by BS and MS. Any disagreement was resolved through discussion with the second supervisor (JA).

4.3.6 Data collection process

Data extraction was performed by BS and independently verified by MS for consistency and completeness using a predetermined data extraction form designed for the purposes of this review (See Appendix A.3). To maximize the reliability of the form, it was piloted on one of the included guidelines to ensure that all essential information relevant to the review question were collected as recommended in the literature (Centre for Reviews and Dissemination, 2009).

4.3.7 Data items

In this systematic review, PICO was defined as follows: P-Population (hand Osteoarthritis); I-Intervention (hand exercises); C-Comparator (physical management strategies other than exercise (Larmer *et al.*, 2014); O-Outcome (guideline quality and content; strength of guideline recommendations). Additionally, "Risk of Bias" was assumed to be "Quality Assessment" and using the PRISMA checklist as a guide, all topics describing "Risk of Bias" were replaced with "Quality Assessment".

4.3.8 Quality assessment of Guidelines

The Appraisal of Guidelines, Research and Evaluation (AGREE) II instrument (Appendix A.4) is a globally accepted and transparent tool for evaluating the quality of guidelines (Brouwers *et al.*, 2010a; Brouwers *et al.*, 2010c; Siering *et al.*, 2013). It is a 23-item instrument arranged into six domains: scope and purpose (3 items), stakeholder involvement (3 items), rigor of development (8 items), clarity of presentation (3 items), applicability (4 items), and editorial independence (2 items). The instrument also includes two additional assessment items on "overall guideline assessment" which allows reviewers to make overall judgments about the use of the appraised guideline. The AGREE II instrument was used for the quality assessment of all included guidelines and consensus recommendations due to its established construct validity (Brouwers *et al.*, 2010c) and satisfactory inter-rater reliability (Brouwers *et al.*, 2010b). BS supported by MS performed the quality appraisal of all the identified records. Disagreements that arose were arbitrated through discussion during supervision meetings (see Appendix A.7 for details of the quality appraisal).

4.3.8.1 Individual Domain Assessment

Each AGREE II domain was scored by summing up all individual item scores and scaling the total as a percentage of the maximum possible score for that domain (Figure 4-2). The AGREE II score calculator was used (https://www.agreetrust.org/resource-centre/). A domain was addressed effectively if its score was ≥ 60%, a choice reported to represent adequate coverage of a criterion in previous systematic reviews of arthritis guidelines (Hurkmans *et al.*, 2011; Larmer *et al.*, 2014; Chang *et al.*, 2016).

$$\frac{\text{Obtained score} - \text{Minimum possible score}}{\text{Maximum possible score} - \text{Minimum possible score}} \text{ X } 100$$

Figure 4-2: Domain Score Calculation for AGREE II instrument.

4.3.8.2 Overall Guideline assessment

According to the AGREE Consortium (Brouwers *et al.*, 2010a), although the quantification of the individual AGREE II domains are useful in comparing guidelines, there are no specific set criteria to quantify the overall guideline assessment. Therefore, in this systematic review, the overall guideline quality was rated following the approach published by Hennessy et al (2016), where the overall AGREE II quality score was determined in the same way as the individual domain scores were calculated (see Figure 4-2). Through discussion among reviewers and based on personal judgement, an overall guideline quality score of 60% was considered as acceptable quality and guideline were graded high (≥ 60%), fair (30% > < 60%) or low quality (< 30%). Recommendations from high quality guideline were adopted for use and those from low quality guidelines were excluded. Fair quality guidelines were recommended with modifications and further classified as either high or low quality based on acceptable (≥ 60%) “Rigour of Development” domain score before adopting their recommendations. This domain choice was made premised on Jackson and Feder (1998) who reported that one of the key components of a useful guideline is its evidence-based development wherein relevant and valid evidence to inform clinical decision-making has been synthesized. Only when the rigour of development domain was adequately met was a recommendation from a fair quality guideline considered as evidence for synthesis in the systematic present review.

4.3.9 Synthesis of Results

Using a narrative approach, all acceptable recommendations on exercises for hand OA management were synthesized based on the levels of evidence and strength of recommendations. The present systematic reviews’ recommendations were formulated using the approach employed by Hennessy et al (2016) where recommendations were graded based on the level of underlying research evidence (A = grade of recommendation based on systematic reviews; B = grade of recommendation based on randomized controlled trials (RCT); C = grade of recommendation based on quasi-experimental studies; D = grade of recommendation based on non-experimental descriptive studies; GCP = Good Clinical Practice based on expert opinion). In addition, the PhD researcher decided iteratively during the conduct of the review to report the strength of the formulated recommendations. This choice was made premised on experts report, which suggests that strengths of recommendations provide clear direction to patients, clinicians and policy makers on the implications of recommended interventions and reflects the extent to which one can be confident that the desirable effects of an intervention outweigh the undesirable (Guyatt *et al.*, 2008a).

The strength of recommendations formulated in this review was rated using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) binary classification approach where “strong” represents strong recommendation for using an intervention and “weak” represents weak recommendation for using an intervention (Guyatt *et al.*, 2008a; Guyatt *et al.*, 2008b).

4.4 Results

4.4.1 Study Selection

The published databases searched generated 667 records. Of the grey literature sources searched, 10 full records were retrieved, and one identified to be in the process of development (see Appendix A.5). Nine records were identified from citation checking and reference tracking of all full text records retrieved making a total of 686 relevant records. Figure 4-3 shows the detailed study identification process. Of the 686 relevant records identified, 42 duplicates were removed. Titles and abstracts of the remaining 644 records were screened against the broad inclusion and exclusion criteria, and 625 irrelevant records were excluded. 19 suitable full text records that met the detailed a priori eligibility criteria were retrieved and scrutinized for inclusion after which 13 were excluded (see Appendix A.6). Six relevant records were identified. Finally, an update of the literature searches was conducted from December 2017 to January 2019 to ensure that all relevant guidelines published during the process of preparing the manuscript for publication were identified. From this search, one eligible guideline (Brosseau *et al.*, 2018) and one evidence-based Recommendation (Kloppenburg *et al.*, 2018) were identified. Overall, eight available published guideline and recommendations were included in this systematic review (see Table 4-3).

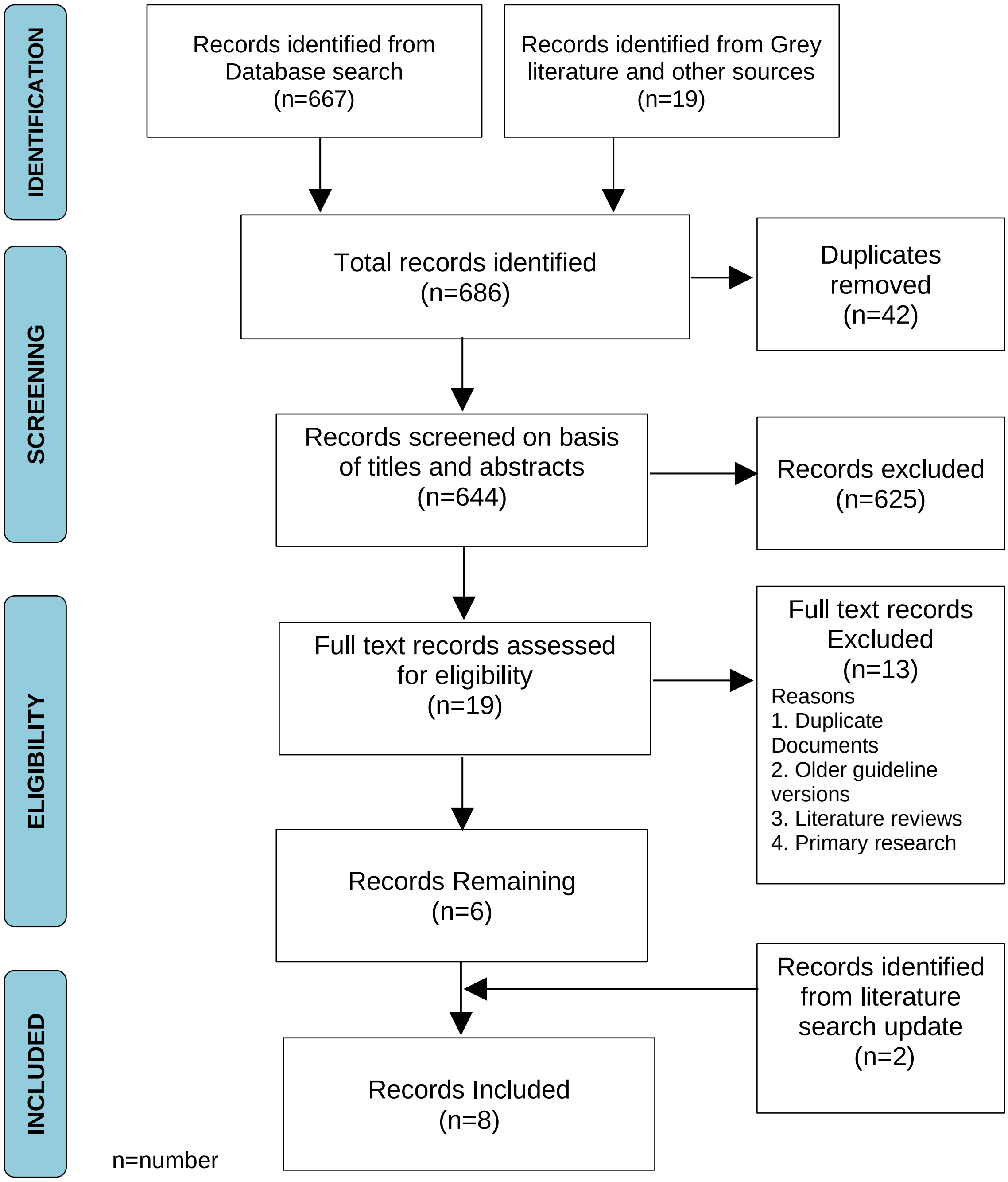


Figure 4-3: PRISMA flow Chart of Search Strategy

4.4.2 Guidelines and Recommendations Characteristics

Table 4-3 shows the summarized characteristics of the guidelines and consensus recommendations included in this systematic review. Of the eight records, three (43%) were developed in North America (ACR 2012, Ottawa 2018, Ottawa 2005), three (43%) in Europe (EULAR 2018, NICE 2014, SIR 2013) and one each (12%) in Africa (SAMA 2003) and Latin America (PANLAR 2016). There were no guidelines identified from Asia and Australasia. Amongst the guidelines included, three (EULAR 2018, SIR 2013, Ottawa 2018) were developed solely for the management of hand OA, whilst the other five for the management of general OA in adults, which included content on hand OA management.

Table 4-3 Characteristics of included Guidelines and Consensus Recommendations

	Guidelines and Consensus Recommendations				
	Authors	**Titles**	**Development organization**	**Country of origin** **Geographical location**	**Purpose**
Guidelines	National Clinical Guideline Centre (UK) (2014)	NICE Clinical Guideline CG177: Osteoarthritis Care and management in adults	National Clinical Guideline Centre (NCGC)	UK Europe	To update 2008 NICE guideline on OA
	Brosseau et al (2018)	The Ottawa Panel guidelines on programmes involving therapeutic exercise for the management of hand osteoarthritis	Ottawa Panel (Ottawa Methods Group and the Expert Panel)	Canada North America	1. To identify programmes involving therapeutic exercise that are effective for the management of hand osteoarthritis 2. To provide stakeholders with updated, moderate to high-quality recommendations supporting exercises for hand osteoarthritis
	Brosseau et al (2005)	Ottawa Panel Evidence-Based Clinical Practice Guidelines for Therapeutic Exercises and Manual Therapy in the Management of Osteoarthritis	Ottawa Panel, University of Ottawa, Canada	Canada North America	To create a guideline for the use of therapeutic exercises and manual therapy in the management of adult patients with a diagnosis of OA
	Brighton et al (2003)	Osteoarthritis: Clinical Guideline 2003	South Africa Medical Association (SAMA)	South Africa Africa	1. To provide an understanding of OA 2. To promote the cost-effective management of OA by doctor and other health care providers

	Guidelines and Consensus Recommendations				
	Authors	**Titles**	**Development organization**	**Country of origin** **Geographical location**	**Purpose**
Consensus Recommendations	Hochberg et al (2012)	ACR 2012 Recommendations for the Use of Non-pharmacologic and Pharmacologic Therapies in Osteoarthritis of the Hand, Hip, and Knee	American College of Rheumatology (ACR)	United States of America North America	To update the ACR 2000 recommendations for hip and knee osteoarthritis (OA) and develop new recommendations for hand OA
	Kloppenberg et al (2018)	2018 update of the EULAR recommendations for the management of hand osteoarthritis	European League Against Rheumatism (EULAR)	Europe	To update the 2007 EULAR Recommendations for the management of hand OA.
	Rillo et al (2016)	PANLAR Consensus Recommendations for the Management in Osteoarthritis of Hand, Hip, and Knee	Pan-American League Association of Rheumatology (PANLAR)	Latin America	1.To obtain agreement on OA treatment and to provide recommendations for the three most common joints affected by OA: the hand, hip, and knee
	Manara et al (2013)	Italian Society for Rheumatology recommendations for the management of hand osteoarthritis	Italian Society for Rheumatology (SIR)	Italy Europe	To update, adapt to national contest and disseminate the 2006 EULAR recommendations for the management of hand OA in Italy.

4.4.3 Quality assessment within Guidelines and Consensus Recommendations

4.4.3.1 Domain 1. Scope and Purpose

This domain deals with the potential health impact of guidelines on society and patients. Except for the SAMA (2003), all other guidelines and consensus recommendations met and addressed the scope and purpose domain effectively as recommended by the AGREE Consortium (see Table 4-4).

4.4.3.2 Domain 2. Stakeholder involvement

All included guidelines and consensus recommendations adequately covered and effectively addressed this domain with an average domain score above 60% (see Table 4-4).

4.4.3.3 Domain 3. Rigor of development

Except for SAMA (2003) (<30%), all others demonstrated adequate and effective coverage (≥ 60%) of this domain by reporting the systematic processes used in gathering and synthesizing evidence, and the methods employed to formulate and update their recommendations (Further details in Appendix A.7).

4.4.3.4 Domain 4. Clarity of presentation

This domain deals with the clarity of presentation of the guideline document with specific focus on the language, structure and format and in this review, all guidelines and consensus recommendations addressed this domain adequately except for SAMA (Brighton *et al.*, 2003) (see Table 4-4).

4.4.3.5 Domain 5. Applicability

Of the eight guidelines and consensus recommendations reviewed, only EULAR (2018) and NICE (2014) demonstrated effective coverage of this domain (≥ 60%) (see Table 4-4). These guidelines fully considered the barriers and facilitators to their implementation and additionally provided all the necessary materials to facilitate their easy applicability (see Appendix A.7).

4.4.3.6 Domain 6. Editorial independence

This domain addresses issues of competing interests in the guideline development groups. Except for SIR (2013) that failed to address this domain, all others demonstrated adequate coverage of this domain (≥ 60%) (see Table 4-4).

It can therefore be concluded that the formulation of recommendations from these guidelines (ACR (2012), EULAR (2018), NICE (2014), Ottawa2018 (2018), Ottawa2005 (2005), PANLAR (2016) and SAMA (2003)) were neither influenced by the funding bodies nor biased by competing interests of their development groups or taskforce.

Table 4-4: AGREE II Domain scores and overall Guideline quality assessment

Guidelines and Recommendations	Guideline Quality Assessment								
	AGREE II Domain Scores						Overall Guideline assessment		
	Scope and Purpose (%)	Stakeholder involvement (%)	Rigor of development (%)	Clarity of presentation (%)	Applicability (%)	Editorial independence (%)	Overall AGREE II Scores (%)	Quality Rating	Guideline recommendation
ACR (Hochberg *et al.*, 2012)	100	94	100	100	38	92	67	High	Recommended
EULAR (Kloppenburg *et al.*, 2018)	100	100	96	100	96	92	83	High	Recommended
NICE (National Clinical Guideline Centre (UK), 2014)	83	94	100	100	100	92	83	High	Recommended
Ottawa2005 (Brosseau *et al.*, 2005)	100	100	75	61	46	92	67	High	Recommended
Ottawa2018 (Brosseau *et al.*, 2018)	100	94	100	78	21	92	67	High	Recommended
PANLAR (Rillo *et al.*, 2016)	100	94	73	94	25	92	50	Fair	Recommended with modification
SAMA (Brighton *et al.*, 2003)	44	67	13	33	17	92	33	Fair	Recommended with modification
SIR (Manara *et al.*, 2013)	94	61	60	100	0	0	50	Fair	Recommended with modification
Mean Domain Scores	90	88	77	83	43	81			

Abbreviations: ACR: American College of Rheumatology; EULAR: European League Against Rheumatism; NICE: National Institute for Health and Care Excellence; PANLAR: Pan-American League Association of Rheumatology; SAMA: South African Medical Association; SIR: The Italian Society of Rheumatology.
Description of AGREE II items and Rating (see Appendix A.11 for further details).

Quality Rating and Interpretation: High quality (≥ 60%); Fair quality (30%> < 60%); Low quality (<30%).

4.4.4 Results of Guidelines and Consensus Recommendations

4.4.4.1 Identified Exercise recommendations

All guidelines and consensus recommendations considered to be of acceptable quality and recommended for use in this systematic review either tentatively or strongly recommended exercises for hand OA management, with the exception of ACR (2012) and Ottawa (2018) (see Table 4-5). Whilst the ACR (2012) did not make any recommendations regarding the use of exercises for hand OA management, the Ottawa (2018) made no strong recommendations. According to the Ottawa Panel (2018), programmes involving hand exercise with or without other interventions seem to have both short and long-term beneficial effects on hand OA. However, no strong recommendations were provided since the evidence to inform this decision was limited. Amongst the five guidelines that recommended exercises, EULAR (2012), NICE (2014) and Ottawa (2005) recommended exercises as a core part of interventions for the management of hand OA based on appreciable evidence, whilst the PANLAR (2016) and SIR (2013) recommended exercises in combination with other interventions (e.g. education, joint protection techniques; splinting based on substantial evidence). The PANLAR (2016), for example, agreed that a combination of an exercise regimen and splinting to improve pain and functionality is effective in the management of hand OA. To conclude, of the seven available high quality guidelines and consensus recommendations, five (EULAR (2012), NICE (2014), Ottawa (2005), PANLAR (2016), SIR (2013)) were found to recommend exercises.

Table 4-5: Exercise recommendations from Guidelines and Recommendations

Guidelines and Recommendations	Are Exercises recommended?	Exercise Recommendations	Strengths of recommendations	Level of evidence
ACR (2012)	No, only joint protection techniques and splints	N/A	N/A	N/A
EULAR (2018)	Yes	Exercises to improve function and muscle strength, and reduce pain should be considered for every patient with hand OA	A: based on consistent level 1 evidence (i.e. systematic review of RCTs)	1a: (Evidence based on systematic review of RCTs according to the oxford grading system)
NICE (2014)	Yes	Advise people with OA to exercise as a core treatment irrespective of age, comorbidity, pain severity or disability. Exercise should include Local muscle strengthening and general aerobic fitness	Limited evidence (not specific though the GRADE approach was used)	Limited generalised evidence was stated (authors reported that fewer studies were considered and most of the content of the recommendation were extrapolated from evidence for the knee).
Ottawa (2005)	Yes	For patients who meet the ACR criteria for hand OA, hand strengthening exercise has a clinically important benefit on pain and grip force	Grade A recommendation	Level I evidence (based on 1 RCT; n=40)
Ottawa (2018)	Yes	1.Programs involving hand exercise with or without other interventions seem to have beneficial short-term effects on hand OA in regard to pain, stiffness, physical function, grip strength, pinch strength, ROM, global assessment, PPT, fatigue, APL moment as well as long-term effects in regard to physical hand function and pinch strength. 2. No strong conclusive recommendations were provided about the effectiveness of programs involving exercise in the management of hand OA since they are based on a limited number of trials	The guideline had different strengths of recommendations for different exercise interventions. Since no specific key recommendation was proposed, the strength of recommendations could not be extracted and documented	Content could not be extracted as no strong recommendation was made

Guidelines and Recommendations	Are Exercises recommended?	Exercise Recommendations	Strengths of recommendations	Level of evidence
PANLAR (2016)	Yes	1.Education on joint protection together with an exercise regimen including muscle strengthening and ROM exercises 2. The combination of an orthosis (splint) with an exercise regimen to improve pain and functionality in the short and long term.	Combined reporting under level of evidence	IC (Based on expert opinion, case studies or case standards, there is general agreement that exercise, and education is beneficial, useful or effective) IIaB (Based on information from a RCT or non-randomized studies, there is evidence, or the authors agree that a combination of splinting and exercise is useful or efficacious in the management of hand OA)
SIR (2013)	Yes	Education on joint protection (how to avoid hand related adverse mechanical factors) together with an exercise regimen (involving both ROM and strengthening Exercises) are recommended for all patients with hand OA.	(95% CI): VAS 80 (73-87) Interpretation: At 95% confidence interval, the strength of the recommendation lies between 73 and 87 of the visual analogue scale	Level IV evidence (expert consensus report or clinical opinion or both)

NB: APL: anteroposteriorlateral movement; N: number; ROM: range of motion; RCT: Randomized Controlled trial; USA: United States of America; VAS: Visual Analogue Scale

Levels of evidence (Rillo et al., 2016)
IC: (I = There is evidence and/or general agreement that a procedure or treatment is beneficial, useful or effective; C= experts' consensus, case studies, or care standards); IIaB (IIa= evidence and/or agreement favour usefulness or efficacy; B=Information from RCT or non-randomized studies).

4.4.4.2 Prescription of Recommended exercises

Regarding the type of exercises, three specific (strengthening, stretching and ROM) and two generic ones (general aerobic fitness and exercise regimens) were recommended (see Table 4-6). All the five guidelines and recommendations recommended strengthening exercises, either as core or in combination with other therapies. Two (PANLAR (2016), SIR (2013)) recommended ROM exercises and one each recommended general aerobic fitness (NICE (2014)) and an exercise regimen to improve pain and functionality (PANLAR (2016)). Limited information regarding exercise dosage (i.e. frequency, intensity, and duration) was reported. Regarding exercise frequency, only EULAR (2018), reported the frequency of its recommended exercises. The authors reported that strengthening and stretching exercises for hand OA can be performed at variable frequencies and although these recommendations were non-explicit, indication for either home-based or supervised exercise sessions per week for several weeks were made.

Regarding exercise intensity, the EULAR (2018) reported, although not adequately, the intensity at which their recommended exercises can be performed. According to the authors, these recommended strengthening and stretching exercises can be performed at variable numbers of repetitions per exercise. All other guidelines and recommendations provided no information about exercise intensity. With regards to the duration of exercise performance, no information was provided by these guidelines and recommendations except for EULAR (2018) who although unspecific, reported that their recommended exercises can be performed for several weeks. In conclusion, it has been identified that for hand OA management, the type of specific exercises recommended by good quality guidelines and consensus recommendations are strengthening, stretching and joint mobility (ROM) exercises. These exercises can be prescribed as either weekly home-based or supervised sessions for several weeks with very few or non-severe adverse effects. It was also identified that an exercise regimen that improves pain and functionality of the hand, and general aerobic fitness may be helpful in managing hand OA.

Table 4-6: Dosage of Recommended exercises

Guidelines and Consensus Recommendations	Exercise Recommendations				
	Content of recommended exercises				Adverse effects
	Frequency	Intensity	Type	Duration	
EULAR (2018)	1. Home-based exercises after single instruction for several weeks 2. Multiple supervised sessions per week for several weeks 3. Variable frequency of exercising	Variable number of repetitions per exercise	1. Home-based or supervised exercises 2.Strengthening or stretching exercises	Several weeks	Few and non-severe adverse effects
NICE (2014)	No information in text	No information in text	1. local muscle strengthening exercises 2. General aerobic fitness.	No information reported in text	No information reported in text
Ottawa (2005)	No information in text	No information in text	strengthening exercise	No information reported in text	No information reported in text
PANLAR (2016)	No information in text	No information in text	1.Muscle strengthening 2.ROM exercises 3. Exercise regimen to improve pain and functionality	No information in reported text	No information in text
SIR (2013)	No information in text	No information in text	1.Strengthening exercises 2.ROM exercises	No information in text	No information in text

4.4.4.3 Summary of hand exercise recommendations for hand OA management.

Table 4-7 shows the summary of five hand exercises recommendations produced from this systematic review based on the underling guideline evidence and balance between the desirable and undesirable effects of exercises. Having considered the report of few and non-severe adverse effects (undesirable effects) and the proposed benefits on function and pain (desirable effects), three of the five recommendations were classified as strong, as the PhD reviewer was certain that the desirable effects outweighed the undesirable. The remaining two were rated weak based on the low quality of underpinning evidence and the uncertainty regarding the trade-offs between the desirable and undesirable effects, as no information on adverse effects were reported.

Table 4-7: Summary of hand exercises recommendations for the hand OA management

Hand Exercises Recommendations	Grade of Recommendation	Strength of Recommendation
Exercises to improve hand function, muscle strength, and reduce hand pain such as strengthening, stretching and joint mobility exercises should be considered for every patient with hand OA. These exercises can either be prescribed as home-based or supervised weekly exercises over several weeks.	A	Strong
Hand strengthening exercises should be considered for hand OA management due to their clinically beneficial effect on hand pain and grip force	B	Strong
Exercises in combination with orthosis improves hand pain and functionality in both short and long term	B	Strong
Education regarding an exercise regimen including muscle strengthening and ROM exercises (in combination with joint protection techniques) should be recommended for all patients with hand OA	GCP	Weak
Advise people with hand OA to exercise as a core treatment irrespective of age, comorbidity, pain severity or disability. Exercise should include local muscle strengthening and general aerobic fitness	GCP	Weak

NB: Grades of Recommendation (GoR) (based on Hennessy et al (Hennessy *et al.*, 2016)
A= GoR based on systematic reviews; B = GoR based on randomized controlled trials; C= GoR based on quasi-experimental studies; D = GoR based on non-experimental descriptive studies; GCP = Good Clinical Practice based on expert opinion.

Strength of Recommendation based on the GRADE's binary system of classification (Guyatt *et al.*, 2008a) Strong: Strong recommendation for using an intervention; Weak: Weak recommendation for using an intervention.

4.5 Discussion

4.5.1 Summary of Evidence

A systematic review with an overall aim to identify all available guidelines and consensus recommendations on hand exercises for hand OA management was undertaken. Eight available guidelines and evidence-based recommendations were identified and critically appraised using the AGREE II instrument. Of the eight, seven (NICE (2014), Ottawa (2018), Ottawa (2005), ACR (2012), EULAR (2018), PANLAR (2016), SIR (2013)) were found to be of fair to high quality based on the robust quality assessment performed, and thus recommended for use, and their recommendations were considered acceptable and synthesized as evidence in the present systematic review. Of this seven, five (EULAR (2018), NICE (2014), Ottawa (2005), PANLAR (2016), SIR (2013)) were found to recommend exercises for hand OA management.

To address objective 1, the PhD reviewer asserted that amongst all the available guidelines and consensus recommendations on hand OA management, exercises are indeed recommended as part of current best practice for the management of hand OA. To address objective 2, it was identified that for hand OA management, the type of specific exercises recommended are strengthening, stretching and joint mobility (ROM) exercises, which can be prescribed as either weekly home-based or supervised sessions for several weeks with very few or non-severe adverse effects. Additionally, it was also identified that an exercise regimen that improves pain and functionality of the hand, and general aerobic fitness may also be helpful in managing hand OA. These exercises however lacked specific details regarding the dosage, as no information relating to the frequency, intensity and duration of exercise performance was identified. Finally, to address objective 3, three strong and two weak recommendations for using different hand exercise approaches for hand OA management were proposed (see Table 4-7).

The present systematic review provides evidence to support patients and clinicians in using the strongly recommended hand OA exercises because they are based on high quality evidence (systematic review and RCT) and their desirable effects outweigh the undesirable. Additionally, policy makers can adopt these strong recommendations, as policies in their institutions, providing time for staff training and delivery of self-management approaches that can impact on hand pain and function. On the other hand, the PhD reviewers (and co-reviewers) are less confident in recommending the weak recommendations for hand OA management as they were largely premised on expert opinion, which, according to experts (Guyatt *et al.*, 2008b) should be considered as very low evidence.

Having said this, we believe that these weak recommendations can suffice as good clinical practice points, which over the years have aided in standardizing the delivery of care in the absence of sound clinical evidence (Hennessy *et al.*, 2016).

In recommending this review's exercise recommendations, the PhD reviewer acknowledge that their implementation particularly within clinical practice may not be without challenges. Firstly, there is still the need for clear and specific details regarding the type of recommended exercises, which are currently lacking in the guidelines similar to previous review findings (Osteras *et al.*, 2017). Unfortunately, the type of strengthening exercises (e.g. isometric or isotonic strengthening) which would help realize this benefit in these people was not indicated in the guidelines reviewed, so could not be reported in this systematic review. The PhD reviewer therefore anticipates and share in the uncertainty of target users of the present systematic review by questioning the research community to define and clarify what type of strengthening exercises may be most beneficial for these patients? Secondly, the lack of definite reporting of the duration for performing these recommended exercises may also influence their implementation as these decisions are left to the discretion of users. It is noteworthy that the above findings are consistent with a previous systematic review of guidelines (Hurkmans *et al.*, 2011), which reported that guideline recommendations on physiotherapy interventions lacked the detailed information regarding the mode of delivery, intensity, frequency and duration. From the present reviewers' perspective, this gap may be due to the lack of comprehensive reporting by guideline developers despite the availability of these important components in the underpinning research evidence or perhaps the underpinning research evidence has not provided content on these components for guideline developers to report on subsequently. Therefore, the reviewers firstly advocate that, for guidelines on hand OA management to realize their full potential of informing clinical decision-making, future primary research studies should comprehensively and explicitly describe the type and dosage (frequency, intensity and time) of hand exercises found to be effective and safe for hand OA. Secondly, it would also be helpful if future guideline developers provide precise and comprehensive description of the exercise interventions recommended to facilitate their implementation for the optimal benefits of all target users.

The implementation of guidelines is reported to be influenced by cultural context or geographical locations amongst other factors (Dans *et al.*, 2007). Among the five guidelines and consensus recommendations that recommended exercises for hand OA management, one (20%) was developed in North America (Ottawa (2005)), three (60%) in Europe (EULAR (2018), NICE (2014), SIR (2013)) and one (20%) in Latin America (PANLAR (2016)).

This largely biases the findings of the present review towards a European context, which may consequently influence its generalizability to other geographical locations due to different cultures and beliefs systems. The present reviewers therefore report that perhaps the findings of this systematic review may not be beneficial within the African, Asian and Australasian context as either guidelines of inadequate quality were identified in the case of Africa or no published guidelines were found in the case of Asia and the Australasia regions.

4.5.2 Strengths and Limitations of Included Guidelines and Consensus Recommendations

Generally, the majority of the guidelines and consensus recommendations reviewed adequately addressed all the six AGREE II domains and overall, the scope and purpose domain were the highest scored domain (see Table 4-4). Previous systematic reviews have reported poor rigour of development domain as most guidelines failed to report the systematic approaches employed in their development (Alonso-Coello *et al.*, 2010; Yao *et al.*, 2017). In the present review, this domain was one of the high scoring domains and contrary to the above report, it was adequately addressed by all the guidelines and consensus recommendations except for the SAMA guideline (2003). The ACR (2012), NICE (2014) and Ottawa (2018) guidelines scored highest for this domain and premised on this, the PhD reviewer is confident that the recommendations from these rigorously developed guidelines are applicable evidence-based resources to inform clinical decision-making as proposed by Jackson and Feder (1998). That said, the Ottawa (2018) despite providing explicit information regarding its development, failed to adequately address other key aspects of quality guidelines such as the clarity of presentation of its formulated key recommendations as recommended by experts (Brouwers *et al.*, 2010a). For example, the panel provided extensive evidence (i.e. population, intervention, outcome and time) for different comparisons of interventions but this also made it difficult for reviewers to extract recommendations from the guideline document as the information provided although detailed was not concise. These observations on the Ottawa guideline recommendations are consistent with previous systematic review of guidelines (Larmer *et al.*, 2014). Alongside others (Brouwers *et al.*, 2010a; Larmer *et al.*, 2014), the reviewer recommends that it will be helpful for guideline users if the panel uses clear and concise language, and user-friendly formats for easy identification, reporting and interpretation of their recommendations as recommended (Brouwers *et al.*, 2010a).

Some seminal authors have argued that the development of good guidelines does not necessarily ensure its optimal uptake (Feder *et al.*, 1999), as such guidelines developers are advised to provide ways to ensure the effective implementation and utility of their products (Alonso-Coello *et al.*, 2010). The applicability domain deals with this integral aspect of guidelines and in the present systematic review, it was the most poorly addressed domain. The Ottawa (2018), the ACR (2012), SAMA (2003), SIR (2013) PANLAR (2016) and Ottawa (2005) guidelines abysmally addressed this domain by providing inadequate information regarding the dissemination and implementation of their formulated recommendations. It would be ideal for these guidelines to follow a more structured approach to developing and reporting guidelines, such as the AGREE II instrument which provides a methodological framework for such purpose (Alonso-Coello *et al.*, 2010; Brouwers *et al.*, 2010a) or the recently published AGREE reporting checklist (Brouwers *et al.*, 2016), a tool to improve the comprehensiveness, completeness, and transparency of reporting guidelines. It is noteworthy that our findings are consistent with other systematic reviews of guidelines (Alonso-Coello *et al.*, 2010; Larmer *et al.*, 2014; Yao *et al.*, 2017) and from the literature, it was particularly conspicuous that, over the years, the applicability domain has continuously fared poorly because guideline developers have either inadequately or not addressed this domain at all. To enhance the performance of guidelines in this domain, which invariably will positively influence their quality, guideline developers are urged to provide the necessary resources and tools to aid in their successful dissemination, implementation, and uptake. Positive examples to inform future works are provided by NICE (2014) and EULAR (2018), who addressed this domain effectively and provided ways to operationalize their recommendations and uptake among the target users (Brouwers *et al.*, 2010a). Overall, it was apparent from the literature that stakeholder involvement, rigour of development, applicability and editorial independence domains have been poorly addressed over time with calls for guideline developers to improve on the quality of guidelines produced (Alonso-Coello *et al.*, 2010; Larmer *et al.*, 2014). The above domains except for the applicability domain were either adequately or fully addressed in our systematic review contrary to the previous reports. It is therefore advanced that perhaps guideline developers have improved the quality of guidelines produced over time due to continuous calls by experts for improvements in the guideline development process and the quality of guidelines (Alonso-Coello *et al.*, 2010; Brouwers *et al.*, 2010a). Noted amongst such domain improvements is the editorial independence domain which although performed generally well by all guidelines in the present review had one of its items poorly addressed.

This item (item 22) is concerned with how guideline developers deal with the influence of funding bodies and in grading this item, an explicit statement declaring the lack of influence of the views of funding bodies on the formulated recommendations should be stated. It was noticed in the present review that, whilst most of the guidelines stated their source of funding as recommended, they failed to provide this explicit statement which largely downgraded their deserved full score (see Appendix A.7).

Future guideline developers are therefore encouraged that whilst users appreciate the improved reporting of this domain, it would also be helpful if explicit statements regarding the influence of funders are articulated to increase the confidence of users in the formulated recommendations as recommended by experts (Brouwers *et al.*, 2010a).

4.5.3 Strengths and Limitations of the Current Systematic Review

One of the strengths of this systematic review is the thorough and transparent search strategy adopted to ensure that all or the presumed available published and unpublished guidelines and consensus recommendations on hand OA management were identified. Although this may have increased the reliability of this review, the reviewers acknowledge that perhaps the inclusion of grey literature sources may have included guidelines of poor quality, which unintentionally may have biased the review findings. Whilst acknowledging this limitation, the reviewers highlight that this is well balanced by its greater gains in reducing the impact of publication bias (Centre for Reviews and Dissemination, 2009). Another strength of this systematic review is the registration of its protocol (CRD42018086440) on PROSPERO, an open access international prospective register for systematic reviews (Booth, 2013; Sideri *et al.*, 2018). Although this is integral to the systematic review process and recommended as good practice, it was also conducted to enhance the transparency of the review process and prevent the duplication by other reviewers who may be commissioning the idea of reviewing this systematic review’s topic (Moher *et al.*, 2014). Finally, one noted limitation of this systematic review is that only records published in the English language were selected, hence the possibility of language bias is acknowledged based on the likelihood that other non-English records may present findings contrary to what was found in the present systematic review.

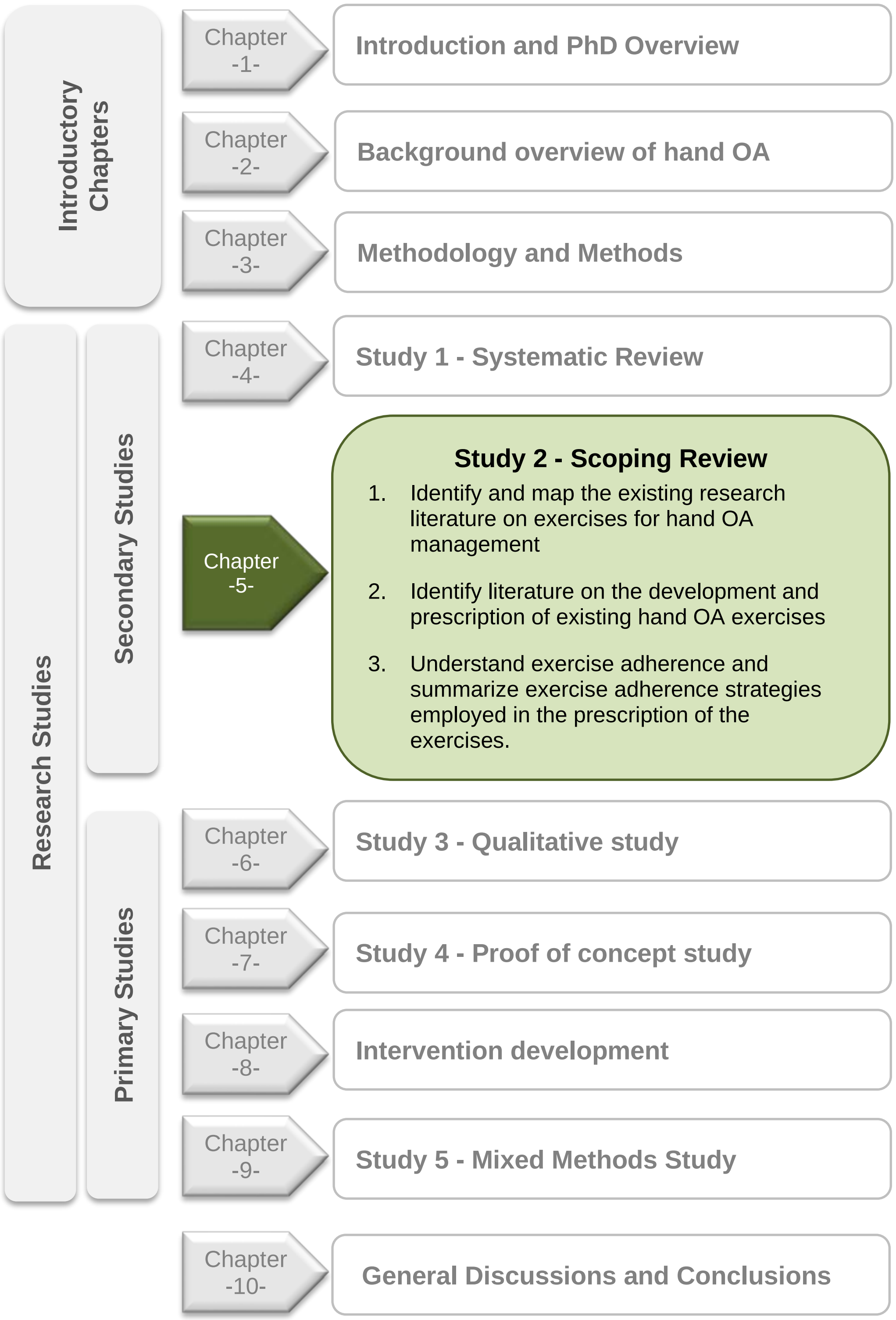
4.6 Conclusions

1. Available guidelines and consensus recommendations recommend exercises as part of current best practice for hand OA management.
2. There is strong evidence to support the recommendation of strengthening, stretching and joint mobility exercises for the management of the hand OA due to their beneficial effects on hand function, muscle strength and pain.
3. These exercises can be prescribed as either weekly home-based or supervised sessions for several weeks. However, their implementation by clinicians in practice may be challenging due to the lack of specific details regarding the type, intensity, and duration of the exercises, which therefore need to be established.

4.7 Chapter Summary

This chapter has presented a systematic review (study 1) that identified clinical practice guidelines recommendations on strengthening, stretching and joint mobility exercises for hand OA management. Findings were consolidated with that of the next two chapters to inform the development of a novel hand OA exercise programme for people with hand OA; to address the aim of this PhD.

Location in thesis



Chapter 5 Study 2 - Scoping Review of Exercise Programmes in the Management of Hand Osteoarthritis: Development, Prescription and Adherence

5.1 Introduction

This chapter describes a scoping review with an overall aim to identify the gaps and recommendations regarding the development, prescription, and adherence to hand OA exercise programmes (Figure 5-1). This scoping review was driven by the questions: 1) “what are the available exercise programmes implemented for people with hand osteoarthritis?”; 2) “are these exercises developed following theory-based treatment approaches?”; 3) “are these exercises prescribed following clinical practice guideline recommendations?” and finally, 4) “is patient adherence to these exercises reported, and what are the exercise adherence strategies used?”. The protocol for this scoping review has been published (Sankah *et al.*, 2018a).

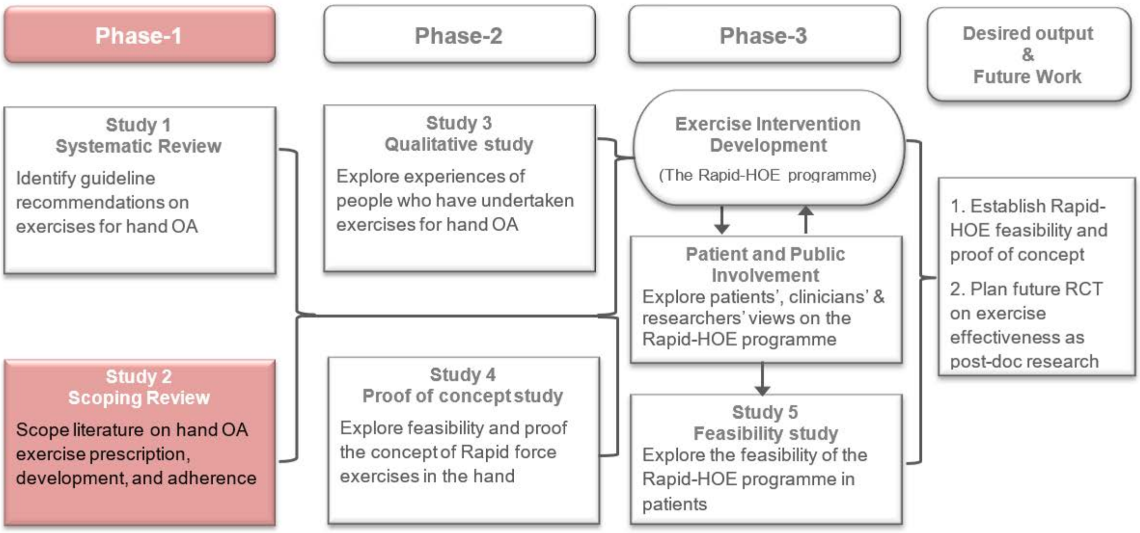


Figure 5-1: Scoping review location within the overall PhD research

5.2 Background

As established in the systematic review in Chapter 4, contemporary literature supports the use of exercises in the management of hand OA, despite low level evidence support (Kloppenburg *et al.*, 2018) and mixed reports of its beneficial effects (Stukstette *et al.*, 2012; Kolasinski *et al.*, 2020). The previous EULAR evidence-based recommendations for the management of hand OA recommended hand ROM and strengthening exercises, based on expert opinion only, due to the paucity of quality and available research evidence (Zhang *et al.*, 2007). The EULAR developers, however, reported the lack of an exhaustive literature review in the guideline development process and acknowledged that less commonly used interventions may have been missed. The updated version (Kloppenburg *et al.*, 2018), although reporting an improvement in the underpinning research evidence for hand OA exercise recommendations (i.e. one systematic review of RCTs), added that this was insufficient. The authors therefore suggested the need for further enquiry into the assessment of the most effective type of exercises, most optimal method of delivery and frequency of exercises, as part of the research agenda for hand OA. The need to scope the literature for all available research evidence on exercises for hand OA management was therefore timely and warranted, which formed the topic of this scoping review.

Several treatment interventions have been criticized as lacking robust evidence-based development and reporting (Glasziou *et al.*, 2008; Hurkmans *et al.*, 2011; Sankah *et al.*, 2019b). According to Rappolt (2003), the development of an evidence-based exercise programme should be based on synthesized evidence from quality research, clinical expertise and client evidence. However, current literature highlights the lack of consensus regarding the design of such programmes for people with hand OA (Kjeken *et al.*, 2015). Due to this uncertainty, there is a need to ascertain whether the existing literature on hand exercise interventions adheres to the recognized evidence-based treatment development approach, as recommended by experts (Rappolt, 2003; Straus *et al.*, 2005). Adherence is described as the extent to an individual 's behaviour correlates with agreed recommendations from a healthcare worker (World Health Organization, 2003). The 2018 update of the EULAR recommendations for hand OA management highlighted the importance of exercise adherence and recommended further investigations into methods that increase adherence in this patient group. The need to understand and summarize beneficial exercise adherence strategies employed in the management of hand OA is therefore warranted.

To avoid evidence duplication (Peters MDJ *et al.*, 2017), the PhD researcher prior to the start of this scoping review conducted a preliminary search of existing scoping and systematic reviews on the review topic in Cochrane Library, Prospero and JBI database of systematic reviews and implementation reports in November 2017. From this search, two systematic reviews were identified: one published Cochrane review (Osteras *et al.*, 2017) and an ongoing systematic review registered on Prospero (Adolph S. M. *et al.*, 2017). Despite having similar themes of reviewing exercises for hand OA, the present scoping review differed from the above systematic reviews regarding its objectives and scope of research literature search. First, whereas the above reviews aimed to establish the effectiveness of exercises in people with hand OA, the present scoping review aimed to identify the breadth of literature on adherence and development of exercises employed in hand OA management. Hence, the PhD researcher was not only interested in RCTs but also other study designs and development papers that contribute to this field of literature. Secondly, the present scoping review aimed to ascertain how hand OA exercises are implemented in clinical practice and research by identifying whether existing exercise programmes are prescribed following clinical practice guideline recommendations. Unlike the above systematic reviews extracting evidence from only RCTs, the present scoping review aimed to identify evidence from all available literature sources to provide a wide spectrum of knowledge available on the review topic. This scoping review is novel. It aims to add new knowledge to the body of evidence by providing a better understanding of the emerging concepts in adherence, development, and prescription of exercises for hand OA management. It also aims to synthesize evidence from a comprehensive range of resources to provide evidence on available exercise programmes used for hand OA management, which will not only inform the exercise development approach used within this PhD but also, future research aimed at developing exercises for hand OA.

The objectives of the scoping review were to:

1. Identify and map the existing research literature on exercises for the management of hand OA.

2. Identify the breadth of literature regarding the development and prescription of existing hand OA exercises according to recommended guidelines

3. Understand exercise adherence and summarize exercise adherence strategies employed in the prescription of hand OA exercises.

5.3 Methods

5.3.1 Methodology

This scoping review was conducted according to the JBI scoping review methodology (Peters *et al.*, 2015; Peters MDJ, 2020) and reported following the PRISMA extension for Scoping Reviews (PRISMA-ScR) Checklist (see Appendix B.1) (Tricco *et al.*, 2018).

5.3.1.1 Eligibility Criteria

As recommended by JBI (Peters et al.2017), the "PCC" mnemonic (Population, Concept, and Context) was used to guide the development of the eligibility criteria (see Table **5-1**) and search strategy.

Table 5-1: Inclusion and Exclusion Criteria for Scoping Review

PCC	Inclusion criteria	Exclusion criteria
Population	1. Adults ≥18yrs with hand OA 2. Male and female	Rheumatoid arthritis or inflammatory arthritis. Children with hand OA
Concept	1. Literature that report the development of exercises targeted at the hand for hand OA 2. Literature that report the evaluation of exercises targeted at the hand for hand OA	
Context	1. Healthcare, community, and home settings 2. Any geographical location or culture.	
Type of Sources	1. Quantitative and Qualitative studies 2. Systematic reviews 3. Conference proceedings 4. Abstracts 5. Text and Opinion pieces	Economic evaluation papers

NB: OA - Osteoarthritis

5.3.2 Information Sources

Both published and unpublished literature were searched in selected data sources as shown in Table 5-2.

Table 5-2 Literature Sources for Scoping Review

Published databases	Unpublished & Grey data sources
Medline (Ebsco host)	NICE evidence search
CINAHL (Ebsco host)	UK clinical research network study portfolio
Cochrane library	Versus Arthritis, UK
PEDro	British library
AMED	WHO International Clinical Trials Registry Platform (ICTRP)
Web of science	International Standard Randomized Controlled Trials Number (ISRCTN) Registry
OT seeker	Open Grey

NB: CINAHL - Cumulative Index to Nursing and Allied Health Literature; NICE – National Institute for Health and Care Excellence; PEDro - Physiotherapy Evidence Database; WHO - World Health Organization; OT - Occupational Therapy; UK - United Kingdom

5.3.3 Search

The JBI recommended 3-step search strategy previously described (see Chapter 4; section 4.3.4) was followed. Identified keywords and index terms were searched across the identified published databases (Appendix B.2.1 - B.2.7) and the grey and unpublished information sources (Appendix B.2.8). Reference lists and citations of all included full text records were searched as well as authors of relevant studies contacted for further information when appropriate. Records published in English language from January 1998 until December 2018 were applied as limiters. Considering the iterative search strategy of scoping reviews (Peters MDJ *et al.*, 2017), additional keywords and search terms were incorporated into the literature search as the researcher become familiar with the evidence base when appropriate. Additionally, a literature search update was conducted from January 2019 to 13th January 2021 to ensure that all relevant records published after the initial search were identified.

5.3.4 Selection of sources of evidence

All identified records were collated and managed with the citation management software Endnote X9.3.3 (Clarivate Analytics, PA, USA). Study titles and abstracts were selected and screened by BS and MS.

Full text retrieval and screening were undertaken by BS and cross-checked by MS for accuracy. All disagreements were resolved through discussion.

5.3.5 Data Charting Process

A data charting form adapted from JBI was used for the data charting process (Appendix B.3). This form was initially piloted following suggestions of scoping review experts to ensure that all key information relevant to the review question was extracted (Arksey *et al.*, 2005; Levac *et al.*, 2010). Due to the iterative nature of the data charting process, the charting form was updated during the review process to chart four emerging themes; mode of delivery, compliance, aim of exercise and adverse effects. The data charting process was undertaken by the PhD reviewer (100%) and cross-checked MS (5%) for accuracy. Any discrepancies were discussed and resolved through discussions (BS, MS, JA).

5.4 Data Items

For the purposes of this review, we defined “development” as the process of planning, implementation, and evaluation of a coordinated set of exercises designed to enhance wellbeing and prevent (or reduce) the health limitations of people with hand OA. “Prescription” is defined as a written directive which constitutes the components and administration of any exercise programme employed in the management of people with hand OA. We also define the word “map” as the process of summarizing the evidence (Levac *et al.*, 2010). We define primary research as research conducted first-hand to obtain data. Secondary research is defined as a research method that involves the use of already existing data, where these data are summarised and collated to increase the overall research effectiveness.

5.5 Synthesis of Results

The study selection process was illustrated diagrammatically with a PRISMA flow diagram (Moher *et al.*, 2009) and narratively as recommended in the literature (Aromataris *et al.*, 2014). The extracted data were summarized with tables. Key findings categorised under the a priori and emerging themes were mapped logically in diagrammatic, tabular, and descriptive formats congruent with the review scope and objective. Gaps identified in knowledge were also be mapped in tabular form, as appropriate, and conclusions drawn based on the review objectives. Clear and specific recommendations for the conduct of future research based on the gaps in knowledge identified from the results were presented as recommended (Khalil *et al.*, 2016).

5.6 Results

5.6.1 Selection of sources of evidence

Details of the records identification process is shown in Figure 5-2. From the initial search (1998 -2018), 1937 records were identified from published databases and 37 from other information sources. Of the 1974 relevant records identified, 497duplicates were removed. Titles and abstracts of the remaining 1477 records were screened against the broad inclusion and exclusion criteria, and 1422 irrelevant records were excluded. Fifty-five suitable full text records were screened against the detailed eligibility criteria after which 25 were excluded (see Appendix B.4). Overall, 30 relevant records were identified. From the literature search update run from January 2019 to 13th January 2021, three additional records were identified: Beasley *et al.* (2019); Hamasaki *et al.* (2020) and Veronese *et al.* (2020), with further details in Appendix B.5. Overall, 33 records were identified and included in this scoping review: 21 primary research studies and 12 secondary research studies.

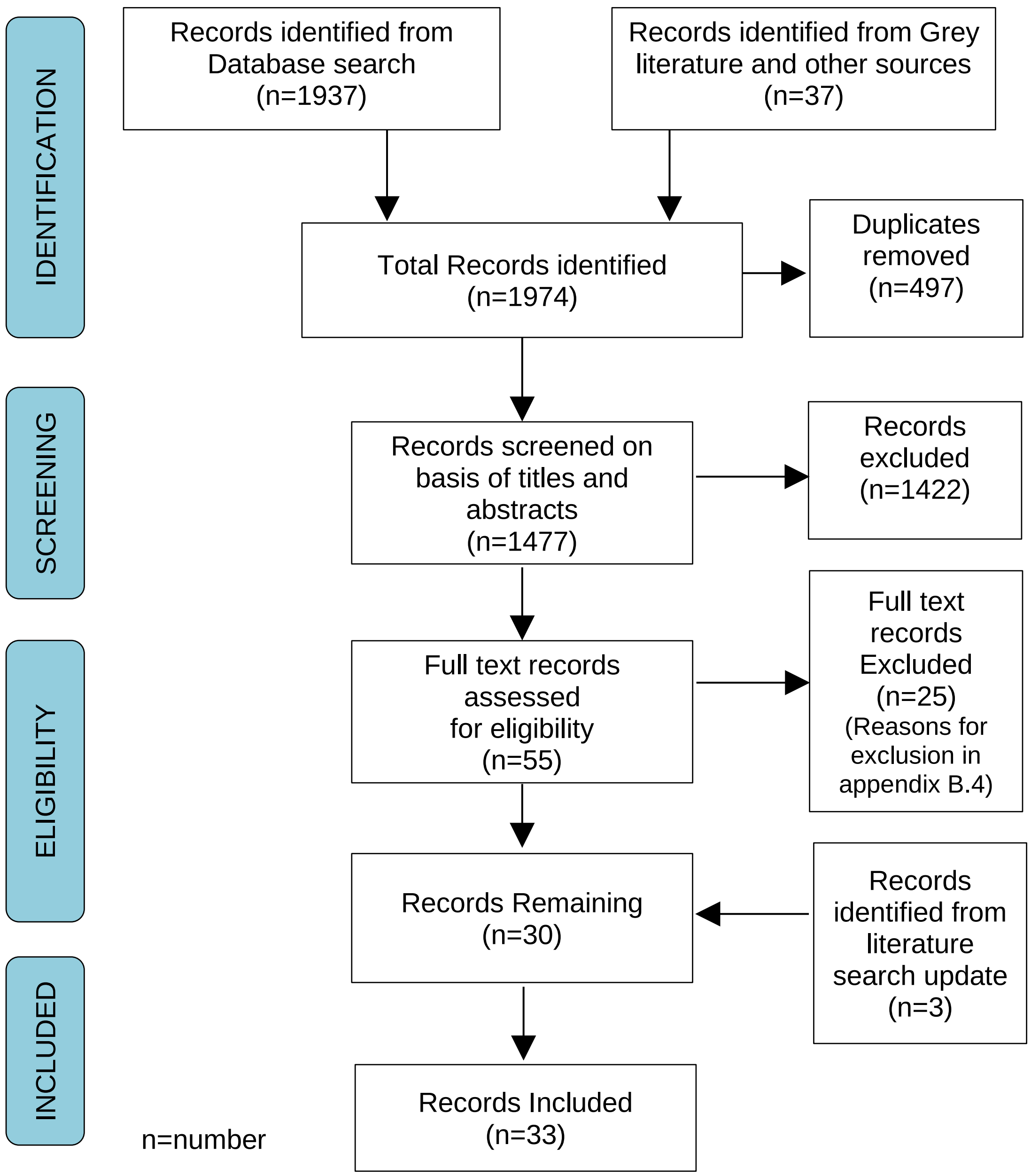


Figure 5-2: PRISMA Flow chart of the Search Strategy

5.6.2 Characteristics of sources of evidence

Table 5-3 shows the summarized characteristics of all the primary research studies that were selected (n=21). Of these 21 records, about 62% were randomized experimental studies and 38% were non-randomized study designs including study protocols and a development paper. Table 5-4 also shows the summarized characteristics of all the secondary research literature identified (n=12). Of the 12 records, there were six systematic reviews, one umbrella review and five other reviews. Regarding the origin of the selected records, about 55% were from Europe, 27% from North America and 3% each from Australia, Asia, and South America with none from Africa. Additionally, about 88% were published journal papers and 12% were collectively conference abstracts and letter to the editor. The population studied by the records varied, about 67% of the records reported of investigating a population of hand OA patients, 30% studied thumb base OA patients and about 3% reported studying both populations. A few of these studies were conducted within the community care settings (14.2%) and healthcare facilities (14.2%) whilst a large proportion were within the home settings or a combination of home and other settings (e.g. hospital, Laboratory, etc.) (See Appendix B.6.1 - B.6.5 for further details).

Table 5-3: Description of selected Primary Studies by study design

Records	Study Aims	Study Characteristics					Key Findings
		Type of publication	Country of Origin	Study design	Participants (n)	Study setting	
Bjurehed *et al.* (2017)	Evaluation of the effects of primary care hand OA group intervention on hand function, activity limitations, and self-rated health	Journal article	Sweden	Prospective cohort study	Hand OA (n= 49; 90% female)	Primary care unit	Hand OA group intervention improves hand function, activity limitation, and self-rated health with sustained benefits after one year
Boustedt *et al.* (2009)	Examining the effect of structured splinting, intensified hand exercise & joint protection programme on hand function.	Journal article	Sweden	Parallel, controlled, non-randomised trial	Women with Hand OA or thumb base OA or both (n=42)	Health care and home setting	Splinting and exercise regimen added to a joint protection programme gives a greater improvement of pain, stiffness, grip force and daily activities than the joint protection programme alone
Brorsson *et al.* (2014)	Studying the effect of two different hand exercises on grip, finger extension, strength and patient reported hand function	Conference abstract	Sweden	Randomized study	Female patients with arthritis (n=121; Hand OA and RA)	Not explicit stated	Hand exercises increased grip strength and finger extension force after eight weeks.
Brosseau *et al.* (2017)	Evaluating the effect of knitting on pain in a right-handed elderly woman with hand OA	Letter to the editor	Canada	Case study	86-year-old woman with moderate to severe bilateral Hand OA	Home programme	Knitting is a promising activity for individuals suffering from HOA pain
Davenport *et al.* (2012)	Testing the effect of CMC joint stabilizing and general strengthening exercises on function, pain, and strength	Journal article	UK	Pilot RCT	Individuals with first CMC joint OA (n=39)	Home programme	1. CMC joint stabilizing exercises did not improve function, pain, APL, or pinch strength. 2. General exercise appears to improve function, pain and APL strength
DeMott (2017)	Describing novel isometric exercises for thumb CMC joint instability	Journal article	USA	Case study	CMC OA	Home programme	Exercise frequency and duration is individually prescribed and is based on the American College of Sport Medicine recommendations.

Records	Study Aims	Study Characteristics					Key Findings
		Type of publication	Country of Origin	Study design	Participants (n)	Study setting	
Deveza *et al.* (2017)	Determining the effect of a combination of conservative therapies for the treatment of thumb base OA compared with an education control group.	Journal article	Australia	Protocol for an RCT	People with CMC OA above 40years	Home programme	N/A as it's a protocol
(Dziedzic *et al.*, 2015)	Evaluating the effectiveness of joint protection versus no joint protection, and hand exercise versus no hand exercise in adults with hand OA	Journal article	UK	RCT	Adults, ≥50 years with hand OA (n=257; 66%female)	Hospital setting+home programme	Study reported no statistically significant differences in the number of 'responders' between those receiving and not receiving hand exercises.
Guitard *et al.* (2018)	Examining the effectiveness of knitting on stiffness and pain in females with mild to moderate hand OA.	Journal article	Canada	RCT Protocol	Females with hand OA (50 ≤ 85 years)	Community centre *(Senior's Club in metropolitan Ottawa)*	N/A
Hennig *et al.* (2015)	Evaluating the effect of hand exercises in women with HOA	Journal article	Norway	RCT	Females adults with Hand OA (n=40)	Home programme plus information	Hand exercises are well tolerated and significantly improved activity performance, grip strength, pain and fatigue in women with HOA.
Kang *et al.* (2019)	Examining the effect of stretching and strengthening exercise programme on hand grip, strength, and function in automobile workers with hand OA.	Journal article	South Korea	RCT	Automobile workers with Hand OA (n=29)	Company clinic	Finger exercise programme combined with paraffin bath therapy appears to be effective in improving pain, physical function, and hand grip strength in automobile workers with Hand OA
Kjeken *et al.* (2015)	Describing the development of an evidence-based exercise programme for people with HOA,	Journal article	Norway	Development paper	People with hand OA	Research setting (National Advisory Unit on Rehabilitation in Rheumatology)	Paper reported the evidence-based development of an exercise programme for people with HOA

Records	Study Aims	Study Characteristics					Key Findings
		Type of publication	**Country of Origin**	**Study design**	**Participants (n)**	**Study setting**	
Lefler *et al.* (2004)	Determining the effects of strength training on OA of the hands	Journal article	USA	Inference of a randomized before and after controlled study was made	Hand OA (n=19; 17 females, 2 males)	Elderly living community centre	Six-week strength training programme significantly improved grip strength and finger rom, and not pain level or pinch strength
Nery *et al.* (2015)	Assessing the effectiveness of progressive resistance strength training programme on pain, function and strength in hand OA patients.	Conference paper (Abstract)	Brazil	RCT	Hand OA (N=60)	Not explicit stated	A progressive resistance strength training programme is effective on pain, function, and treatment satisfaction for patients with hand OA
Østerås *et al.* (2014a)	Determining the clinical effectiveness of an exercise programme on self-reported hand activity performance in people with hand OA.	Journal article	Norway	RCT	Hand OA (n=130; 90%Female).	Health care plus home setting	The exercise programme investigated was well-tolerated but resulted in small, beneficial short-term improvements on self-reported measures and not on most performance-based outcomes.
Pérez-Mármol *et al.* (2017)	Assessing the effectiveness of a rehabilitation programme on upper limb disability, independence of activities of daily living, fine motor abilities, functional independency, and general self-efficacy in older adults with Hand OA.	Journal article	Spain	RCT	Hand OA (n=45; 74-86 years)	Community health centres	1. Fine motor skill increased manual dexterity and thimb nad index finger ROM , and not upper limb disability, ADLs performance, pinch strength, functional independency, and general self-efficacy 2. Exercises can be used by hand therapist to treat HOA patients when they present with problems in manual dexterity or ROM
Rocchi *et al.* (2018)	Assessing the effect of 10 sessions of physiotherapy versus a single corticoid intra-articular injection.	Journal article	Italy	Open-label trial	TMC OA (n=25)	Clinical setting (outpatient surgery)	Application of heat, passive and active mobilization of the arthritic joint, massage therapy and stretching improved symptoms of hand OA
Rogers *et al.* (2009)	Investigating the effects of home-based hand exercise among persons with hand OA	Journal article	USA	RCT	Hand OA (n=46; ≥50 years)	Laboratory and home-based	Home-based daily 16-week regimen of hand strength and ROM exercises modestly improved grip and pinch strength, and not self-reported hand function or pain

Records	Study Aims	Study Characteristics					Key Findings
		Type of publication	Country of Origin	Study design	Participants (n)	Study setting	
Stamm *et al.* (2002)	Evaluating the effect of joint protection instruction and hand exercise intervention in persons with hand OA	Journal article	Austria	RCT	Hand OA (n=40)	Home programme	Joint protection and hand home exercises increased grip strength and global hand function in persons with hand OA.
Stoffer-Marx *et al.* (2018)	Evaluating the effect of interdisciplinary intervention compared to routine care plus placebo in patients with hand OA	Journal article	Austria	RCT	Hand OA (n=151)	Home programme plus (Follow up visit at outpatient clinic	Combined, interdisciplinary, individual, one-session intervention significantly improved grip strength and self-reported satisfaction when compared to treatment with routine care plus placebo.
Villafane *et al.* (2013)	Examining the effectiveness of manual therapy and exercise approach in comparison with a placebo intervention in individuals with CMC OA.	Journal article	Italy	RCT	CMC OA (n=60 RT handed individuals); Age: ≥80years	Physiotherapy unit	Combination of joint mobilization, neural mobilization, and exercise is more beneficial in treating pain than a sham intervention in patients with CMC joint OA.

NB: ADLs= Activities of Daily Living; CMC= Carpometacarpal joint; HOA=Hand osteoarthritis; OA: Osteoarthritis; RCT: Randomized Controlled trial; ROM: Range of Motion: n = Participants; RT= Right; QoL= Quality of Life; TMC = Trapeziometacarpal; UK= United Kingdom; USA= United States of America

Table 5-4: Description of selected Secondary studies by study design

Records	Study Aims	Study Characteristics					Key Findings
		Type of publication	Country of Origin	Study design	Participants (n)	Study setting	
Aebischer *et al.* (2016)	Evaluating the effectiveness of physiotherapy and occupational therapy on pain, function, and quality of life in people with TMC OA	Journal article	Switzerland	Systematic review and meta-analysis	People with primary TMC OA (n =1179)	N/A	Physical and occupational therapy-related interventions, especially multimodal interventions appear to be effective in treating pain in patients with TMC OA
Beasley *et al.* (2019)	Evaluating the evidence supporting conservative therapeutic interventions for the treatment of OA of finger joints	Journal article	USA	systematic review	OA of finger joint	N/A	Evidence supports the use of active ROM, resistive exercises and joint protection for OA of finger joints
Beasley (2012)	Reviewing conservative therapeutic management for OA patients as well RA of the hand related to basic science and evidence-based practice	Journal article	USA	Narrative review	People with Hand OA	N/A	1. Combining joint protection and pain-free hand home exercises are effective in increasing hand function 2. Exercise programmes involving active ROMs opposed to pinch strengthening are more effective
Bertozzi *et al.* (2015)	Reviewing the effect of conservative interventions on pain and function in people with thumb CMC OA	Journal article	Italy	Systematic review and meta-analysis	People with thumb CMC OA (n=377)	N/A	1. Manual therapy and exercise are effective in improving pain and function in patients with thumb CMC OA 2. Manual therapy and therapeutic exercise improves pain in patients with thumb CMC OA
Hamasaki *et al.* (2020)	Reviewing the literature on the efficacy of existing nonsurgical interventions for TMC OA.	Journal article	Canada	systematic review	TMC OA	N/A	hand exercises and TM joint/nerve mobilization may benefit TMC patients
Kjeken *et al.* (2011)	Evaluating the design and effects of splints and exercise programmes in hand OA	Journal article	Norway	Systematic review	Hand OA	N/A	Hand exercises may reduce pain and increase ROM and strength, while a combination of splints and daily exercises may reduce pain and stiffness and improve function.

Records	Study Aims	Study Characteristics: Type of publication	Country of Origin	Study design	Participants (n)	Study setting	Key Findings
Kroon *et al.* (2018b)	Updating the evidence on efficacy and safety of non-pharmacological, pharmacological and surgical interventions for hand OA	Journal article	Europe *(Netherlands; Spain)*	SLR	Hand OA	N/A	1. Exercises lead to beneficial effects on hand pain, function, joint stiffness and grip strength, although effect sizes are small. 2. Non-pharmacological treatments that were shown to result in symptom relief included hand exercise and prolonged splinting of the thumb base,
Nguyen *et al.* (2016)	Reviewing the literature on efficacy and safety of exercise therapy, strength training and evidence-based recommendations for knee, hip and hand OA.	Journal article	France	Narrative review	Hand OA	N/A	1. Strengthening and ROM exerciseS is recommended for hand, knee and hip OA 2. Strengthening of hand joint stabilizer muscles could improve joint stability
Osteras *et al.* (2017)	Assessing the benefits and harms of exercise compared to other interventionsin people with hand OA.	Conference paper	Norway	Systematic review	Hand OA	N/A	Exercises showed small beneficial effects on hand pain, function and finger joint stiffness
Scott (2018)	Evaluating the effectiveness of joint-specific exercise in CMC OA patients	Journal article	Australia&UK	Critical review	CMC OA	N/A	It is recommended that future studies consider optimal frequency of strengthening exercises and the potential role of adductor pollicis release and passive CMC joint mobilization in home exercise programs for first CMC OA
Valdes *et al.* (2012)	Providing recommendations for a hand exercise programme for CMC OA based on a biomechanical analysis of the CMC joint.	Journal article	USA	Literature review	CMC OA	N/A	1. Hand exercises for CMC OA are aimed at maximizing pain-free functional ROM, increasing functional strength, maintaining joint stability, and avoiding fixed deformities of the thumb

Records	Study Aims	Study Characteristics: Type of publication	Country of Origin	Study design	Participants (n)	Study setting	Key Findings
							2. Lateral-pinch and key-pinch strengthening exercises should be avoided in patients with advanced CMC OA who have thumb instability and deformity, as these exercises may result in further joint subluxation and pain
Veronese *et al.* (2020)	Mapping the effect of interventions for health outcomes in hand OA.	Journal article	Italy & UK	Umbrella review	Hand OA	N/A	Moderate certainty of evidence supports the use of resistance training or physical exercise in improving hand pain and finger joint stiffness in hand OA

NB: AE = Adverse Events; ACSM = American College of Sports Medicine; CI= Confidence Interval; CMC= Carpometacarpal joint; OA: Osteoarthritis; n = Participants; N/A = Non-Applicable; SLR= Systematic Literature Review; RCT: Randomized Controlled trial; TMC = Trapeziometacarpal; RA: Rheumatoid Arthritis; UK= United Kingdom; USA= United States of America

5.6.3 Results of individual sources of evidence

5.6.3.1 Exercises for hand OA management reported in literature

The description of exercises for hand OA management are provided in Table 5-5. From the results, two exercises were mostly used: strengthening and ROM exercises. For the strengthening exercises, 20 records reported using isometric, isotonic, and resistive strengthening exercises which included grip exercises (n=12), pinch exercises (n=4) and strengthening thumb abduction and extension exercises with the elastic band (n=4). For the ROM exercises, 13 records included either active, passive, or standardized ROM exercises. More specifically, these exercises were: i) general ROM exercises (without specific reported details); ii) upper limb joints ROM (shoulders, elbows, wrists, finger and thumb, exercises as those involving the upper limb joints); iii) making an O sign and iv) making a fist exercise. Commonly used amongst these ROM exercises are “making “O” sign” (n=11) and “making a fist” (n=9) exercises, which were also classified as mobility exercises (Stoffer-Marx *et al.*, 2018) or joint flexibility exercises (Rogers *et al.*, 2009; Villafane *et al.*, 2013). Other less commonly used exercises were low intensity dynamic knitting programme (Brosseau et al., 2017; Guitard et al., 2018), fine motor skill intervention (making pictures with tissue paper balls) (Pérez-Mármol et al., 2017) and Trapeziometacarpal (TMC) joint mobilization (Rocchi *et al.*, 2018; Hamasaki *et al.*, 2020) (see Appendix B.7 for complete reporting).

Table 5-5: Description of exercises for the management of people with hand OA

Records	Description of Exercises
Aebischer *et al.* (2016)	Stabilization, standardized ROM, general strengthening, abduction, pinch, and thumb web exercises
Beasley *et al.* (2019)	AROM and resistive exercises
Beasley (2012)	1. Pain-free hand home exercises 2) Active ROM exercises
Bertozzi *et al.* (2015)	1. exercises that strengthen the stabilizing muscles of the thumb 2. exercises that provide unconscious neuromuscular control
Bjurehed *et al.* (2017)	1. ROM exercises (Shoulders, elbows, wrists, finger and thumb) 2. Strengthening exercises with a soft ball (wrists & hands)
Boustedt *et al.* (2009)	ROM and pain free moderate strengthening of hand intrinsic 2) thumb extrinsic muscles
Brorsson *et al.* (2014)	1. Isolated finger opposition (digits II-V); rolling putty with a flat hand; squeezing putty; finger extension with putty resistance
Brosseau *et al.* (2017)	Structured low-intensity home knitting program
Davenport *et al*. (2012)	1. Specific CMC joint exercises (passive & active extension; passive extension with rubber band; pinching activities e.g. writing; practice turning or twisting activities e.g. undoing jars). 2. General exercises (touch thumb to fingertips (O sign); pinching activities; stretching thumb)

Records	Description of Exercises
DeMott (2017)	1. Isometric grip exercises (ball) 2) CMC joint extension/abduction with MP joint flexion,
Deveza *et al.* (2017)	1. Thumb opposition 2. paper tearing 3) line tracing on ball 4) using chopsticks to pick up objects 5) squeezing a ball
Dziedzic *et al.* (2015)	1. ROM exercises (wrist flexion & extension; pronation & supination; tendon gliding; radial finger walking; making an 'O' sign; thumb extension; abduction & opposition to the base of the 5th finger) 2. Strengthening exercises (Thumb extension, abduction & finger extension with elastic band and Play-Doh; wrist flexion and extension exercise with 0.5–0.75 kg weight)
Guitard *et al.* (2018)	1. knitting program (low intensity dynamic and isometric movement of fingers, thumbs, and wrists)
Hamasaki *et al.* (2020)	Combination of hand exercises and TM joint mobilization
	1. Making "O" sign 2. Roll into fist 3. Grip strength (rubber ball) 4. Thumb abduction/extension (with rubber band) 5. Finger stretch
Kang *et al.* (2019)	1. Finger stretch; Roll into fist 2. Make O sign &Thumb abduction/extension with power web hand exerciser
Kjeken *et al.* (2011)	Combination daily exercises (ROM and strengthening exercises)
Kjeken *et al.* (2015)	Strengthening and ROM exercises 1. Shoulder flexion& extension (exercise band) 2. Biceps curls (with stretch band) 3. Making "O" sign & Roll in a fist 4. Thumb abduction &extension (with elastic band) 5. Grip strength (with pipe insulation tube) Warm up & cool down exercises (rubbing the hands together, arm swings &finger stretch exercise).
Kroon *et al.* (2018b)	Use of exercises indicated (specific details not reported)
Lefler *et al.* (2004)	Isometric and isotonic strengthening exercises 1. rice grabs (making fist squeezing rice); 2. pinch grip lifting (sandbags); 3. wrist rolls (piece of PVC pipe)
Nery *et al.* (2015)	Progressive resistance strength training program for intrinsic muscles of the hand
Nguyen *et al.* (2016)	Strengthening and ROM exercises
Østerås *et al.* (2014a)	Used Kjeken *et al.* (2015) exercises (Shoulder flexion& extension; biceps curls; making "O" sign; roll in a fist; thumb abduction &extension; grip strength). Warm up & cool down exercises
Osteras *et al.* (2017)	No specific exercises recommended
Pérez-Mármol *et al.* (2017)	Fine Motor Skill intervention (using structured activity of making pictures with tissue paper balls on a figure painted at the background of the picture).
Rocchi *et al.* (2018)	Therapeutic exercises (passive & active TMC joint mobilization; stretching of the first web span)
Rogers *et al.* (2009)	1. Joint flexibility exercises - Tabletop; small & Large fist; okay signs (making "o") &finger spread exercises 2. Strengthening grip and pinch exercises - thumb reach & (gripping; key pinch & fingertip pinch with resistance balls)
Scott (2018)	1.Strengthening exercises for Extensor pollicis brevis, Abductor pollicis brevis, Opponens pollicis (resisted 'C' position -use of rubber band or other hand) 2. Resisted tip/functional pinch with exercise balls (whilst focussing on correct positioning)

Records	Description of Exercises
Stamm *et al.* (2002)	1. Making a fist 2. Making a small fist 3. flexing the MCP joints while keeping the PIP and DIP joints stretched 4. Touching the tip of each finger with the tip of the thumb 5. Spreading the fingers as far as possible with the hand lying flat on a table 6. Pushing each finger in the direction of the thumb with the hand lying flat on a table 7. Touching the MCP V joint with the tip of the thumb
Stoffer-Marx *et al.* (2018)	Strengthening and mobility exercises (make small fist; build a housetop, make O sign; spread fingers; lateral pinch; exercise with therapy putty
Valdes *et al.* (2012)	1.Grip and Pinch strengthening exercises (foam wedge squeeze; putty squeeze; hand gripper exercises) 2. AROM and PROM exercises (CMC web space, thumb IP, thumb MP and CMC motions). *Warm up activities* (moist heat packs, paraffin bath, or low-intensity aerobic exercise)
Veronese *et al.* (2020)	resistance training
Villafañe et al. (2013)	Used Rogers *et al.* (2009) exercises 1. Joint flexibility exercises - Tabletop; small & Large fist; okay signs (making "O") &finger spread exercises 2. Strengthening grip and pinch exercises - thumb reach & (gripping; key pinch & fingertip pinch with colour coded resistance balls)

NB: CMC= Carpometacarpal joint; MP=Metacarpal; ROM-Range of Motion; TMC= Trapeziometacarpal; PIP=Proximal interphalangeal; DIP= Distal interphalangeal; MCP; PROM= Passive Range of Motion; AROM= Active Range of Motion; IP= Interphalangeal

5.6.3.2 Development of exercises for hand OA management

Details of the records and summary of the evidence-based exercise development recommendations are provided in Table 5-6. Of the 33 records, only 6 records (Østerås *et al.*, 2014a; Dziedzic *et al.*, 2015; Kjeken *et al.*, 2015; Guitard *et al.*, 2018; Scott, 2018; Stoffer-Marx *et al.*, 2018) investigated exercises that were developed according to exercise development recommendations (i.e. research, expert and patient evidence). Five records (Rogers *et al.*, 2009; Villafane *et al.*, 2013; Hennig *et al.*, 2015; Bjurehed *et al.*, 2017; Pérez-Mármol *et al.*, 2017) were developed based on only research and expert opinion. Five were based on research evidence only. About 15 records provided no information regarding the evidence underpinning exercise development (further details in appendix B.8.1).

For the exercise development guideline used, seven records used the American College of Sports Medicine (ACSM) guideline for exercise development and prescription (ACSM 1998; 2011; 2014). Two used the framework for design and evaluation of complex interventions (Craig *et al.*, 2013) and one each used the European standards of care for OA (Stoffer *et al.*, 2015) and the Occupational therapy-based and evidence-supported recommendations (Kjeken, 2011).

Table 5-6: Description of exercise programmes according to evidence-based treatment recommendations

Records	Evidence-based Intervention development Recommendations			Evidenced-based Exercise development Guidelines
	Research evidence	**Expert expertise**	**Patient/client evidence**	
Aebischer *et al.* (2016)	Not described	Not described	Not described	Not described
Beasley *et al.* (2019)	Not described	Not described	Not described	Not described
Beasley (2012)	Not described	Not described	Not described	Not described
Bertozzi *et al.* (2015)	Not described	Not described	Not described	Not described
Bjurehed *et al.* (2017)	Based on Kjeken (2011)	Underpinning evidence included an expert group	No	Non reported
Boustedt *et al.* (2009)	Not described	Not described	Not described	Not described
Brorsson *et al.* (2014)	Not described	Not described	Not described	Not described
Brosseau *et al.* (2017)	Not described	Not described	Not described	Not described
Davenport *et al*. (2012)	Research evidence	Not described	Not described	Non reported
DeMott (2017)	Research evidence	Not described	Not described	Non reported
Deveza *et al.* (2017)	Based on Hunter *et al* (2004); Mobargha *et al.* (2016)	Not described	Based on consumer focus group (group details not reported)	Non reported
Dziedzic *et al.* (2015)	(international guideline evidence)	OTs	patient and public involvement	Non reported
Guitard *et al.* (2018)	Several evidence sources e.g. Kjeken *et al.* (2015); Brosseau *et al.* (2017),etc	Followed EULAR 2007 taskforce report (Zhang *et al.*, 2007)	People living with OA and hand OA	American College of Sports Medicine (ACSM) (Pescatello *et al.*, 2014)
Hamasaki *et al.* (2020)	Not described	Not described	Not described	Not described
Hennig *et al.* (2015)	Based on Kjeken (2011) which included a literature search	(Norwegian Network for OTs in rheumatology (Kjeken, 2011)	No (underpinning evidence did not include client evidence due to limited time& resources)	1) ACSM (Pollock *et al.*, 1998) 2) Occupational therapy-based and evidence-supported recommendations (Kjeken, 2011)
Kang *et al.* (2019)	Based on (Østerås *et al.*, 2014a)	Not described	Not described	Non reported
Kjeken *et al.* (2011)	Based on systematic review	Not described	Not described	ACSM (Pollock *et al.*, 1998)

Records	Evidence-based Intervention development Recommendations			Evidenced-based Exercise development Guidelines
	Research evidence	Expert expertise	Patient/client evidence	
Kjeken *et al.* (2015)	Literature review of key records	Clinicians (3 OTs & 2 PTs)	People with and without HOA	1)ACSM(Pollock *et al.*, 1998) 2)Framework for design and evaluation of complex interventions (Craig *et al.*, 2013)
Kroon *et al.* (2018b)	Not described	Not described	Not described	Not described
Lefler *et al.* (2004)	Not described	Not described	Not described	Not described
Nery *et al.* (2015)	Not described	Not described	Not described	Not described
Nguyen *et al.* (2016)	Not described	Not described	Not described	Not described
Østerås *et al.* (2014a)	Systematic review	Based on Kjeken *et al.* (2015) which included experts	Based on Kjeken *et al.* (2015) which included client knowledge	1) Framework for the design and evaluation of complex interventions(Craig *et al.*, 2013) 2) ACSM (Pollock *et al.*, 1998)
Osteras *et al.* (2017)	Not described	Not described	Not described	Not described
Pérez-Mármol *et al.* (2017)	Research (Lockard, 2000; Stamm *et al.*, 2002)	Underpinning evidence i.e. involved expert	No	Non reported
Rocchi *et al.* (2018)	Not described	Not described	Not described	Not described
Rogers *et al.* (2009)	Based on Stamm *et al.* (2002)	Consultations with OT; hand therapist)	No	Non reported
Scott (2018)	Yes Recommendatio ns based on research e.g. (Valdes *et al.*, 2012); Kjeken *et al.* (2015)	Not explicitly reported *Partly meets criteria* Underpinning evidence (Kjeken *et al.* (2015) included exerts opinion	Not explicitly reported Underpinning evidence i.e. Kjeken *et al.* (2015) included patient knowledge	Underpinning evidence reported using the ACSM guidelines.
Stamm *et al.* (2002)	No	Based on clinical experience of authors	No	Non reported
Stoffer-Marx *et al.* (2018)	Based on Stoffer *et al.* (2015) which included existing guidelines	Eumusc.net-working group (Stoffer *et al.*, 2015)	Based on Stoffer *et al.* (2015) which included patient perspectives	European standards of care for OA (Stoffer *et al.*, 2015)
Valdes *et al.* (2012)	Based on review of	No	No	ACSM (Garber *et al.*, 2011)

Records	Evidence-based Intervention development Recommendations			Evidenced-based Exercise development Guidelines
	Research evidence	Expert expertise	Patient/client evidence	
	biomechanical studies			
Veronese *et al.* (2020)	Not described	Not described	Not described	Not described
Villafañe et al. (2013)	Based on (Rogers *et al.*, 2009)	Underpinning evidence i.e. Rogers *et al.* (2009) involved expert	No	Non reported

NB: ACSM - American College of Sports Medicine; OT – occupational therapist

5.6.3.3 Prescription of Exercises according to best Hand OA Clinical Guideline recommendations

The exercise programmes advocated by best hand OA guidelines and consensus recommendations are provided in Table 5-7. Of the 33 records, only three (Davenport *et al.*, 2012; Dziedzic *et al.*, 2015; Hennig *et al.*, 2015) met these recommendations and included all three exercise types in their exercise programme. Majority of records (n=18) included two of the recommendations. Of these 18 records, two included strengthening and stretching exercises only (Aebischer *et al.*, 2016; Kang *et al.*, 2019) , two included Stretching and flexibility exercises only (Stamm *et al.*, 2002; Rocchi *et al.*, 2018) and 14 included strengthening and flexibility exercises only. Collectively, eight records included only one of the recommendations; strengthening exercises only (n=6), stretching exercises only (n=0) and flexibility exercises only (n=2) (see Appendix B.8.2 for further details).

Table 5-7: Exercise Prescription according to summarized best hand OA Guidelines and Consensus recommendations (Sankah et al., 2019b)

Records	Summarised Guideline Recommendations		
	Strengthening exercises	**Stretching exercises**	**Joint flexibility (ROM) exercises**
Aebischer *et al.* (2016)	x	x	–
Beasley *et al.* (2019)	x	–	x
Beasley (2012)	–	–	x
Bertozzi *et al.* (2015)	x	–	–
Bjurehed *et al.* (2017)	x	–	x
Boustedt *et al.* (2009)	x	–	x
Brorsson *et al.* (2014)	x	–	x
Brosseau *et al.* (2017)	–	–	x
Davenport *et al*. (2012)	x	x	x
DeMott (2017)	x	–	x
Deveza *et al.* (2017)	x	–	x
Dziedzic *et al.* (2015)	x	x	x
Guitard *et al.* (2018)	–	–	–
Hamasaki *et al.* (2020)	–	–	–
Hennig *et al.* (2015)	x	x	x
Kang *et al.* (2019)	x	x	–
Kjeken *et al.* (2011)	x	–	x
Kjeken *et al.* (2015)	x	–	x
Kroon *et al.* (2018b)	–	–	–
Lefler *et al.* (2004)	x	–	–
Nery *et al.* (2015)	x	–	–
Nguyen *et al.* (2016)	x	–	x
Østerås *et al.* (2014a)	x	–	x
Osteras *et al.* (2017)	–	–	–
Pérez-Mármol *et al.* (2017)	x	–	–
Rocchi *et al.* (2018)	–	x	x
Rogers *et al.* (2009)	x	–	x
Scott (2018)	x	–	–
Stamm *et al.* (2002)	–	x	x
Stoffer-Marx *et al.* (2018)	x	–	x
Valdes *et al.* (2012)	x	–	x
Veronese *et al.* (2020)	x	–	
Villafañe et al. (2013)	x	–	x

NB: “x” = included; “–” =did not include / meet criteria

5.6.3.4 Exercise Adherence reporting and adherence strategies for Hand OA exercise management.

Table 5-8 shows a summary of the description of the included records that reported on exercise adherence and the adherence strategies employed in the description of the hand OA exercise programmes. Of the 33 records selected, only 12 reported on exercise adherence and described the adherence strategies employed in the description of their exercise programmes. Of the remaining records, 18 did not report on exercise adherence and three reported on exercise compliance instead.

Table 5-8: Summary of exercise adherence reporting and adherence strategies employed in the prescription of hand OA exercises.

Records	Exercise adherence	
	Was Adherence Reported?	Strategies used
Aebischer *et al.* (2016)	No	Not described
Beasley *et al.* (2019)	No	Not described
Beasley (2012)	No	Not described
Bertozzi *et al.* (2015)	No	Not described
Bjurehed *et al.* (2017)	No	Not described
Boustedt *et al.* (2009)	Compliance reported instead	N/A
Brorsson *et al.* (2014)	No	No
Brosseau *et al.* (2017)	Yes	Patient exercise logbook Periodic patient goal Setting
Davenport *et al*. (2012)	Compliance reported instead	N/A
DeMott (2017)	No	Not described
Deveza *et al.* (2017)	Yes	Exercise diaries Supervised face -to -face treatment sessions
Dziedzic *et al.* (2015)	Yes	1. self-reported performance of exercises 2. Use of diaries
Guitard *et al.* (2018)	Yes	1. telephone reminders 2. logbooks (record daily activities, pain levels, etc) 3. Adherence estimated as the number of knitting sessions attended at Club and home divided by the number of knitting sessions prescribed as recorded in the participants' logbooks
Hamasaki *et al.* (2020)	No	Not described
Hennig *et al.* (2015)	Yes	1. Exercise diary. 2.Telephone calls (weekly in first month & every second week for rest of study period)
Kang *et al.* (2019)	No	Not described
Kjeken *et al.* (2011)	Yes	Not described
Kjeken *et al.* (2015)	Yes	1.Exercise Diary 2.Weekly telephone follow-up
Kroon *et al.* (2018b)	No	Not described
Lefler *et al.* (2004)	Compliance reported instead	N/A
Nery *et al.* (2015)	No	Not described
Nguyen *et al.* (2016)	No	Not described
Østerås *et al.* (2014a)	Yes	1. SMS reminders sent one day in advance of group sessions

Records	Exercise adherence	
	Was Adherence Reported?	Strategies used
		2. weekly telephone calls by researchers during period of home programme
Osteras *et al.* (2017)	No	self-reported adherence
Pérez-Mármol *et al.* (2017)	Yes	Therapist recorded daily intervention
Rocchi *et al.* (2018)	No	Not described
Rogers *et al.* (2009)	Yes	1. Daily logbook 2. Once monthly contact by investigator (e.g. telephone, email or postal letter) to encourage adherence to the protocol and to help subjects adjust the exercises if needed
Scott (2018)	No	Not described
Stamm *et al.* (2002)	Yes	Exercise diary
Stoffer-Marx *et al.* (2018)	Yes	Telephone follow-up calls
Valdes *et al.* (2012)	No	Not described
Veronese *et al.* (2020)	No	Not described
Villafañe et al. (2013)	No	Not described

NB: SMS – Short Message Service.

Figure 5-3 shows the frequency of the adherence strategies employed in the prescription of hand OA exercise programmes in the records selected. Nine different strategies were reported and of these strategies, the most frequently used were telephone follow up calls and reminders (27%) (Rogers *et al.*, 2009; Østerås *et al.*, 2014a; Hennig *et al.*, 2015; Kjeken *et al.*, 2015; Guitard *et al.*, 2018; Stoffer-Marx *et al.*, 2018). Participants were either telephoned weekly, biweekly, or monthly by the research investigators or clinical professionals involved in the research projects to encourage adherence or help subjects adjust exercises if needed. Other popular strategies reported were exercise diaries (23%) (Stamm *et al.*, 2002; Dziedzic *et al.*, 2015; Hennig *et al.*, 2015; Kjeken *et al.*, 2015; Deveza *et al.*, 2017) and logbooks (14%) (Rogers *et al.*, 2009; Brosseau *et al.*, 2017; Guitard *et al.*, 2018). These were kept by study participants to record their exercise performance and other hand related details such as their hand activities, morning stiffness and pain levels. Other less frequently reported strategies were self-reported exercise performance by participants (9%), recorded exercise sessions by investigating therapists (5%), periodic patient goal setting (4%) and Short Message Service (SMS) reminders (4%). Lastly, one record in addition to other strategies also reported their intention of estimating adherence mathematically by calculating the number of knitting sessions attended at a senior's club and home divided by the number of knitting sessions prescribed (Guitard *et al.*, 2018).

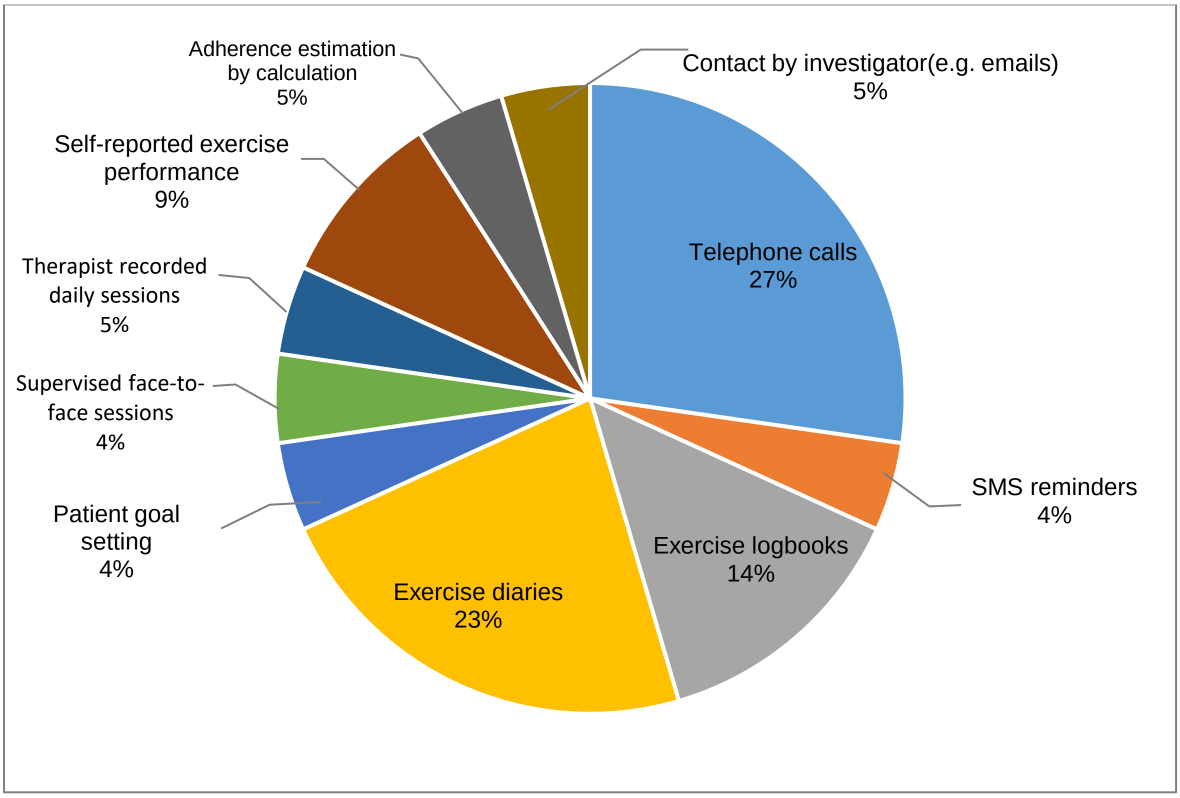


Figure 5-3: Summary of adherence strategies frequently employed in the prescription of hand OA exercises

5.6.4 Emerging themes

In addition to the a priori themes presented above, four emerging themes of relevance to the review were identified during the review process. These were mode of exercise delivery, adverse effects/events, compliance and aim of exercises (see Appendix B.9). Findings of the first two are presented based on their relevance in informing the choice of exercises to include in the exercise programme to be developed.

5.6.4.1 Mode of delivery

The frequently used method for delivering hand OA exercise programmes was the supervised method (n=9) (Table 5-9). Other forms reported were the delivering exercises as home programmes only (n=6) or a combination of home and supervised programme (n=7). Some exercise programmes included warm-up exercises (Valdes *et al.*, 2012; Kjeken *et al.*, 2015; Scott, 2018; Stoffer-Marx *et al.*, 2018). For some home programmes, exercises were delivered with exercise booklets (n=4) containing written and pictorial instructions and advice (see Appendix B.9 for complete reporting).

Table 5-9: Mode of delivery of exercise programmes

Mode of delivery	Numbers of records	Contributing records
Home	6	Beasley (2012); Brosseau *et al.* (2017) Davenport *et al.* (2012); DeMott (2017) Hennig *et al.* (2015); Stamm *et al*. (2002)
Supervised	9	Bjurehed *et al.* (2017); Deveza et al. (2017); Kang *et al.* (2019); Kjeken et al. (2011); Lefler *et al.* (2004); Pérez-Mármol *et al.* (2017); Rocchi *et al*. (2018); Villafane *et al.* (2013)
Home + supervised	7	Boustedt *et al*. (2009); Dziedzic *et al.* (2015); Guitard *et al.* (2018); Osteras *et al.* (2017); Rogers *et al.* (2009); Stoffer-Marx *et al.* (2018);Østerås et al. (2014a)
Exercise booklet (written information & advise)	4	Deveza *et al*. (2017); Dziedzic et al. (2015); Rogers *et al.* (2009); Scott (2018)
Website (Visual description of exercises)	1	Deveza *et al.* (2017)
Group sessions	3	Bjurehed *et al.* (2017); Østerås *et al.* (2014a); Stoffer-Marx *et al.* (2018)

5.6.4.2 Adverse effects/events of exercises

Of the 33 records, only nine reported adverse effects of the exercises used. There was an absence of reporting in the 24 remaining records (see Table 5-10). Regarding the records that reported on adverse effects, four stated no reported adverse effects of the exercises used (Stamm *et al.*, 2002; Villafane *et al.*, 2013; Dziedzic *et al.*, 2015; Pérez-Mármol *et al.*, 2017). Others reported severe pain (Hennig *et al.*, 2015), increased finger inflammation and pain (Østerås *et al.*, 2014a; Osteras *et al.*, 2017) and withdrawal (see Table 5-10).

Table 5-10: Reported adverse effects/events of exercises for hand OA

Adverse effects/events	Numbers of records	Contributing records
Intervention had no reported adverse effects	4	Dziedzic *et al.* (2015); Pérez-Mármol *et al.* (2017); Stamm *et al.* (2002) Villafañe *et al.* (2013)
Severe pain after 9th week of exercise	1	Hennig *et al.* (2015)
1. Increased inflammation & pain in finger (n=1) 2. Increased swelling & pain of all fingers (n=2). 3. Increased shoulder/ neck pain in participants with such previous problems (n=5) 4. One withdrawal	4	Østerås *et al.* (2014a); Osteras *et al.* (2017)
High withdrawal (n=18) (due to e.g. increased hand symptoms; loss of interest or lack of remembrance to do exercises, etc)	1	Rogers *et al.* (2009)
Tendovaginitis	1	Stoffer-Marx *et al.* (2018)

5.7 Synthesis of results

5.7.1 Summary of frequently used exercises for hand OA

Based on the frequency of reported use in literature (section 5.6.3.1) and the no or minimal adverse effects related to the exercises, a summary of six frequently used exercises for hand OA management were summarized (see Table 5-11). These exercises included: “making O sign, making a fist; finger and thumb stretch, grip strengthening, and pinch strengthening (using exercise balls or putty) and thumb extension & abduction with elastic bands.

Table 5-11: Summary of frequently included exercises for hand OA management

Exercises	Numbers of records	Contributing records
1. Making O sign	11	Brorsson *et al.* (2014); Davenport *et al*. (2012) Dziedzic *et al.* (2015); Hennig *et al.* (2015); Kang *et al.* (2019); Kjeken *et al.* (2015); Østerås *et al.* (2014a); Rogers *et al.* (2009); Stamm *et al.* (2002); Stoffer-Marx *et al.* (2018);
2. Making a fist	9	Hennig *et al.* (2015); Kang *et al*. (2019) Kjeken *et al.* (2015); Lefler *et al.* (2004); Østerås et al. (2014a); Rogers *et al.* (2009); Stamm *et al.* (2002); Stoffer-Marx *et al.* (2018); (Villafañe *et al.*, 2013)
3. Finger and thumb stretch	5	Davenport et al. (2012); Hennig *et al*. (2015); Kang *et al.* (2019); Kjeken *et al.* (2015); Rocchi *et al.* (2018)
4. Grip strengthening	12	DeMott (2017); Brorsson *et al.* (2014); Bjurehed et al. (2017); Deveza *et al.* (2017); Hennig *et al.* (2015); Kjeken *et al.* (2015); Lefler *et al*. (2004); Østerås *et al.* (2014a); Rogers *et al.* (2009); Stoffer-Marx *et al.* (2018); Valdes *et al.* (2012); Villafañe *et al.,* (2013)
5. Pinch strengthening	5	Lefler *et al.* (2004); Rogers *et al.* (2009); Scott (2018); Valdes *et al.* (2012); Villafañe et al., (2013)
6. Thumb extension & abduction with elastic band	4	Davenport *et al.* (2012); Hennig *et al.* (2015) Kjeken *et al.* (2015); Scott (2018)

5.8 Discussion

5.8.1 Summary of evidence

A scoping review to identify the gaps and evidence recommendations on existing exercise programmes for hand OA management, their development, prescription, and adherence strategies was conducted. From the results, six strengthening and ROM exercises were identified as commonly used exercises for hand OA management: (1) “making O sign” (2) making a fist (3) finger and thumb stretch (4) grip strengthening (5), pinch strengthening and (6) thumb extension & abduction with elastic bands were identified. These exercises are targeted at improving muscle strength and joint flexibility and meet evidence-based recommendations for hand OA as the 2018 EULAR recommendations recommended that exercises for hand OA should aim to improve joint flexibility, muscle strength and thumb base stability (Kloppenburg *et al.*, 2018). From the previous systematic review (Chapter 4), good quality guidelines and consensus recommendations recommend the use of strengthening, stretching and joint flexibility exercises for hand OA due to their positive effect on hand pain, function and muscle strength (Katz *et al.*, 2001; Sankah *et al.*, 2019b). The six exercises identified from the present scoping review can be grouped into these three exercise categories: joint flexibility (making O sign”; making a fist), stretching (finger and thumb stretch) and strengthening exercises (grip and pinch strengthening; thumb extension & abduction with elastic bands). The use of these exercises for hand OA management are therefore supported in the literature and based on the highlighted benefits and minimal related adverse effects, the inclusion of these exercises in hand OA programmes is proposed.

Literature highlights the deficiency in the development of interventions for hand OA (Kjeken *et al.*, 2015) as many available programmes do not meet the evidence-based development requirement (i.e. quality research, clinical expertise and client evidence) (Rappolt, 2003). Findings from the present scoping review agree with previous reports on this evidence deficiency as only six out of the 33 records (Østerås *et al.*, 2014a; Dziedzic *et al.*, 2015; Kjeken *et al.*, 2015; Guitard *et al.*, 2018; Scott, 2018; Stoffer-Marx *et al.*, 2018) investigated exercises informed by the recommended evidence-based development. Similarly, a few exercises were informed by research and expert opinion, some by research evidence only, and majority provided no information. Whilst such findings may limit the confidence in the use of the exercises due to the uncertainty regarding its robust development, it also highlights the challenges regarding insufficient intervention reporting previously documented in literature (Glasziou *et al.*, 2008; Sankah *et al.*, 2019b).

Congruent with previous arthritis reviews (Hurkmans *et al.*, 2011; Sankah *et al.*, 2019b), future authors are encouraged to provide sufficient information underpinning their exercise development to inform decision-making on the use of the exercises amongst stakeholders (i.e. patients, clinicians and researchers).

In evidence-based practice and clinical decision making, the value of patient evidence with regards to their views, wishes and expectations is equally important, as that of research evidence and clinical expertise (Rappolt, 2003;2004; Kloppenburg *et al.*, 2018). Of note, conspicuously missing amongst the three evidence sources underpinning the development of the exercises reviewed within the present scoping review was patient or client evidence contrary to evidence recommendations (Rappolt, 2003). Despite a few authors (Østerås *et al.*, 2014a; Dziedzic *et al.*, 2015; Hennig *et al.*, 2015; Kjeken *et al.*, 2015; Deveza *et al.*, 2017; Guitard *et al.*, 2018; Scott, 2018; Stoffer-Marx *et al.*, 2018) documenting the inclusion of patient evidence by way of information from consumer groups, people living with hand OA and patient and public involvement (PPI) activities, the majority did not include such information and if included, this was not reported. In agreement with previous evidence recommendations, authors are encouraged to consider and incorporate patient evidence in the development of future exercises for hand OA management to inform decision-making on the use of the exercises (Kloppenburg *et al.*, 2014; Kjeken *et al.*, 2015). A positive example to follow is the use of PPI as advocated by the UK national initiative: INVOLVE (Turk *et al.*, 2017) to engage hand OA patients in the planning and development of exercises to ensure acceptability and relevance of the exercises developed.

Whereas the majority of the records reviewed did not document the exercise development guideline followed, a few indicated using the ACSM guidelines for exercise development and prescription in adults (Kjeken *et al.*, 2011; Østerås *et al.*, 2014a; Hennig *et al.*, 2015; Kjeken *et al.*, 2015; Guitard *et al.*, 2018; Scott, 2018). The use of the ACSM guideline (ACSM 1998; 2011; 2014) for hand OA exercise development and prescription has attracted mixed reports. Whilst some researchers simply recommend its use as there are no guidelines currently available for such purpose (Kjeken *et al.*, 2011), others have queried its use as the evidence informing its development is largely extrapolated from literature on large joints (such as hips, knees, lower limbs) and not the hand or upper limbs (Lockard, 2000; Colditz, 2013). Nonetheless, the inconsistencies regarding exercise prescription and the limited evidence available on hand OA exercise development (Kjeken *et al.*, 2011; Kjeken *et al.*, 2015) warrant the need to be guided by an established guideline.

Hence, until a hand OA or upper limb exercise development guideline is developed, the ACSM guideline still remains the most appropriate guideline for hand OA exercise development and prescription. In line with previous review recommendations (Kjeken *et al.*, 2011), hand OA exercise development can be informed by the ACSM guideline however, this can be used flexibly in combination with evidence from hand OA patients and expert advice.

A systematic review to evaluate the design and effects of splints and exercises in hand OA emphasized the need for adherence reporting as this allows the feasibility and dose-response of the interventions to be assessed (Kjeken *et al.*, 2011). Contrary to this report, more than half of the records within the present review did not report on adherence. These findings are however not different from a previous systematic review that reported that most studies either poorly or inconsistently reported adherence to hand therapies (Cole *et al.*, 2019). Thus, results from the present review further highlight the gaps in exercise adherence reporting as previously documented in literature. In agreement with other reviewers, future authors are encouraged to document exercise adherence as this will not only facilitate the evaluation of the feasibility of the exercises by readers but also the ability of the research authors themselves to assess the effect of these exercises.

Given the importance of exercise adherence in evaluating long-term exercise outcomes, investigations into methods that improve adherence in hand OA exercise management are warranted (Brosseau *et al.*, 2011; Brosseau *et al.*, 2018; Kloppenburg *et al.*, 2018). Within the present review, telephone follow-up calls reminders and exercise diaries were the two most reported adherence strategies used either as single approach or a combination of both with positive exercise outcome effects. These findings are consistent with previous literature that reported that such approaches minimizes dropouts (Clough *et al.*, 2011) and in addition to self-reported performance, improves adherence (between 47% -94%) and maximizes the implementation of intervention adjustments (Brosseau *et al.*, 2018). According to the World Health Organization (2003), a combination of different adherence strategies has the potential to improve the success of interventions. Based on this, a combination of telephone calls and exercise diaries can be considered for monitoring exercise programmes for hand OA management with an expectation to yield positive benefits, which should be tested in future studies.

Lastly, majority of the records reviewed were from Europe (55%) and North America (27%), a few from Australia, Asia, and South America (3% each) and none from Africa. Findings from the review are therefore largely biased towards the European and North American context and as such its interpretation within the least represented world regions (i.e. Australia, Asia, and South America) should be done with care.

More particularly, extreme caution should be exercised in the generalization and implementation of the results within the African context as no records were identified from that region. These findings are consistent with findings from Chapter 4 (Sankah *et al.*, 2019b) which reported that only one guideline on OA (Brighton *et al.*, 2003) was identified from the African region which did not only need an update but was also of poor quality. This highlights the huge research gap regarding hand OA within this region and future research into the assessment, management and epidemiology is highly warranted.

5.8.2 Strengths and limitations

Prior to the year 2018, a lack of consensus existed regarding scoping review reporting (Tricco *et al.*, 2016; Peters MDJ *et al.*, 2017), however this was greatly minimized with the development of the PRISMA-ScR checklist (Tricco *et al.*, 2018). One of the strengths of this review is its reporting according to this checklist. In the publication of the scoping review protocol (Sankah *et al.*, 2019a) as guided by the JBI scoping review methodology, the PhD reviewer pledged her compliance to use the PRISMA-ScR checklist upon availability to support the global standardization in the conduct and reporting of scoping reviews (Peters MDJ *et al.*, 2017). Another strength of this scoping review is that, this pledge was upheld to maintain the fidelity of the reviewers, minimize publication bias and enhance the transparency of the review process.

The registration of scoping review protocols has now been strongly encouraged by scoping review methodologists (Tricco *et al.*, 2016; Tricco *et al.*, 2018; Peters MDJ, 2020) to prevent the duplication of reviews similar to the guidance for the conduct of systematic reviews. One of the limitation of this review is that contrary to this recommendation, details of this scoping review were not registered because at the time of preparing the review protocol, the PRISMA-ScR Checklist (Tricco *et al.*, 2018) was not available to inform this process. However, the review protocol was published (Sankah *et al.*, 2019a) and therefore served the same purpose in addition to enhancing the transparency of the review process. Another limitation is the possibility of language bias as only records published in the English language were selected.

5.9 Conclusions

1. Six strengthening and ROM exercises were identified as commonly used exercises for hand OA management: (1) “making O sign” (2) making a fist (3) finger and thumb stretch (4) grip strengthening (5), pinch strengthening and (6) thumb extension & abduction with elastic bands.

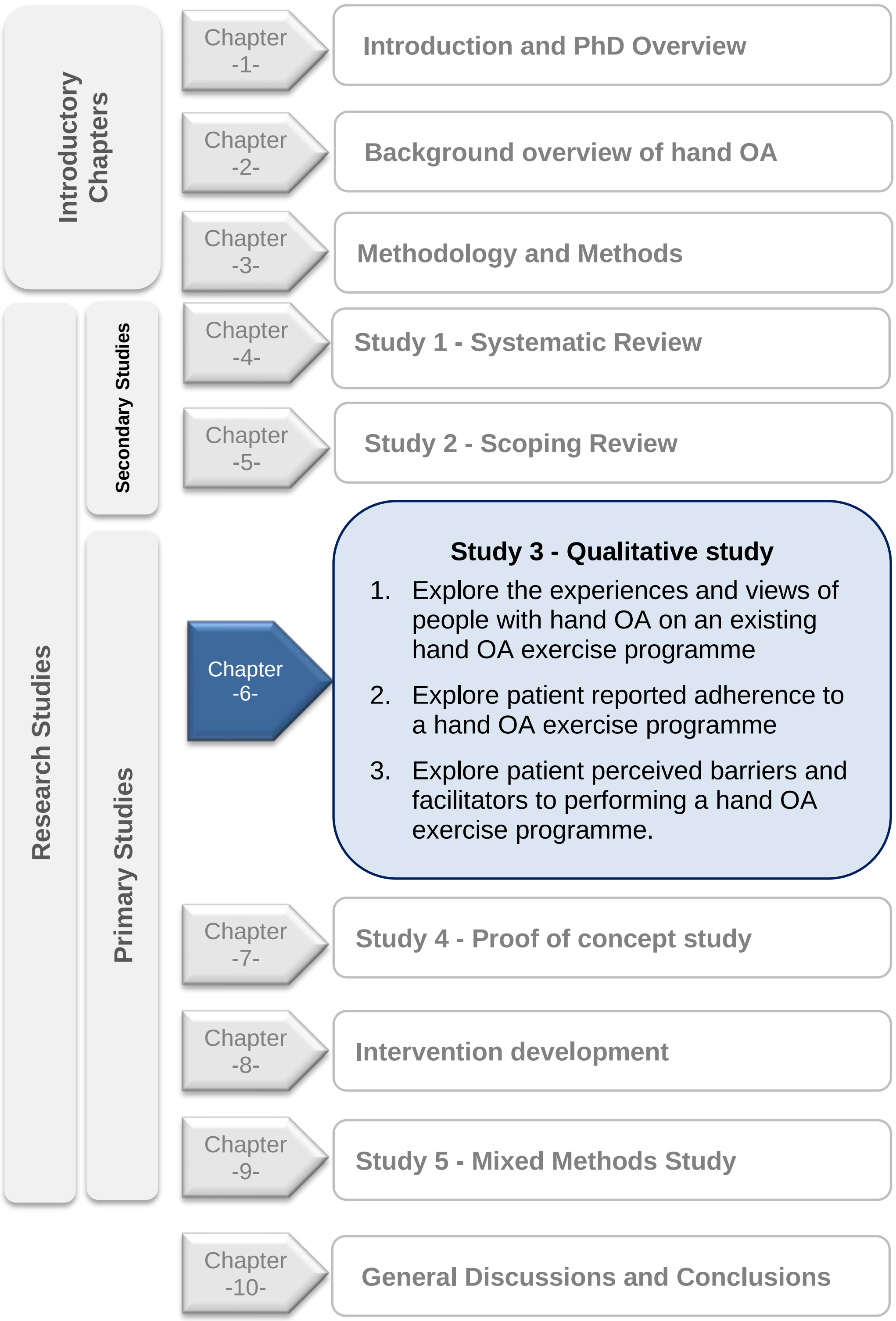
The use of these exercises is supported in literature and based on the highlighted benefits and minimal related adverse effects, the inclusion of these exercise in hand OA programmes is proposed.

2. Findings highlight the deficiency in the development of interventions for hand OA as many available programmes did not meet the evidence-based development requirement. Future authors are encouraged to provide sufficient information underpinning their exercise development to inform decision-making on the use of the exercises amongst stakeholders.
3. The best practice recommendation for exercise development and prescription were the ACSM guideline and the MRC guidance for the developing and evaluating complex interventions, which should be followed for future hand OA exercise developments.
4. Telephone follow-up calls and exercise diaries were the two most reported adherence strategies used for hand OA exercise management with reported positive exercise outcome.
5. This scoping review adds to previous literature by highlighting the huge research gap regarding hand OA research within the African region as no records were identified from the region. Future research into the assessment, management, and epidemiology of hand OA within this context is therefore highly warranted.

5.10 Summary

This chapter has described a scoping review aimed at identifying evidence regarding the development and prescription of, and adherence to, hand OA exercise programmes. Six recommended hand exercises have been identified to inform the development of the novel exercise programme within this PhD. Other findings within this scoping review served as a guide and useful resource in addressing the aim of the PhD, which is to develop an exercise intervention for people with hand OA. The next chapter introduces Study 3, a qualitative analysis study to explore the views of hand OA patients on an existing hand OA exercise programme.

Location in thesis



Chapter 6 Study 3 - Patients' Experiences and Views of a Hand Osteoarthritis Exercise Programme: A Qualitative Analysis Study

6.1 Introduction

Alongside reviewing the literature to identify key evidence, it was important to seek an in-depth understanding about patient perspectives regarding existing hand OA exercises to address the overall research aim. This chapter describes a qualitative analysis study (Figure 6-1) conducted as part of the OTTER II trial, a pragmatic, multi-centre and single blinded RCT with an objective to determine the clinical effectiveness and efficacy of thumb splints, when added to a self-management programme. This study was informed by the following research questions:

1. What are the experiences and views of people with hand OA on an existing hand OA exercise programme?
2. What is the patient reported adherence to this exercise programme (OTTER exercise programme)?
3. What are patient perceived barriers and facilitators to the performance of hand OA exercises?

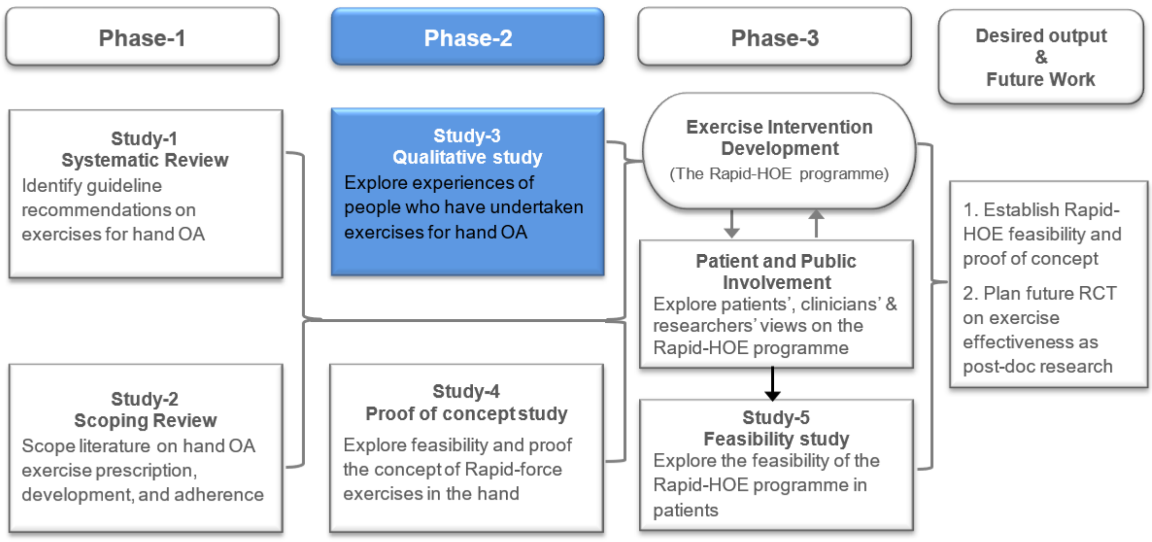


Figure 6-1: Qualitative study location within the overall PhD research

6.2 Background

Emerging evidence suggests poor patient adherence, and tolerance, to existing exercise programmes used in clinical practice for hand OA management (Bassett, 2003; Hill *et al.*, 2011). A qualitative enquiry exploring perceptions and experiences of hand OA management further reported that people appeared to be unsure as to whether exercising their hands and fingers might aggravate their symptoms (Hill *et al.*, 2011). Such ambivalence in patient perceptions may affect outcome expectations in patients and exercise adherence to hand OA exercise programmes. From evidenced-based perspectives, the voice of the patient regarding their views, wishes and expectations is equally relevant, in the clinical decision-making, as the research evidence and clinical expertise. The overarching purpose of this doctorate is to develop an exercise intervention for people with hand OA. To address this, it was necessary to understand the experiences of people with hand OA, regarding their uptake, tolerance, and adherence to existing hand OA exercise programmes. From the perspectives of the researcher, such patient information will serve as a guide, and a useful resource, to inform the development of the new exercise programme (the aim of this PhD).

The WHO defines adherence as ‘‘the extent to which a person’s behaviour corresponds with agreed recommendations from a healthcare provider’’ (World Health Organization, 2003). Across health disciplines, adherence to treatment interventions is reported as one of the most complex and challenging issues (Clough *et al.*, 2011). Within the rehabilitation domain, the levels of adherence to prescribed exercises are often low, and this, limits the physiological adaptations that may be accrued by exercise programmes. The concept of adherence is multidimensional (Bassett, 2003) and can relate to the exercise frequency, correct performance of exercise techniques, following advice (doing more or less than advised) and attendance at appointments to list some examples. Consequences of non-adherence are extensive, it can result in poorer and ineffective treatment outcomes at various stages of the therapeutic process, as well as increased treatment costs and poor use of resources, staff and client time (Clough *et al.*, 2011). Due to several interventional and methodological factors, non-adherence may vary within different interventions. However, for home-based exercise therapies where individuals are required to self-manage their rehabilitation programme, non-adherence rates have been reported to be high (63%–70%) (Shang *et al.*, 2012). Jack *et al.* (2010) therefore highlighted the importance of identifying specific barriers to treatment adherence to enable either the creation, or adaptation of programmes, to address these challenges.

Understanding the barriers and facilitators to exercise performance and adherence of existing exercise programmes, such as the OTTER study's programme (Table 6-1), is crucial to the overall PhD aim. These findings will provide patient-centred information on adherence approaches for the development of the exercise programme within this PhD as well as future exercise programmes.

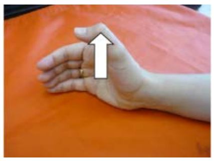
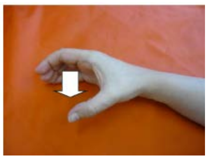
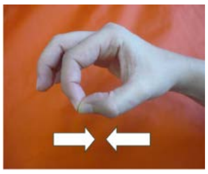
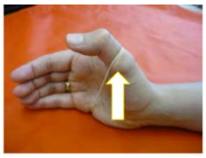
This qualitative enquiry aimed to understand the experiences and views of hand OA patients on an existing hand OA exercise programme. To achieve this, data from a sample of hand OA patients, who have been prescribed a hand exercise programme as part of a self-management package within the Osteoarthritis Thumb base Therapy (OTTER II) trial was analysed. The OTTER II trial is a pragmatic, multi-centre, and single blinded RCT. The trial's primary objective was to determine the clinical effectiveness and efficacy of thumb splints, when added to a self-management programme, which included exercises for people with symptomatic thumb base OA (Adams *et al.*, 2019). Whilst the trial was active (February 2017 - March 2019), the current PhD researcher analysed interview data on the exercises used in the trial with approval from the trial's chief-investigator (Prof Jo Adams) and management team (Oxford Clinical Trial Research Unit – OCTRU). The OTTER exercise programme was a home exercise programme, containing three levels of exercises; Level 1: thumb joint mobility; Level 2: resistive strengthening with the elastic band; and Level 3: functional task performance. Depending on their ability and successful completion of Level 1 exercises, participants progressed their exercise performance to Level 2 and 3 (Table 6-1). These exercises were performed in total, for at least 20 minutes, three times a week, over a three-month period.

6.2.1 Objectives

The study's objectives were:

1. To explore the experiences and views of people with hand OA on the OTTER exercise programme
2. To explore patient reported adherence to the OTTER exercise programme
3. To explore patient perceived barriers and facilitators to performing the exercise programme.

Table 6-1: Description of hand exercises and exercise levels delivered in the OTTER trial

Exercise Levels	Exercise description	Exercise illustration
Level 1 exercises	Warm-up (exercise gently moving thumb in warm water).	
	Exercise 1: thumb extension (Hold for 10 seconds; repeat 10 times)	
	Exercise 2: thumb abduction (Hold for 10 seconds; repeat 10 times)	
	Exercise 3: making an O sign (Hold for 10 seconds; repeat 10 times)	
Level 2 exercises (rubber band placed around the hand crossing the middle of the thumb).	Exercise 1: warm-up exercises	
	Exercise 2: resisted thumb extension with the thumb joint flexed (Hold for 5 seconds; repeat 10 times)	
	Exercise 2: resisted thumb abduction (Hold for 5 seconds and repeat up to 10 times.)	
Level 3 exercises	Exercise 1: warm-up exercises	
	Exercise 2: pinch tasks e.g. writing, holding plates, opening clothes pegs, tearing sheets of paper NB: keep thumb joints slightly bent, wrist slightly extended.	
	Exercise 3: Grip and turn tasks e.g. putting nuts on bolts, turning keys in locks, undoing jar tops, turning taps.	

NB: Content of table extracted from the exercise and information booklet of the OTTER trial with permission from the trial chief investigator (Jo Adams)

6.3 Methods

6.3.1 Reporting Checklist

The reporting of qualitative research can be restrictive and a "one-size-fits-all" approach cannot suffice (Peditto, 2018). Commonly used reporting checklists are the Consolidated Criteria for Reporting Qualitative Research (COREQ) and Standards for Reporting Qualitative Research (SRQR) (Peditto, 2018). The SRQR and COREQ serve as valuable tools for developing responsible qualitative research proposals and communicating effective research decisions (Giacomini *et al.*, 2000; O'Brien *et al.*, 2014; Peditto, 2018) However, from a brief review (see Table 6-2), the 21-item SRQR tool (Appendix C.1) was used to guide the reporting of this qualitative study as it reflects the essential information required for inclusion in a qualitative research report.

Table 6-2: Comparison between COREQ and SRQR (Peditto, 2018)

COREQ **(Tong *et al.*, 2007)**	**SRQR (O'Brien *et al.*, 2014)**
32-item checklist	21-item checklist
Interviews and focus groups	Interviews and focus groups, but extended to other qualitative studies
Constructed without consultation from outside researchers	Created with feedback from qualitative experts
Checklist divided into three domains: 1. research team 2. study design 3. analysis and findings	Checklist organised into three domains: 1. methods 2. results 3. findings & discussion
Healthcare field, but has been adapted by many other research disciplines	Healthcare field, but has been adapted by many other research disciplines
Oriented towards grounded theory research, making it inappropriate for other designs	

NB: COREQ - Consolidated Criteria for Reporting Qualitative Research; SRQR - Standards for Reporting Qualitative Research

6.3.2 Qualitative approach and research paradigm used

Qualitative research is described as studies that explore the "how?" and "why?" questions related to social or human problems or phenomena. Its main purpose includes the understanding of meanings from participants perspectives and how they interpret or make sense of an event, situation, or action (O'Brien *et al.*, 2014). From the literature, qualitative studies are categorized into several traditions, the common ones been narrative research, phenomenology, grounded theory, ethnographic studies and case studies (Creswell *et al.*, 2016).

For this study, the narrative qualitative research tradition was used, this choice was informed by the ability of the design to develop the narrative about the lived experiences which was the focus of the study (i.e. experiences of people living with hand OA on exercise programme undertaken) (Creswell *et al.*, 2016).

The previously discussed philosophical assumptions (Ontology, Epistemology, Axiology and Methodology) that informed the overall mixed methods study also informed this qualitative study (see Chapter 3). There are many paradigm interpretive frameworks that guides the conduct of qualitative research, a few known examples are pospositivism, constructivism (interpretivism), transformative and postmodernism paradigms (Denzin *et al.*, 2011). Amongst these, the PhD researcher in the conduct of this qualitative study was guided by the Constructivism framework and more specifically, the Social Constructivism framework.

6.3.2.1.1 Social Constructivism (Interpretivism)

6.3.2.1.1.1 Tenets of Social Constructivism (Nature of the framework)

The social constructivism framework seeks to understand the meanings individuals give to their experiences and the knowledge created in the interaction between researchers and participants (Denzin *et al.*, 2011). Using this framework, data are generated with an aim to understand a phenomenon from the viewpoint of the individuals experiencing it through observation and dialogue using researcher-initiated data generation efforts, such as interviewing (Denzin *et al.*, 2011).

6.3.2.1.1.2 How Social Constructivism informed the present study

The aim of this qualitative study was to explore the views of people with hand OA on an existing exercise programme, with specific focus on the subjective views, and meanings of their lived experiences. From literature, such lived experiences were best produced through the social constructivism paradigm. As these experiences are not simply imprinted in the minds of people and can be forgotten, the researcher recognized the need to interact with participants through their social, historical, and cultural norms. According to Creswell *et al.* (2016), such interactions allows researchers to gain a deeper understanding of the lived experiences achievable with the constructivism paradigm based on its tenets. To achieve this, the interview questions (Table 6-3) were formulated as broad and general as they can possibly be to allow the participants to construct the meaning of their experience as would be in a typical conversation with others.

Table 6-3: Patient Exercise Interview Questions

Interview Questions
1. Please tell me what you think about the exercise programme. Prompts a. Please would you describe your experience in doing the hand exercise programme? b. How often did you do the exercises? c. Was there anything that made it easier or difficult to perform these exercises? d. Was there anything you liked in your exercise programme, or not? e. Was there anything you disliked about your exercise programme, or not?
2. The researcher wants to make sure that the exercise programme is as good as it can be. Are there things you think should be changed about the exercise programme? Prompts a. Are there things that you think could be added to the programme? b. Are there things that you think could be taken away from the programme? c. Would you do anything differently if you were to do the exercises again or not? If yes, what would these be? d. Do you have any other suggestions on ways to improve the exercise programme?

6.3.3 Context and Sampling strategy

Guided by gender (female) and age (above 50 years), which are known risk factors for hand OA, 10 transcribed interview data were conveniently sampled from 40 OTTER II trial data with support from the OTTER trial team. A decision to use this sample size was made because the PhD researcher believed it was a feasible and practical number to analyse as the qualitative enquiry forms part of a mixed methods study, and not the main research paradigm for the overall PhD. The PhD researcher had access to only the data on the two questions on exercise, and not the entire interview responses.

6.3.4 Ethical issues

The OTTER II Trial was approved by the Ethics and Research Governance Online (ERGO II) of University of Southampton and the Integrated Research Application System (IRAS) of the National Health Service (NHS) (IRAS 198227). Ethical amendment was obtained to add two qualitative interview questions on exercise formulated by the PhD researcher to the approved interview script by the OTTER II Trial team.

To access the OTTER II Trial data for analysis, the PhD researcher completed mandatory OCTRU online training on Management of OCTRU Regulatory compliance, Training And Review system (MORTAR) from University of Oxford.

Additionally, all participants' data received and analysed were anonymised and cleaned of all personal and medical information to ensure data protection of the trial participants.

6.3.5 Data collection method and instruments

Permission was sought from the chief investigator (Jo Adams) of the OTTER II trial by the PhD researcher to access and explore the transcribed interview data collected from the OTTER II trial participants. The PhD researcher drafted two main interview questions aimed at exploring: i) the experiences of people with hand OA, regarding exercises they had undertaken to manage their hand OA, their adherence; and ii) perceived barriers and facilitators to these exercises (Table 6-3). These questions were reviewed and approved by qualitative experts and added to the Trial interview guide for data collection by an OTTER II Trial qualitative researcher.

6.3.6 Data processing and management

To maintain OTTER II trial compliance to the Standard Operating Procedures (SOPs) of the trial management team (OCTRU), the researcher worked, stored and managed transcribed files on the exercise section of the interviews in a folder created within the OTTER electronic trial master file. Through an account created with OCTRU, the researcher periodically reviewed OCTRU SOPS and completed mandatory tests during the active phase of the trial, to be abreast with, and adhere to, current SOPs and ensure the fidelity of the data management process (see Appendix C.2). Good Clinical Practice (GCP) is the international ethical, scientific and practical standard, to which all clinical research is conducted (NIHR, 2021). To have this skill and knowledge, and to manage the exercise section of the interview data in compliance with international standards, the researcher completed the National Institute of Health Research (NIHR) GCP training as required by the UK Policy Framework for Health and Social Care Research. All sampled interview data on experiences of hand OA exercise, were initially managed with Microsoft Word and later organized with the NVIVO qualitative data management software in readiness for data analysis (Silver *et al.*, 2014).

6.3.7 Data analysis

6.3.7.1 The Analytic Method - Thematic Analysis

Braun *et al.* (2006) defined thematic analysis as a method for identifying, analysing, and reporting patterns or themes within data. It is described as a useful research tool, which can offer a detailed and rich, yet complex, account of data.

Thematic analysis is recommended for novice qualitative researchers as it provides a more accessible form of analysis compared to other approaches, such as discourse analysis and grounded theory, which require more detailed theoretical and technological knowledge. This therefore influenced the decision-making on the use of thematic analysis. More so, the present qualitative study was aimed at exploring the views of patients regarding exercise therapy therefore using thematic analysis was deemed suitable for identifying trends in the interview data. All themes were crosschecked by JA to enhance the trustworthiness and credibility of the data analysis.

6.3.7.2 Definitions for thematic analysis

For the description of the thematic analysis used in this study, the following definitions adapted from Braun *et al.* (2006) were made (see Table 6-4).

Table 6-4: Definitions for thematic Analysis relating to this study

Terms	Definitions	Meaning within present study
Data corpus	All data collected for a particular research project	The entire OTTER trial data
Data set	Data from the data corpus used for a particular analysis (e.g. transcripts)	Transcriptions from the 10 study participants sampled from the 40 otter trial data corpus
Data items	Each individual piece of data collected, which make up a data set or corpus	Individual participant interviews (e.g. P1 transcribed interview data).
Data extract	Individual coded chunk of data identified within and extracted from a data item.	Individual coded chunk of data identified within and extracted from the individual participant interview transcripts
Theme	A level of patterned response or meaning within a data set and captures something significant about the data in relation to the research question	Patterned meaning within the OTTER transcripts which captured something significant about in relation to the research question
Code	Most basic element of the raw data that appears interesting to the analyst and can be assessed in a meaningful way regarding the phenomenon	Basic data that appears interesting to the PhD researcher and was assessed in a meaningful way regarding the study objective

6.3.7.3 Claims for thematic analysis

With thematic analysis, experts advise on the need for researchers to consider, and make certain, their choices before beginning analysis. These choices are:

1. What counts as a theme?
2. A rich description of the data set, or a detailed account of one aspect
3. Inductive versus theoretical thematic analysis
4. Semantic or latent themes
5. Epistemology: essentialist/realist versus constructionist thematic analysis

Below, the description of the claims (Table 6-5) and the PhD researcher's choices regarding each claim which guided the thematic analysis conducted within this qualitative study are provided.

Table 6-5: Claims informing the thematic analysis process (Braun *et al.*, 2006)

Claims		Researcher's choices
Claim-1: What counts as a theme?		
Prevalence of the theme in terms of the space it occupies within each data item	Prevalence of the theme in terms of the space it occupies across the entire data set.	Prevalence at the data item level (i.e. individual interview transcript).
Claim-2: Description of the data set		
Rich description of an entire data set	**Detailed account of some themes within the data set**	
1. provides rich overall description of the data 2. some depth and complexity are lost when writing with limitations on word count	1. provides details of certain themes 2. guided by the research or area of interest	Detailed account of themes within the data set
Claim 3 - Inductive versus theoretical thematic analysis		
Inductive thematic analysis	**Theoretical (deductive) thematic analysis**	
1. Bottom up approach **2.** data-driven **3.** themes identified are strongly linked to data 4. provides a rich overall description of the data, but lacks depth to some aspects of the data	1. Top down approach 2. analyst-driven 3. driven by researcher's theoretical or analytic interest in the area 4. provides detailed analysis of some aspect of the data but less rich overall description of the data	Inductive thematic analysis.
Claim 4 - Semantic or latent themes		
Sematic thematic approach	**latent thematic analysis**	
1. Themes identified within explicit meanings of data 2. Analyst not looking for anything beyond what participants have said 3. Analysis progresses from description to summarization - to interpretation (theorize the significance of patterns, their broader meanings, and implications)	1. Analysis goes beyond the semantic content, involves interpretative work 2. Analyst examines underlying ideas, assumptions and ideologies 3. Analysis produced is not just description, but is already theorized	Semantic thematic approach
Claim-5: essentialist/realist versus constructionist thematic analysis		
Essentialist/realist paradigm	**Constructionist thematic paradigm**	
1. Seeks to theorize motivations, experience, and meaning inherent within individuals **2.** Meanings and experiences are produced in a straightforward and unidirectional way **3.** Often clusters with sematic thematic analysis	1. Seeks to theorize the sociocultural contexts, and structural conditions, that enable the individual accounts that are provided 2. Meanings and experiences are socially produced and reproduced 3. Often clusters with latent thematic analysis	Essentialist/realist thematic analysis

6.3.7.4 Doing the thematic analysis - the 6 Stage process

The thematic analysis conducted within this study was 6-stage analysis recommended by Braun *et al.* (2006). The PhD researcher therefore followed the six thematic analytic phases recursively throughout the entire study analysis. Below, the six phases as conducted within the present study is described.

6.3.7.4.1 Phase-1: Data familiarisation

To understand the depth and breadth of the content of the data, the PhD researcher in Phase-1 repeatedly read and reread to familiarized herself with the data set. After this, she immersed herself in the data by reading in an active way to initially search for meaning and patterns. As advised for this phase, some notes were taken, interesting preliminary thoughts were marked for coding and an initial list of code ideas were drafted for the coding process (see Appendix C.3).

6.3.7.4.2 Phase-2: Generating initial codes

The formal coding process was undertaken during this phase of the analysis. Initial code ideas (Appendix C.3) identified from the immersion process were formalized and new codes that appeared interesting to the researcher and identified features of the raw data were generated following the sematic approach (i.e. identifying codes based on the surface meanings of data). Guided by the previous choices made for this thematic analysis (Table 6-5), the coding was inductively done and the codes generated were entirely driven by the interview data, and not influenced by any specific pre-existing themes previously published on the topic. Based on the previous decision made (see section 6.3.7.3), the entire content of the data set was not coded, rather only sections that detailed interesting features of data regarding the study objectives were coded. As advised by experts, coding was conducted in a systematic fashion across the entire data set and data relevant to each code were identified and collated.

6.3.7.4.3 Phase-3: Searching for themes

The analysis of the codes and its development into overarching themes took place in Phase 3. Here, the different codes identified across the entire data set were sorted into potential themes, and the relevant coded data extracts were organized within these identified themes. As shown in the mind map (Figure 6-2), the relationships between the identified codes, between themes and between the different levels of themes were also examined to produce a collection of candidate themes and sub-themes. Finally, all data extracts coded in relation to these candidate themes and sub-themes were organized for Phase 4 (see Appendix C.4).

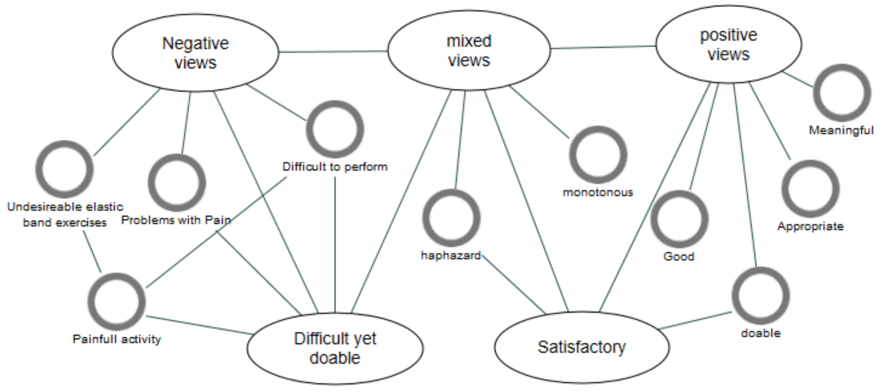


Figure 6-2: The initial thematic map, showing five main themes (elliptical circles) reflecting the views of study participants on the OTTER exercises

(Map produced using NVivo output concept map)

6.3.7.4.4 Phase-4: Reviewing themes

In Phase 4, the list of candidate themes and sub-themes created were reviewed to ascertain whether meaningful coherence, as well as clear identifiable distinctions existed between them. Two levels of reviewing were conducted: one at the coded extracted data level (Level 1) and the other at the entire data set level (level 2). For level 1, collated coded extracts were reviewed to check whether they formed coherent patterns with the related candidate themes. Candidate themes that did not fit were reworked; new themes were created. Extracts were re-coded to produce the candidate thematic map (see Figure 6-3). All irrelevant coded data extracts were discarded from the analysis. This candidate thematic map was then reviewed to ascertain whether it accurately reflected the meanings of the entire data set. Additionally, relevant data within themes missed during the initial coding process were coded and refined until a satisfactory thematic map reflective of the entire data set was generated (see Figure 6-4).

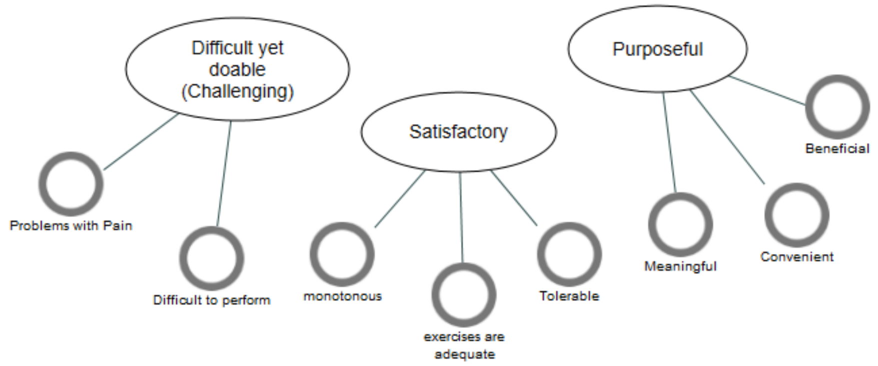


Figure 6-3: Developed candidate thematic map showing three themes after reviewing the initial five themes reflecting the views of study participants on the OTTER exercises

6.3.7.4.5 Phase-5: Defining and naming themes

The final themes (Figure 6-4) were clearly defined and named, the essence of what each stood for was determined and the aspect of the data that each captured was outlined. Finally, the relationship between each theme, how they fitted together and the story each told about the broader data in relation to the research objective was analysed and documented.

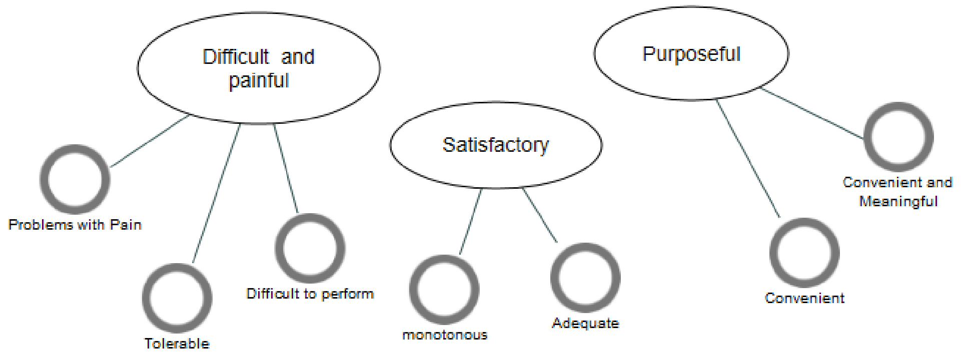


Figure 6-4: Final satisfactory thematic map showing the three main themes and subthemes reflecting the views of study participants on the OTTER exercises.

This map is reflective of the entire data set (all 10 interview transcripts). Full details of description are reported in the results (see section 6.4.2).

6.3.7.4.6 Phase-6: Producing the report

In Phase 6, analysis of the data extracts was finalized and vivid and compelling extracts examples that clearly illustrated the story of the overall data were selected. Using an analytical narrative approach, a concise and coherent account of the story the data communicated within and across the themes were reported (see section 6.4.2).

6.3.7.5 Software Assisted Analysis

The use of computer assisted qualitative analysis software such as MAXqda, NVivo or N6 is recommended to lessen the burden on researchers and facilitate the data management process (Silver *et al.*, 2014; Zamawe, 2015). Amongst these software packages, a decision to use NVIVO was made due to its high compatibility with several qualitative research designs and data analytical approaches such as thematic analysis which was the method of choice for this study (Zamawe, 2015).

To use the NVivo software to support the study analysis process, the PhD researcher completed a two-day intensive NVIVO training (Qualitative Data Analysis- 'Using Nvivo to manage and analyse qualitative and mixed data'; University of Southampton). Using the NVivo software, the 8 steps qualitative analysis process recommended by Adu (2016) was followed (see Table 6-6).

Table 6-6: 8-step NVivo analysis

Steps	Analysis process
Step-1 (Data Cleaning)	The transcribed data of the 10 study participants were cleaned using Microsoft word (data organized according interview questions)
Step-2 (Uploading)	Data uploaded into the NVivo software as file data.
Step-3 (Reorganizing)	Imported data were reorganized into three different categories for easy analysis. 1. Nodes according to the interview questions using NVivo auto coding process (anchor codes) 2. Cases for each participant's information 3. Case classifications for each participant demographic information (see Table 6-7)
Step-4 (Exploring)	Interview responses (i.e. reorganized data) were explored for categorization and potential code ideas in preparation for step 5.
Step-5 (Coding)	1. Data coding conducted (codes reflecting the three study objectives were first created (i.e. anchor codes) to drive the analysis. 2. All relevant information to address the research objectives (data extracts or quotes) were coded using the descriptive coding method (Adu, 2016) 3. 6-step thematic analysis followed (see section 6.3.7.1)
Step-6 (Visualizing)	Coded data was visualized using the NVivo Explore functions (e.g. Query wizard, project maps, etc): 1. to capture the essence of the themes 2. direction of the analysis 3. identify the trends in the interview responses and 4. explore the evolving generated nodes and codes
Step-7 (Exporting)	Generated codes were refined and organized into themes Thematic map of the final themes were created (see section 6.3.7.4.4)
Step-8 (Communicating)	Thematic maps were exported into Microsoft word files to tell the story of the data findings

6.4 Results

This section describes the findings from the qualitative study conducted, which are presented in two parts. The first section describes the characteristics of the 10 participants whose interview data were analysed. The second section describes the emerging themes from the inductive thematic analysis conducted. The themes and sub-themes are presented according to the three study objectives: (1) patient views and experiences; (2) reported adherence; and (3) perceived barriers and facilitators to performing the OTTER exercise programme.

6.4.1 Participant characteristics

Ten people living with base of thumb OA were purposively sampled from the 40 OTTER study participants for this qualitative enquiry and data analysis. All participants were right-handed, white British females between the ages of 56 to 72 years (64± 6.3) years. Of the 10, seven were treated for right thumb base OA, whilst three were treated for left thumb-base OA. In terms of educational level, three had higher degrees or equivalent, six had qualifications below higher education degrees (NVQ, GCE A or O levels, etc) and one had no qualification. Of the 10 participants, only two were employed full-time (see Table 6-7).

Table 6-7: Participants' Characteristics

Participant ID	Age	Hand treated as part of trial	Educational qualification	Employment Status?
P 1	56	left	Higher education below degree	Yes
P 2	58	right	Higher degree	Yes
P 3	68	right	Higher education below degree	No
P 4	56	right	Higher education below degree	No
P 5	68	right	NVQ3/GCE A level equivalent	No
P 6	72	right	NVQ2/GCE O level equivalent	No
P 7	57	left	No qualification	No
P 8	69	right	NVQ4/NVQ5/Degree or equivalent	No
P 9	68	left	Higher degree	No
P 10	67	right	NVQ3/GCE A level equivalent	No

NB: NVQ3 National vocational qualification-level 3- ; GCE- General certificate of education

6.4.2 Patient views and experiences on the OTTER exercises

Figure 6-5 shows the themes and subthemes that reflected the views of participants on the OTTER exercise programme from the data analysed. The three major themes were difficult and painful, satisfactory, and purposeful. Below the three themes with their subthemes are discussed.

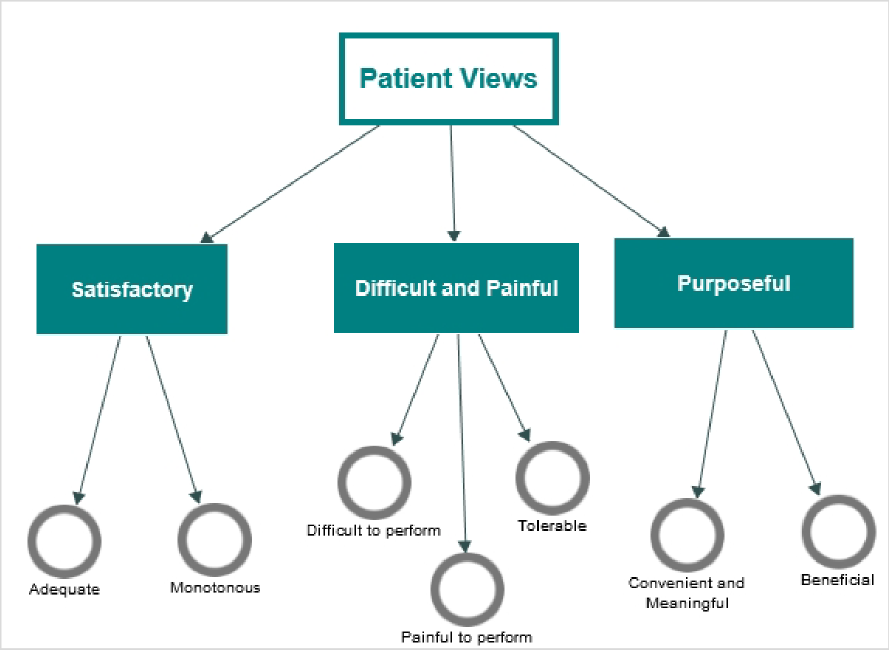


Figure 6-5: Major- and sub-themes about the views of patients on the OTTER exercise programme

6.4.2.1 Theme-1: Exercises are difficult and painful

This theme captures the challenging nature of the OTTER exercise programme expressed by most study participants (n=9) (Table 6-8), with the performance of some of the OTTER exercises, as well as the associated pain experienced during exercise performance. The three subthemes reflecting this theme are discussed below.

Table 6-8: Summary of themes, subthemes and supporting references for views and experiences

Study Objective	Themes	No of Participants	No of References
Views and experiences	Difficult and painful	9	31
	Satisfactory	7	7
	Purposeful	6	18

6.4.2.1.1 Difficult to perform exercises

Six participants reported how they largely struggled to perform some of the exercises within the OTTER exercise programme. The two reportedly difficult exercises were level-2 (elastic band exercises) and level-3 (functional tasks) exercises with the elastic band exercises being the most difficult (see Table 6-1). Regarding level-2 exercises, Participant-5 commented:

> *"I did struggle with the elastic band one. When I first put the thin elastic band on, I couldn't move my thumb at all. It's that kind of thing that I have problems with"* ***(P5)***

For some participants, their inability to perform the band exercises (difficult exercises) triggered negative emotions. Participant-8 stated:

> *"as I say, I couldn't do the second set of exercises, it made me angry and frustrated"* ***(P8)***

For level-3 exercises, participants stated that, their inability to perform the exercises outside their home setting due to the exercise aids needed made the exercising difficult. Participant-10 commented:

> *"Level three [Functional exercises] more of a problem because then there is more, [..] you've got the pegs and the plate and the writing to do which is more difficult if you are not at home. I'd have had a job to do it if I was working".* ***(P10)***

Some participants also viewed the exercise duration as another difficult aspect of the OTTER exercise programme as they thought 20 minutes to endure difficult exercise performance was tough. One participant recounted:

> *"…I did find more than 10 minutes to be quite tough going and I thought, I can't do this for another 10 minutes constantly, so I'm going to have to have a break.* ***(P7)***

6.4.2.1.2 Painful to perform

This subtheme describes the pain experiences of participants with the elastic band exercises during and after exercise performance. Some participants described how painful it was to perform the exercises and how this contributed to their overall difficult and painful experience with the OTTER exercise programme. Three pain experiences were captured, the first two were the pain associated with performing the elastic band exercise activity itself and the pain symptoms it caused in the hand and thumb joints. One participant captured both experiences and stated:

> *"I found that it (elastic band exercises) made the joint painful, it was painful to do, and it was painful afterwards".* ***(P9)***

The third pain experience was the pain inflicted on the thumb by the elastic band during the exercise activity. One participant recounted:

"When I first put the elastic band on, I thought, crikey! This isn't the right size, it's so tight before I'd even move my thumb. So, it was painful when it was on, because it made a big dent in my finger as well". ***(P5).***

6.4.2.1.3 Exercises were tolerated

Some participants (n=4) (Table 6-8) thought the OTTER exercise programme was tolerable and endured the training despite complaints of pain and difficulty in performing some exercises. Two main reasons were given, the notable benefits of exercises and the perception of how exercises should be done. For instance, some participants saw the early benefits of the exercises on their thumb OA symptoms and resorted to endure the exercises to achieve the most of it. One participant stated:

"I can move my thumb both out and up a lot better than I could before, although I wouldn't say I enjoyed doing the elastic band one, because it does make the joint sore". ***(P5)***

6.4.2.2 Theme-2: Exercises were satisfactory

This theme captures the perception of participants (n=7) who thought the OTTER exercise programme was acceptable and although not necessarily outstanding, met their expectations and needs (Table 6-8). This theme reflects both the satisfactory nature of the whole OTTER exercise programme as well as the individual exercise content. Two subthemes were identified: "monotonous" and "adequate" which are briefly discussed (full details in Appendix C.5).

With regards to monotonous, some participants described how the OTTER exercises were uninterestingly repetitive and lacked variety with exercise progression. Participants (n=3) also commented on how such perceptions lowered their interest in the exercises as training progressed into the final level of exercise training. One participant recounted:

"As time has gone on, I was alright up to 2 months, then it's starting to get a bit monotonous [..]. You know what it's like when your thumb starts to feel better, you say I won't do the exercise, you think it's OK now". ***(P10)***

Another participant also hinted on how boring the exercises were and stated:

".. it doesn't sound a long time [..] but to sit there 10-15 minutes is quite a long time just to sit and do the exercises and you are doing the same sort". ***(P4)***

Regarding the perception of the exercises as "adequate", some participants thought the OTTER exercises were modestly adequate and acceptable but not exceptionally outstanding. When participants were asked what they thought of the exercises, four participants responded:

"yes, i found that (otter exercise programme) ok" ***(P1; P8; P7)***

6.4.2.3 Theme 3 - Exercises are Purposeful

This theme captures the views of participants (n=7) who thought the OTTER exercise programme was useful, had purposeful exercise activities and tasks and its performance was worthwhile (Table 6-8). Three subthemes emerged (convenient, meaningful, and beneficial exercises) which are discussed below.

6.4.2.3.1 Convenient and Meaningful

A few of the participants thought the OTTER exercise programme overall was convenient and had some meaningful exercise content. Regarding convenience, three participants described how well some of the exercises fitted into their life schedules and routines. One participant narrated her continuous exercise training whilst on holidays due to its convenience.

> *"Even on holiday I'd sit on my sunbed […] and doing all the finger and the thumb ones and even on the plane. So, those sorts of things you can do them anywhere".* ***(P7)***

For the description of the OTTER exercises as meaningful, four participants commented on the relevance of the exercises to their hand OA symptoms. Two participants stated:

> *"I think [..] they (exercises) definitely made a difference [..]. Obviously, the exercises you've given me have worked"* ***(P10)***

> *"...I think to do the exercises is very good. It does keep it (thumb) moving.* ***(P7)***

6.4.2.3.2 Beneficial

This subtheme captured the views of participants who thought the OTTER exercise programme was useful and produced beneficial outcomes for their thumb OA. Three outcomes were identified from the data: (1) "awareness" of the appropriate use of the hands, (2) "new knowledge gained on hand activity performance and (3) Improvement in hand OA symptoms.

With regards to awareness and knowledge gained, one participant commented:

> *"I think because you don't tend to think about how you turn a bottle top or a key or something like that or hold a plate, you don't think about it you just do it. But it (OTTER exercises) did make me realise that there are different ways of doing things"* ***(P9)***

For the hand OA symptoms, participants narrated the improved stretching and mobility of their thumb joints with the exercise performance. Participant-5 commented:

> *"Well as I said, the first ones I found they certainly did help, and I have found over the three months I do have more movement now in my thumb joint than I had when I first started. So,*

they've obviously done something in that, my thumb is more mobile. I think probably it's a little bit stronger as well" ***(P5)***

6.4.2.4 Experiences

Based on the above discussed patient views, three patient experiences were identified from the data, participants largely had a painful, less enjoyable, and emotional experience with the OTTER exercise programme. In summary, the above section has presented the findings to address the study' objective one (i.e. views of participants on the OTTER exercise programme). The next section discusses findings for objective two (i.e. patient reported adherence)

6.4.3 Patient reported adherence to the OTTER exercises

Figure 6-6 shows the themes and subthemes that reflected participants reported adherence to the OTTER exercise programme. Three major themes emerged, behavioural and lifestyle modifications, beliefs and attitudes, and pain and physical limitations, which are discussed below.

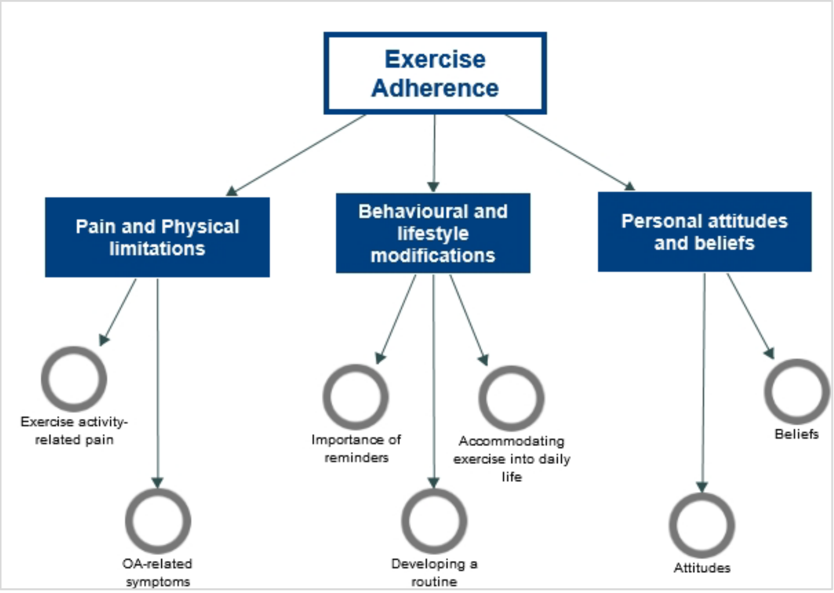


Figure 6-6: Major- and sub-themes on patient reported adherence to the OTTER exercise programme.

6.4.3.1 Theme 1 - Behavioural and lifestyle modifications

This theme captures the actions and impact of participants' behavioural changes and lifestyle modifications that ensured or limited their adherence to the OTTER exercise programme. From the data, three subthemes emerged: accommodating exercise into daily life, developing a routine and importance of reminders and these are discussed below.

6.4.3.1.1 Accommodating exercise into daily life

The first behavioural and lifestyle changes that impacted adherence was "accommodating exercise into daily life". Participants who adapted their lifestyles and deliberately made room within the day to exercise commented on how that ensured their adherence. One participant stated:

> *"With the exercises, I had to fit it in with other things, make sure I had the time to do it, spend the time warming up my thumb joint and then sit somewhere and concentrate on doing it". **(P5)***

Other participants who were less accommodating narrated how certain life events (e.g. away from home, holidays) and limited access to personal exercise aids affected their adherence. One stated:

> *"In Manchester for a week [..] so then it's difficult isn't it if you've got to remember to take paper and a pen and have a plate and have a bottle to unscrew. […] It was alright while I was at home, but if you wanted to go somewhere it was difficult". **(P10)***

6.4.3.1.2 Developing a routine

The second behavioural and lifestyle modifications that impacted adherence was "developing an exercise routine". Participants who set exercise routines and consistently followed them reported a positive exercise adherence. Examples used were setting specific times of the day to exercise (e.g. mornings or evenings) or scheduling exercise sessions around certain life events (e.g. husband's hospital visit). Participant-10 stated:

> *"I like to do the exercises first thing in the morning really and get them out the way, and then they're done then, aren't they?". **(P10)***

On the other hand, participants who lacked regular exercise routines were inconsistent with their exercise performance. One participant commented:

> *"I haven't really got a set routine in the day; it depends on what happens. Just looking at my charts, I would say three times a week, definitely! Sometimes, I'd do it for 20 minutes three times a week, and then do another five or ten minutes here and there" **(P3)***

6.4.3.1.3 Importance of reminders

The third behavioural and lifestyle modifications that affected exercise adherence was the "importance of reminders". Some participants narrated how the use of certain life events or exercise related materials acted as reminders for exercising. One participant recounted how she used her husband's gym time as a reminder for her exercising:

“most times you are sitting down, [..] and watching the TV and my husband said, I’m going to the gym and I said, ‘OK, I’m just going to do my exercises as well, sitting on the settee’”. ***(P7)***

Participants also recounted how the absence of their regular exercise reminders affected their exercise adherence. One participant commented:

“So, when we’ve been away, obviously it’s not the first thing on my mind, so I have to do them when I remember. When I’m at home I’ve got my folder already out so that tends to remind me a little bit more. So, it’s a little bit easier to carry them out at home. ***(P4)***

6.4.3.2 Theme 2 - Beliefs and attitudes

This theme captures participants’ (n=9) personal beliefs and attitudes that influenced their adherence to the OTTER exercise programme which are discussed below (Table 6-9).

Table 6-9: Summary of themes, subthemes and supporting references for patient reported exercise adherence (Objective 2)

Study Objective 2	Themes	No of Participants	No of References
Reported exercise adherence	Behavioural and lifestyle modifications	7	16
	Beliefs and attitudes	9	22
	Pain and Physical limitations	6	12

6.4.3.2.1 Beliefs

The data reflected how some participants’ inherent positions and perceptions (beliefs) on exercises influenced their exercise adherence. One participant’s belief that physiotherapy requires focussed attention, tolerance and high compliance positively influenced her exercise adherence. She likened the OTTER exercises to physiotherapy and stated:

“…it [exercise programme] was just, this is physio, just do it. (P2)

6.4.3.2.2 Attitudes

This subtheme captures the influence of participants’ personal character and attitudes on exercise adherence. As shown in Table 6-10, participants that were committed, compliant, persistent, and had positive outcome expectations reported better adherence. For example, Participant-9 commented on how she persisted to perform the elastic-band exercise despite her difficulty and the consistency and commitment she added to achieve this. She recounted:

> *"..I did find that (elastic band) difficult [..] and I spent a long time, [..] several weeks using the rubber bands because I felt that I wanted to conquer the problems I was having and I did eventually move on after several weeks."* ***(P9)***

Similarly, participants with less desirable attitudes such as poor time management, non-compliance and laziness struggled with exercise adherence. For instance, Participants-6's dislike for exercises negatively impacted her compliance and invariably her adherence.

> *"I'm not a great fan of doing that kind of exercise to be honest with you and as I say, I was a bit of a wuss with it I'm afraid.* ***(P5)***

Table 6-10: Positive and Negative attitudes that influenced participant exercise adherence

<table>
<tr><th colspan="2">Positive attitudes</th><th colspan="2">Negative attitudes</th></tr>
<tr><th>Attitudes</th><th>Data extracts</th><th>Attitudes</th><th>Data extracts</th></tr>
<tr><td rowspan="2">Committed</td><td rowspan="2">"with the exercises i had to fit it in with other things, make sure i had the time to do it, spend the time warming up my thumb joint and then sit somewhere and concentrate on doing it (P2)</td><td>Poor time management</td><td rowspan="2">"it was the time, it's my time management. I'm a bit rubbish and bit haphazard. (P3)</td></tr>
<tr><td>Disorganized</td></tr>
<tr><td>Compliant</td><td>"I would do whatever the trial had said. I followed it religiously" (P1)
"I think I've followed it as required and as my body has accepted it on any given day" (P6)</td><td>Non-compliant</td><td>""I'm not a great fan of doing that kind of exercise to be honest with you and as I say I was a bit of a wuss with it (exercise programme) I'm afraid. (P5)</td></tr>
<tr><td>Positive outcome expectations</td><td>"So, on my hand I'm doing the exercises and I'm thinking, well this is actually helping me so when I get back to my upholstery work in September, I will find it easier to do my stitching" (P8)</td><td>Dislike for exercises</td><td>"I don't like doing exercises". (P5)
"I'm not a great fan of doing that kind of exercise to be honest with you."</td></tr>
<tr><td>Persistent (a keep-going attitude)</td><td>"I got a bit fed up with trying to do that [rubber band exercises], but I persisted because I'm one of those people that will persist when I'm given a challenge (P9)</td><td>Laziness</td><td>"But I am as a person I am little bit lazy about exercise I must admit. So, I did initially say that I would do them every morning after breakfast, but my days just vary so much that sometimes I'd forget" (P3)</td></tr>
<tr><td></td><td></td><td>Busy life schedule (Lack of time')</td><td>"I mean I'll be honest there were some days when I'd forget or was too busy doing things" (P4)</td></tr>
</table>

NB: Further details in Appendix C.6

6.4.3.3 Theme 3 - Pain and physical limitations

Captured within this theme is how the painful exercise experiences and associated physical limitations previously discussed (section 6.4.2.1.2) hindered participants' exercise adherence. From the data, participants reported how their "hand OA-related symptoms" and "exercise-related pain" impacted their adherence to the OTTER exercise programme.

1. **Hand OA-related symptoms**

For hand OA-related symptoms, Partcipant-5 narrated how she exercised less than advised (twice weekly instead of three times) during her hand OA flareups to prevent her symptoms worsening.

> *"when I was doing the band, sometimes I'd only done it twice a week because it was just, I didn't feel I wanted to aggravate it really on the days when it was bothering me". **(P5).***

2. **Exercise-related pain**

For exercise-related pain, some participants reported how they avoided exercise sessions, performed incorrect exercise techniques, and stopped exercising entirely sometimes due the greater pain and functional limitations caused by the exercise activities (i.e. elastic band). Participant-8 stated:

> *"I can't do number two (elastic band exercises) at all with the bands on my thumb for obvious reasons. It's just too, it's just impossible. So, I've given up trying. **(P8).***

In summary, the above section has presented the findings to address the study's objective two (i.e. patient reported adherence to the OTTER exercise programme). The next section discusses findings for objective three (i.e. barriers and facilitators to the OTTER exercise programme).

6.4.4 Barriers and facilitators to the OTTER exercises

This section presents the participants' perceived barriers and facilitators to performing the OTTER exercise programme to address study objective three. The barriers are discussed followed by the facilitators.

6.4.4.1 Barriers

Figure 6-7 shows the themes and subthemes reflected patient reported barriers. Three major themes emerged; "remembering to exercise, "the exercise programme" and "hand OA symptoms" which are presented below.

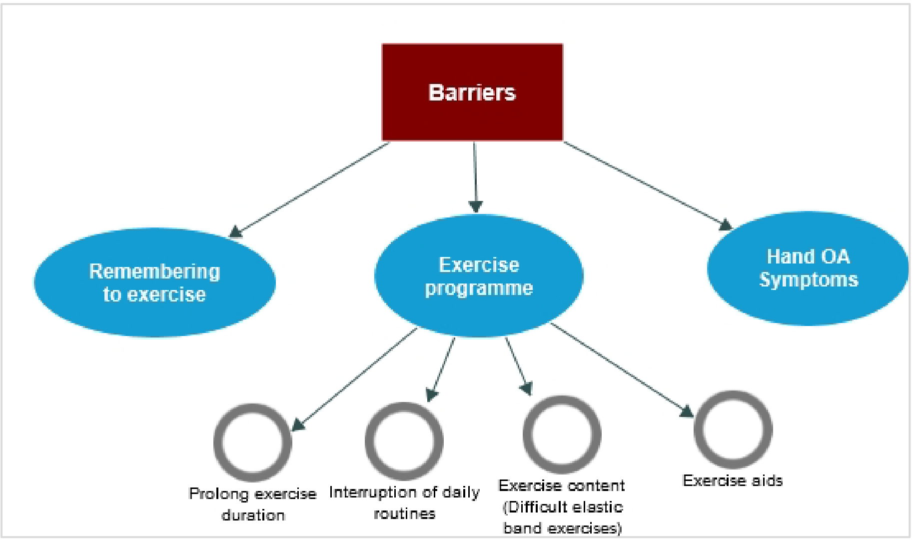


Figure 6-7: Themes and subthemes of patient reported barriers to the OTTER exercise performance

6.4.4.2 Theme-1 Remembering to exercise

Two participants (Table 6-11) mentioned forgetfulness or inability to remember to exercise as practical daily challenges that prevented their exercise performance. Whilst some forgot to exercise, others remembered to exercise but forgot to record their exercise sessions. One stated:

> *"I'll be honest, there were some days when I'd forget or was too busy doing things. When we've been away, obviously it's not the first thing on my mind, so I have to do them when I remember". (P4)*

Table 6-11: Summary of themes and supporting references for barriers and facilitators to exercise performance (Objective 3)

Study Objective 3	Themes	No of Participants	No of References
Barriers	Remembering to exercise	2	4
	Exercise programme	7	25
	Hand OA symptoms	3	3
Facilitators	Individual attributes	8	14
	Support	3	6
	Exercise experience and beliefs	3	3

6.4.4.3 Theme-2 The OTTER exercise programme

For seven participants (Table 6-11), barriers to the OTTER exercise programme was the programme itself. Participants highlighted four aspects that acted as barriers: difficult exercise content, use of exercise aids, prolonged exercise duration and how exercises interrupted their daily lives (see Table 6-12).

1. **Difficult exercise content and prolonged duration**

As previously captured, participants mentioned the elastic band exercises as the most difficult (see sections 6.4.2.1 and 6.4.3.3). Of the 10 participants, seven (P1, P3, P5, P6, P8, P9, P10) largely expressed challenges with the elastic band exercises and this hindered their exercise performance. Similarly, the perception of the OTTER exercises having a prolong exercise duration (section 6.4.2.1.1), also acted as a barrier to exercising. Participant-9 commented:

> *"The thicker band [..] (exercises) was quite difficult. And doing it for 20 minutes is a long time". (P9)*

2. **Use of exercise aids & Interruption of daily life**

Whilst some exercise aids were handy (e.g. elastic bands), some participants complained of the use of other aids for level-3 exercises (functional tasks) as this made exercising difficult. Participant-10 shared her concerns as well as hinted on how these interfered with her life:

> *"I mean just having the bands [..] in your pocket and if you are going out for the day or if you are sitting in the car, you can just do them [..]. But when you've got the plate and the writing to do, that's difficult. You've got to sit at the table to do that really, haven't you?"* ***(P10)***

For theme-3 (hand OA symptoms), the hand OA-related symptoms previously discussed (section 6.4.3.3) that impacted exercise adherence also acted as exercise barriers (see Appendix C.7 for full details)

Table 6-12: Aspects of OTTER exercise programme as exercise barriers

Aspects of Exercise	Data extracts
Difficult exercise content	"I did struggle with the elastic band one. When I first put the thin elastic band on, I couldn't move my thumb at all. It's that kind of thing that I have problems with" (P5) "Lifting the plate strangely enough was the one that caused the most problems really. I don't know why [..] the hardest one really". (P10)
Use of exercise aids	"A lot of exercises are difficult, because of the items you have to have to hand". (P10) "In Manchester for a week [..] so then it's difficult isn't it if you've got to remember to take paper and a pen and have a plate and have a bottle to unscrew […]. It was alright while I was at home, but if you wanted to go somewhere it was difficult. Stage of the exercises using the aids that was difficult then". (P10)
Prolonged exercise duration	"I just thought that 20 minutes at one sitting was quite a long time to be sitting doing the exercises". (P3) "20 minutes is an awfully long time. On a couple of occasions, I split the time into two lots of 10, because I couldn't do the 20". (P9)
Exercises interrupted daily lives	"I mean just having the bands, even having them in your pocket and if you are going out for the day or if you are sitting in the car you can just do them then can't you, but when you've got the plate and the writing to do that's difficult, You've got to sit at the table to do that really." (P10) "Well, if my daily routine was interrupted then yes". (P2)

NB: Please see Appendix C.7 for complete reporting.

6.4.4.4 Facilitators

From the data analysed, three major themes emerged (Figure 6-8): “support”, “exercise experience and beliefs” and “individual attributes” which are presented below

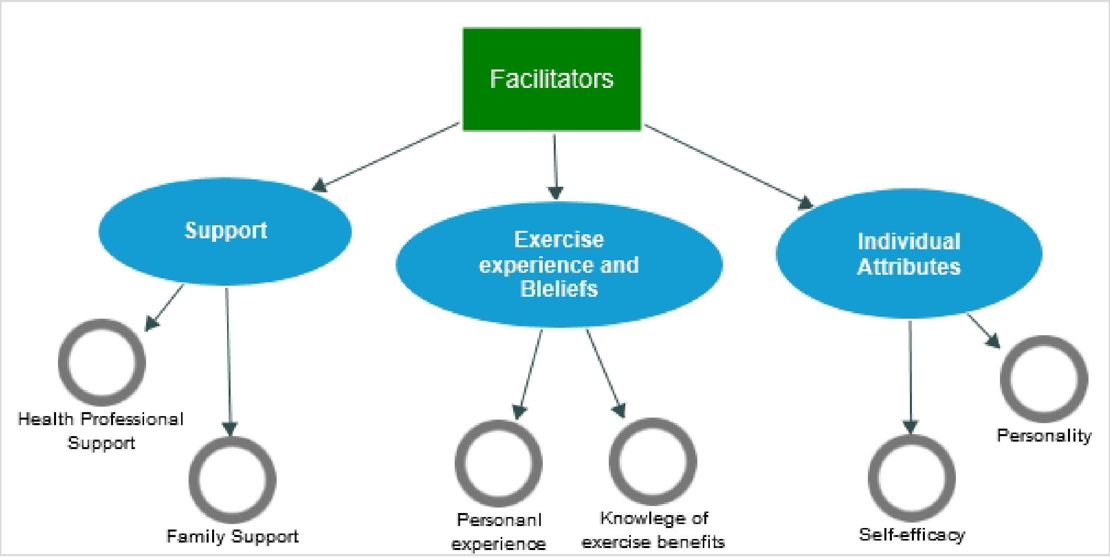


Figure 6-8: Patient reported facilitators to the OTTER exercise performance

6.4.4.4.1 Theme-1: Support

Three participants commented on how the support and encouragement from family and health care professionals facilitated their exercise performance (Table 6-11). Two commented:

> *“In fairness, my husband will say sometimes, have you done your exercises. So, then I feel like a naughty schoolgirl whenever I haven’t”.* ***(P4)***

> *“I think the only thing, well it comes with a very good set of instructions, you get a follow up, so you have somebody to talk to.”* ***(P5)***

6.4.4.4.2 Theme-2: Exercise experience and beliefs

This theme captures participants’ exercise experiences and knowledge of exercise benefits that facilitated their exercise performance. Participant-8 captures both domains by narrating how her experience with knee exercises and knowledge of its benefits influenced their positive exercise behaviour to perform the OTTER exercises.

> *“I’ve been doing a programme of quite vicious exercises [..] and although it’s painful to do those knee exercises, I’m doing them because I know that I’m strengthening the muscles [..]. So, on my hand I’m doing the exercises and I’m thinking, well this is actually helping me so when I get back to my upholstery work in September, I will find it easier to do my stitching.* ***(P8)***

6.4.4.4.3 Theme-3 Individual attributes

This theme captures participants' inherent qualities that positively influenced their exercise performance. As shown in Table 6-13, two broad participants' attributes were identified: Self-efficacy and Personality. Participants hinted on how their self-motivating, organized, and focused personalities facilitated their exercise performance. Others also mentioned how taking ownership of the exercise programme by making personal efforts and splitting exercise sessions facilitated exercise performance. For instance, Participant-9 described how she split her exercise sessions to shorten the exercise times to suit her lifestyle and personal needs.

> *"20 minutes is an awfully long time. On a couple of occasions, I split the time into two lots of 10 because I couldn't do the 20". (P9)*

Other participant stated time constraints, pain, easier to manage exercises in shorter blocks and prolonged exercise duration as some reasons for dividing their exercise sessions (see Appendix C.7 for further details).

Table 6-13: Participants' attributes that facilitated exercise performance

Participants Attributes		**Data extracts**
Self-efficacy	Motivation	"...there's none of it (exercises) that I won't have a go at every now and again [..], if I thought exercising the thumb was going to help keep it going and preventing it from getting worse. Sometimes that's something that you've just got to accept" (P6)
	Taking ownership of exercise programme	***Making personal effort and adjustment*** "I just put aside a set time and said, right it's now. I've got to do it now and just got on with it". (P9) ***Dividing exercise sessions*** "I'd do 5 plus 5 minutes, because it was quite difficult to sit there and do it for 20 minutes.". (P7)
Personality	Organisation	"It was good to begin with. I've got the programme in front of me and I've got notes written down. I am a very organised person". (P9)
	Focused and concentration	"I can do [..] the first lot of exercises and of course it's doing it slowly, [..] to watch my hand whilst I'm doing it. It's no good trying to watch a bit of good telly and the exercises at the same time [..]. You've really got to make sure that you are really doing it and concentrate [..]. You really do need to make it work". (P6)
	Perseverance	"...as I say, I couldn't do the second set of exercises, it made me angry and frustrated I suppose, but there's no harm in trying, is there" (P8)

6.5 Discussion

A qualitative enquiry was conducted with a broad aim to understand the views and experiences of hand OA patients on a three levelled exercise programme prescribed as part of a self-management package within an RCT (OTTER trial). Findings from this study provide evidence to show that whilst some patients considered the OTTER exercises as satisfactory and purposeful, the majority described them as largely difficult and painful due to the difficult elastic band exercise activities and associated pain it caused. Whilst such views translated into a painful, less enjoyable, and emotional experience with the OTTER exercise programme, participants however acknowledged the meaningful benefits of the exercises on their hand OA symptoms. These findings resonates with results from a previous RCT that used similar exercises and reported that despite considerable pain reports after exercising, participants tolerated the exercises and reported improvements in their general joint pain (Hennig *et al.*, 2015).

To achieve the best clinical outcomes, continuous patient adherence to regular exercise programmes is paramount. From the study results, participants reported complete, inconsistent, and some occasional non-adherence to the OTTER exercise programme. Whilst some participants persistently adhered to the programme despite challenges of pain and exercise difficulty, others simply exercised less than advised, avoided some exercise sessions, performed incorrect exercise techniques, or stopped exercising entirely. These findings are not different from previously published research and therefore add to the discourse of the complexity of the concept of treatment adherence and its challenging impact on treatment outcomes (Bassett, 2003; Petursdottir *et al.*, 2010; Clough *et al.*, 2011; Bennell *et al.*, 2014). Factors that influenced the aforementioned adherence reports identified from the data were participants' behavioural and lifestyle modifications, developing exercise routines and setting exercise reminders. These findings are consistent with previous reports of exercise adherence in people with knee and hip OA (Holden *et al.*, 2012; Bennell *et al.*, 2014; Kanavaki *et al.*, 2017).

Beliefs, attitudes and perceived effectiveness of interventions have been reported to positively impact intervention adherence (Bennell *et al.*, 2014). For example, for people with knee OA, high levels of continued compliance due to perceptions that physiotherapy is effective has been reported (Bennell *et al.*, 2014). Similarly, results from the present study show that participant's that were committed, persistent and possessed strong beliefs that physiotherapy requires focussed attention, tolerance and high compliance positively reported good adherence to the OTTER exercise programme.

This therefore suggests that to ensure good adherence to OA exercise programmes, such positive attitudes and exercise beliefs should be identified, considered, and proactively utilized for utmost exercise benefits in patients with thumb base OA.

The uncertainty about exercise worsening hand OA symptoms has been previously reported as hand OA patients in a qualitative study were unsure whether exercising their hands may aggravate their symptoms (Hill *et al.*, 2011). Contrary to the above findings, such uncertainties were not reported within the present study as participants were educated and made aware of exercise associated discomfort as well as benefits of exercises which encouraged their exercise performance. Indeed, majority of participants reported hand and thumb joint pain during and after exercising and this sometimes impacted their exercise adherence. However, some recognised the early positive effects of the OTTER exercises on their thumb OA and tolerated the exercises to achieve its utmost benefit. Whilst it might be argued that exercising through pain might be maladaptive and should be discouraged, some participants' based on previous exercise experience appreciated the place of pain in achieving exercise benefits and used the "no pain, no gain" approach to progress through their exercise training which is acceptable based on previous research (Roos, 2002).

As aforementioned, modest amounts of pain and discomfort often associated with exercises in people with OA are acceptable (Roos, 2002) and indeed, patient education on such pains being normal and safe have been advocated (Bennell *et al.*, 2014). Despite such reports, researchers have called for the consideration of severe pain complaints by patients as this negatively impacts exercise performance (Petursdottir *et al.*, 2010; Bennell *et al.*, 2014). In the present study, exercise related pain was a major barrier to both exercise performance and adherence. Most of the participants stated that the elastic band exercises (level-2 exercises of the OTTER exercise programme) were not only the most difficult exercise to perform but also the most painful. Three pain experiences were described: i) the elastic band exercise activity itself was painful to perform, ii) the exercise activity caused and also aggravated thumb joint pain and other OA symptoms (made the thumb joints sore) and, iii) the elastic band material inflicted pain on the thumb and hand (created painful dents in the thumbs). Based on these reports, participants hinted of the removal of the elastic band exercises from the OTTER programme as they avoided the exercise during the exercise training. From literature, the timely modification of exercise programmes or removal of exercises that cause severe pain or symptom aggravation has been recommended (Bennell *et al.*, 2014). Based on the above evidence recommendation and suggestions of the study participants, future thumb base OA exercise programmes should exclude elastic band exercises.

Alternate sources of resistance for thumb abduction and extension strengthening exercises should be explored.

From literature, personality traits of adaptability and initiative have been reported to have strong influence on the exercise behaviour of people living with OA (Petursdottir *et al.*, 2010). Notably identified within the present study was how participants took ownership of their exercising based on positive exercise history and beliefs by making informed decisions such as splitting exercise sessions to facilitate their exercise performance. This demonstrated the power of the patients' voice in the evidence-based self-management approach as this influenced their positive exercise behaviour and subsequently their exercise adherence and performance. These findings add to previous evidence that reported that hand OA patients were no longer passive but were making their own reasoned decisions about treatments and its administration based on personal beliefs and available information (Hill *et al.*, 2011).

The availability of support, care and encouragement from families are amongst the important factors that influence exercise performance for people with OA (Petursdottir *et al.*, 2010). In the present study, participants provided evidence to show that spousal support and encouragement facilitated their exercise performance and adherence. Our findings therefore add to existing OA literature to propose that for people with thumb base OA, the availability of family support acts as prompts for exercising which positively influence exercise behaviour. Similarly, several participants also appreciated the good health professionals' support and agreed that opportunities to talk during in person physiotherapy sessions and telephone follow-up calls enhanced their exercise training. This finding adds to previous studies that reported that good connection and communication between OA patients and physiotherapists positively influence adherence and exercise outputs (Petursdottir *et al.*, 2010). A few participants however expressed dissatisfaction and cited how deficient knowledge of some health professionals on requested information and insufficient support particularly whilst performing the difficult exercises limited their exercise performance. These findings also resonate with previous qualitative research that documented the dissatisfaction of some hand OA patients about the perceived lack of understanding, help and type of information received from some health care practitioners (Hill, 2011). The present study participants therefore suggested the provision of additional support and encouragement during exercises as this boosts their confidence to know that they are exercising properly. Participants additionally advised the need for further training of health professionals to provide the relevant and correct information when requested to avoid any uncertainties about their hand OA managements.

This qualitative analysis study aimed to explore the views of hand OA patients on an existing exercise programme, with specific focus on their subjective views, and meanings of their lived experiences and from literature (Denzin *et al.*, 2011), such experiences are best produced using the social constructivism paradigm. The use of a rigorous qualitative method by way of the methodological paradigm followed is a major strength of the study. The axiological assumptions underpinning the social constructivism paradigm recognizes that a researcher's experiences and background can shape their interpretation within research and allowable room should be created for this (Creswell *et al.*, 2016). The PhD researcher, as a social constructivist, acknowledges that certain personal characteristics and historical experiences may have influenced the study's interpretation. Firstly, the PhD researcher is new to qualitative research and despite efforts to acquire the skills for the conduct and analysis of this study, she acknowledges that certain decisions may have been done differently if she were to be experienced in the field. Secondly, the researcher also acknowledges that her cultural heritage as a non-British (Ghanaian) may have influenced her understanding and interpretation of some aspects of the interview data, particularly those relating to certain British cultural norms and colloquial slang. In addition, the population studied were all righted-handed females with thumb base OA. Therefore, when interpreting these findings, it is important to note that generalization to general hand OA population should be done with care.

This study was part of an RCT and as previously mentioned, although the researcher formulated the interview questions, she was not involved in the data collection and transcription, which have been reported to inform the qualitative data analysis process where initial meanings are created (Braun *et al.*, 2006). However, the researcher spent considerable amount of time to familiarise herself and develop an in-depth understanding of data to facilitate the data analysis process as advised by experts (Braun *et al.*, 2006). It is documented that although qualitative research cannot be subjected to the same criteria as quantitative approaches, it does provide analytical methods that should be applied rigorously to produce trustworthy, credible and dependable evidence (Shenton, 2004; Braun *et al.*, 2006). The inductive thematic analysis approach (Braun *et al.*, 2006) in combination with the 8-steps NVivo analytical process (Adu, 2016) were conducted with sufficient description of the processes to allow the repeatability of the research, which was a major strength in this study.

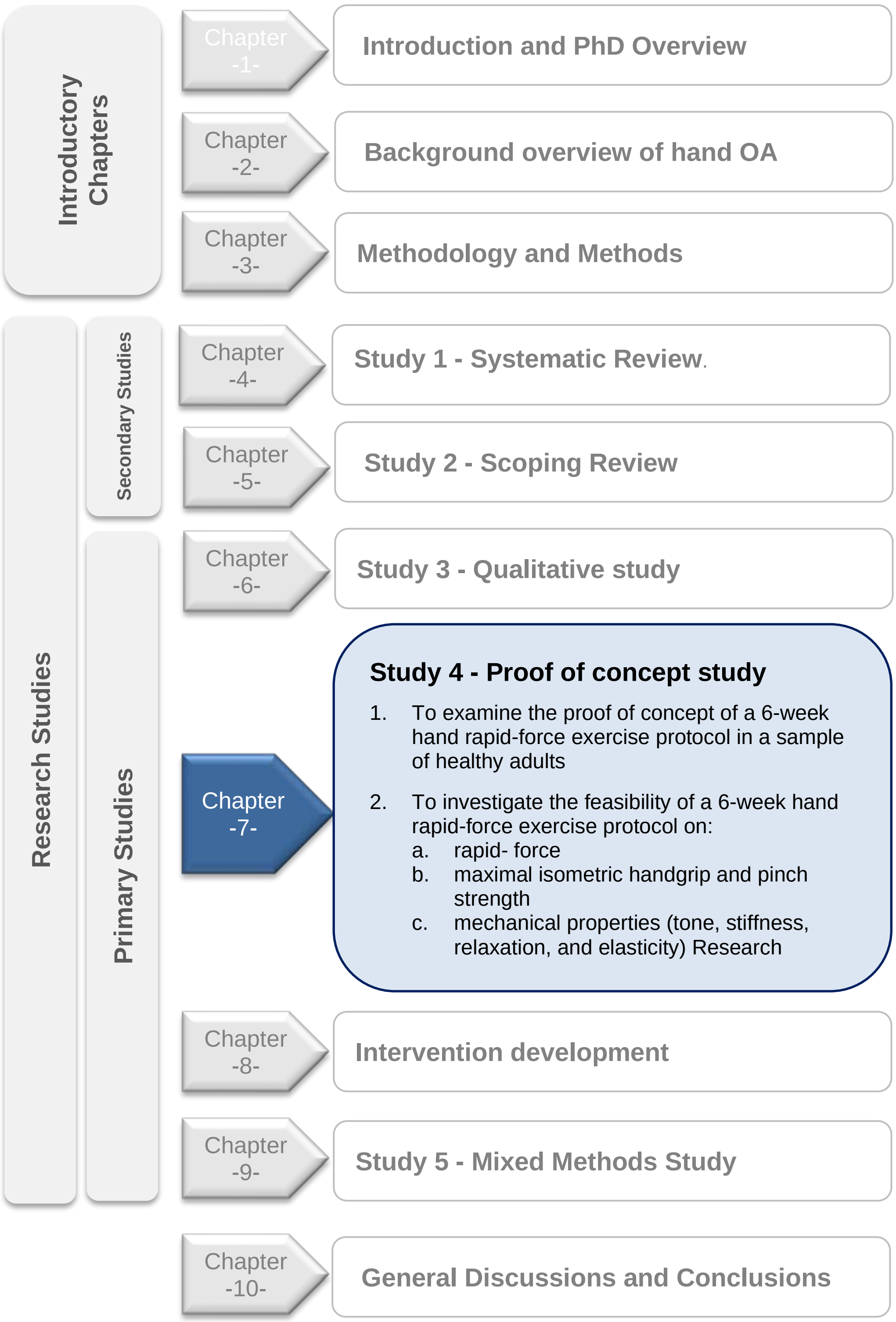
6.6 Conclusions

1. For thumb base OA patients, the three levelled OTTER exercise programme was difficult and painful to perform, yet contains some satisfactory and purposeful exercise contents except the elastic band exercises.
2. Future thumb base OA exercise programmes should exclude elastic band exercises and explore alternate ways of improving thumb abduction and extension strengthening.
3. Despite a less enjoyable, and emotional experience with the exercise programme, participants acknowledged the meaningful benefits of the exercises on their hand OA symptoms.
4. To ensure good adherence to thumb base OA exercise programmes, positive attitudes and exercise beliefs should be identified, considered, and proactively utilized for utmost exercise benefits in patients with thumb base OA.

6.7 Chapter Summary and Novelty

This chapter has described a qualitative enquiry to explore and understand the views and experiences of hand OA patients on the OTTER exercise programme. Key finding within this study is the recommendation of participants on the removal of the rubber band exercises from future hand OA exercise programmes. Findings from this study in addition to the previously discussed reviews in studies 1 (Chapter 4) and 2 (Chapter 5) were consolidated with that of study 4 (chapter 7) to inform the development of the novel exercise programme, to address the overall aim of this PhD.

Location in thesis



Chapter 7 Study 4 - Investigating the effects of rapid-force exercises in the hand: a proof of concept study

7.1 Introduction

This chapter introduces Study 4, a quantitative study to explore the proof of concept (PoC) and feasibility of rapid-force exercises in the hand (Figure 7-1). This study was driven by research recommendations to explore other strength training concepts for hand OA exercises due to mixed reports regarding the benefits of existing programmes. Based on benefits of rapid-force exercises (emerging concept used in lower limb strength training), the PhD researcher explored its use in the hand for possible inclusion in the hand OA exercise programme to be developed in this PhD.

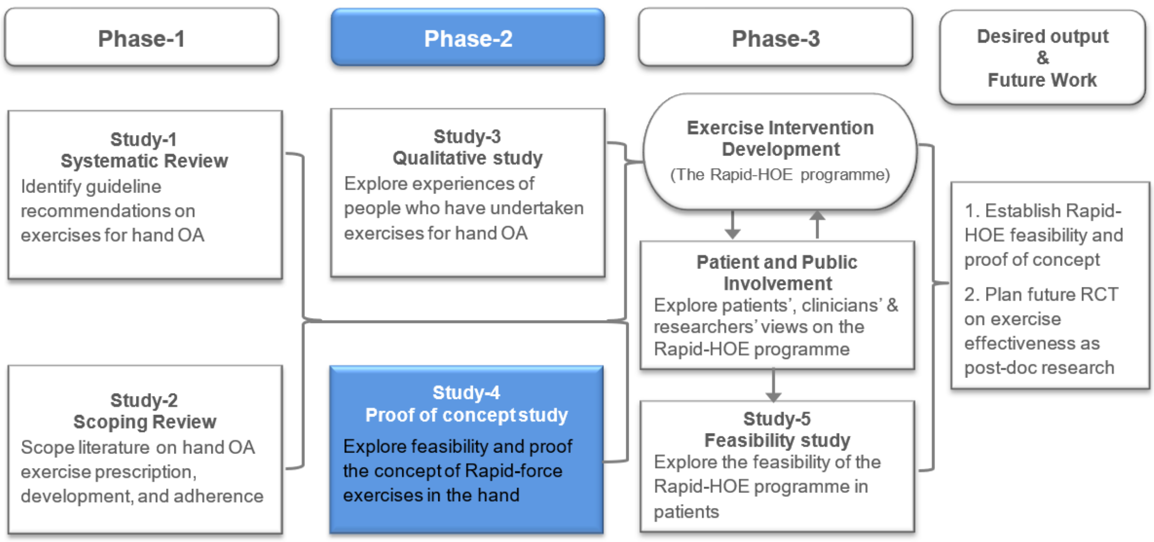


Figure 7-1: Proof of Concept study location within the overall PhD research

7.2 Background

Hand OA is a global public health concern and as previously discussed (see section 1.2), the need for further enquiry into promising interventions to improve the QoL of individuals living with OA is justified (CDC 2017). More specifically, the focus on hand grip strengthening programmes has been recommended (Lefler *et al.*, 2004; Kjeken, 2011) due to the relevance of hand grip strength in performing many functional tasks (Lefler *et al.*, 2004; Rogers *et al.*, 2009; MacDermid *et al.*, 2015).

Despite the emphasis on the relevance of strength training exercises, only low to moderate beneficial effects in people with hand OA have been documented (Lefler *et al.*, 2004; Rogers *et al.*, 2009; Østerås *et al.*, 2014a). In two RCTs to evaluate an evidenced-based hand OA exercise programme, mixed views were reported. Whilst one reported favourable gains in pain (p=0.02) and grip strength (p<0.001) (Hennig *et al.*, 2015), the other reported limited improvement in performance-based outcomes such as maximal grip strength, which was the intention of the exercise programme (Østerås *et al.*, 2014a).The latter researchers (Østerås *et al.*, 2014a) explained that perhaps the exercise intensity and/or progression employed in their trial, although specific instructions were given, might have been too low. A recommendation to investigate the optimal grip strengthening exercises for hand OA with a focus on higher exercise dosage and more resistance was made.

Regarding strength training, the American Geriatric Society (Katz *et al.*, 2001) reported that isometric strength-training is less useful in improving strength in OA patients when used as the sole form of strength training (Katz *et al.*, 2001). The Society therefore recommended the use of isotonic muscle strengthening (example of dynamic muscle training) for OA strength training. This informed the explosive strength training concept, an emerging and promising muscle strengthening concept based on explosive contractions and neuromuscular activations (Tillin *et al.*, 2013; Tillin *et al.*, 2014; Maffiuletti *et al.*, 2016). Explosive force (from here on called Rapid-force) is the ability to increase the force generated by a muscle as quickly as possible during rapid voluntary contractions from low or resting levels (Maffiuletti *et al.*, 2016). Rapid-force strength training is characterized by a series of short (≤1second) muscular contractions, which induces type IIb muscle fibre activities leading to increases in rapid-force (Maffiuletti *et al.*, 2016). Physiologically, type IIb muscle fibres are fast twitch glycolytic fibres which are characterised by high force and speed production, to bring about rapid and powerful short bouts of movements. From the literature, rapid-force strength training is reported to have a strong stimulatory effect on the rate of explosive force development (RFD) (De Ruiter *et al.*, 2012). RFD, (from here on called rate of rise of force) is defined as the capacity to produce maximal voluntary activation in the early phase of explosive (rapid-force) contractions (i.e. first 50 -75 microseconds) (Maffiuletti *et al.*, 2016). Rate of rise of force is therefore considered to be of important functional value as it correlates better with the performance of some sports and functional tasks. Premised on the above, previous authors have recommended the use of high-force contractions in strength training programmes (Aagaard *et al.*, 2010) as they are more logically relevant to daily functional tasks performance and are relatively non-fatiguing which may be well tolerated in patients such as those with OA (Balshaw *et al.*, 2016; Maffiuletti *et al.*, 2016).

The use of rapid-force strength training in the lower limbs has been justified (Tillin *et al.*, 2014) and its importance in daily life such as improving strength and physical function of lower limbs in healthy populations also reported (Aagaard *et al.*, 2010; Maffiuletti *et al.*, 2016). Whilst objectively justified in the lower limbs, the functional application of this concept in the hand is emerging. Recently, Schettino *et al.* (2014) proposed that similar to lower limb reaction during falls, rapid-force generated from the hand and forearm may assist the lower limbs or trunk in restoring balance during sudden movement imbalances by grabbing for support (e.g. rail, walking stick or other fixed supports). The quest to explore this concept in upper limb strength training is therefore timely and warranted.

It is documented that handgrip strength declines with increasing age (Schettino *et al.*, 2014). In recent studies, it was reported that rapid-force handgrip strength comparatively declines faster than maximum handgrip strength with increasing age and at an even faster rate in women above 50 years (Watanabe *et al.*, 2011; Schettino *et al.*, 2014). With aging and women being key risk factors for hand OA, the need to explore the feasibility and possible integration of the rapid-force strength training concept in a hand exercise programme based on its highlighted relevance is therefore timely and warranted. The present study adopted the concept of rapid-force strength training employed for lower limb strength training and investigated its feasibility and effect in the hand. To the best of the PhD researchers' knowledge, this is the first time the use of a concept such as a strength training protocol is explored in the hand, although previous studies have investigated explosive handgrip strength measurements (Watanabe *et al.*, 2011; Schettino *et al.*, 2014).

Thus, the explosive quadriceps strength training protocol published in Tillin *et al.* (2014) (Table 7-1) was adapted and investigated in the present study. Due to the novelty of this study and the uncertainty regarding the effect of the concept in the hand, the adopted exercise protocol, which from here on is referred to as **Hand Rapid-Force exercises**, was evaluated in healthy individuals.

Table 7-1: Explosive exercise Protocol published by Tillin *et al.* (2014)

Exercise Protocol	Content
1 explosive exercise set	1 explosive contraction as fast and hard as possible in 1s (Each contraction last 1s followed by 5s rest)
Explosive exercise protocol	4 sets of 10 explosive contractions

m: minutes; s: seconds

7.2.1 Aim

To explore the effects of hand rapid-force exercises on muscle rate of rise of force, maximal hand and pinch strengths, and mechanical properties in the hand over a six-week training programme to establish proof of concept.

7.2.2 Objectives

1. To examine the proof of concept of a 6-week hand rapid-force exercise protocol in a sample of healthy adults
2. To investigate the feasibility of a 6-week hand rapid-force exercise protocol on:
    a. rapid-force
    b. maximal isometric handgrip and pinch strength
    c. mechanical properties (tone, stiffness, relaxation, and elasticity)

7.2.3 Hypothesis

1. Six weeks rapid-force hand exercises of the left hand would increase left hand grip strength and grip rate significantly and not change the measurements on the control right side
2. Six weeks rapid-force pinch exercises of the right hand would increase right pinch grip strength and pinch rate significantly and not change the measurements on the control left side
3. Rapid-force hand exercises would significantly increase muscle mechanical properties in the FCR muscles of the left hand and not the control right hand.
4. Rapid-force pinch exercises would significantly increase muscle mechanical properties in the thenar muscles of the right hand and not the control left hand.

7.3 Methods

7.3.1 Study design

A before-and-after, longitudinal experimental design was used. Although critiqued to be influenced by attrition, this study design is used to measure change in a phenomenon. The literature recommends it as the most appropriate design to measure the impact of interventions (Kumar, 2014).

7.3.2 Setting

The study site was either a research laboratory in the School of Health Sciences, University of Southampton, or homes of participants. All testing was conducted in the laboratory and exercises were either performed in the laboratory or homes of the participants based on convenience.

7.3.3 Sampling Design and Sample size

Adult volunteers were recruited using a convenience sampling technique. Premised on the unknown possible effects and the uncertainty of its feasibility, a sample size of 10 appeared appropriate to evaluate change in the study participants as similarly employed in a feasibility study on hand arthritis with favourable results (Spicka *et al.*, 2008).

7.3.4 Participants

7.3.4.1 Participant Characteristics and Recruitment

Ten healthy male and female adults (18-45 years) were recruited from in and around the university using posters (see Appendix D.1), emails and word of mouth. Interested individuals were invited to contact the researcher via email or telephone calls.

7.3.4.2 Eligibility Criteria

Below in Table 7-2 are the details of the eligibility criteria for the study.

Table 7-2: Details of the eligibility criteria

Inclusion criteria	Exclusion criteria
Individuals with no: 1. Self-reported cases of hand deformity 2. Observed cases of hand deformity injury or disease	Individuals with: 1. Orthopaedic or neurological impairments 2. Upper limb injuries (within six months prior to the study) 3. Painful hands 4. Arthritic disorders of the hand 5. Cardiovascular, or respiratory system disorders were excluded.
Individuals who have not engaged in any structured physical activity programme for at least 1 year before the study	Individuals who perform athletic sports or active exercise

7.3.5 Materials

The MIE Pinch/Grip Digital Analyser, the MyotonPRO device; modified Borg scale and thera-band hand exerciser balls were the materials used within this study. Details of the materials; description, psychometric properties and purpose within the study are provided below (see Table 7-3).

Table 7-3: Study materials

Materials	Psychometric properties	Description and Purpose
MIE Pinch/Grip Digital Analyser (MIE Medical Research Ltd, Leeds)	Reliable, discriminatory and sensitive tool (Wallström *et al.*, 2001)	Measure the rate of rise of force (rapid-force), handgrip and pinch grip strengths. MIE device was calibrated to ensure accuracy of measurement (see Appendix D.2).
MyotonPRO device (Myoton AS, Tallinn, Estonia)	Good inter-rater and intra-rater reliabilities (Agyapong-Badu *et al.*, 2012; Aird *et al.*, 2012)	Non-invasive, portable hand held device for quantitative measurement of skeletal muscle mechanical properties (Agyapong-Badu, 2014). Measure muscle tone, stiffness, elasticity, and relaxation of hand muscles involved in hand and pinch gripping (thenar eminence and flexor carpi radialis)
Modified Borg Scale	Validated and reliable tool (Appendix D.3)	Set load (resistance) for the rapid-force exercises based on the participants' self-perception of effort (Heine et al., 2012).
Thera-Band hand exerciser balls (Performance Health, UK)		Non-latex polymer balls with 5 colour-coded levels of resistance to meet individual strength abilities (yellow-0.68kg; red-1.36kg; green-2.27kg; blue-3.63kg and black-7.5kg). Used to set load (Modified Borg Scale) and for the hand rapid-force exercise training

NB: UK - United Kingdom; kg- kilograms

7.3.6 Data Collection Procedure

One week before data collection, interested volunteers were provided with the Participant Information Sheet (Appendix D.4) to provide them sufficient time to consider taking part in the study. Those who agreed were screened against the eligibility criteria (see Table 9-1). Participants who met the eligibility criteria were provided with either an 8-minute face-to-face or a telephone briefing on the study description and possible adverse events associated with data collection (see section 7.3.8). The study involved 18 exercise sessions (3 times weekly for 6 weeks). Out of the 18 exercise training sessions, three hand assessment sessions were performed; two at baseline (one week apart) and one after the six-weeks training period (see Appendix D.5). On average, data collection lasted about 50 minutes on days when both assessments and exercise training were performed, 40 minutes on days when only assessments were performed and 12 minutes on days when only exercise training were performed (Appendix D.6). Below, the procedure for hand assessments are described followed by the procedure for exercise training.

7.3.6.1 Outcome measures and Assessment Procedure

On the first day of data collection, participants were consented (Appendix D.7) after which their weights and heights were measured. Hand assessments were performed in the order detailed below. In line with expert recommendations (MacDermid *et al.*, 2015), all measurements were demonstrated by the PhD researcher and participants were given the opportunity to practice sub-maximally before the actual measurements were taken.

On the second day of data collection (after one week), all outcome measures were re-assessed to examine reliability of the outcome measures used. Reliability was measured because it is fundamental to clinical assessment, it increases confidence in measurements taken and helps readers draw rational conclusions from clinical measurements (Koo *et al.*, 2016). More specifically, the test-retest reliability (variation in measurements taken by an instrument on the same participant) was assessed for all grip strength outcomes by the MIE device. Also, test-retest and intra-rater reliabilities (variation of data measured by one rater across 2 or more trials) were assessed for all Myoton outcome data.

7.3.6.2 Assessment of Muscle Mechanical properties

The MyotonPRO device (see section7.3.5) was used to measure muscle mechanical properties of the thenar eminence (Figure 7-2) and flexor carpi radialis muscles (FCR) (Figure 7-3) based on their contribution to hand and pinch gripping (full description of method in Appendix D.8).

This measurement was conducted first because Myoton measurements must be tested in rested muscles. Two consecutive sets of five mechanical impulses produced by the probe of the device were applied to the skin while the muscles were at rest. These impulses induced muscle oscillations from which measurements of decrement (elasticity), muscle tone (frequency), stiffness and relaxation time were recorded.

Figure 7-2: Measurement of the thenar muscle mechanical properties using the MyotonPRO device

Figure 7-3: Measurement of the flexor carpi radialis muscle mechanical properties with the MyotonPRO device

7.3.6.3 Grip Strength Assessment

Testing strength involved the measurement both rapid-forces and maximum hand grip and pinch grip strengths using the MIE digital pinch and grip analyser.

7.3.6.3.1 Rapid-force and maximum handgrip strength testing

Maximum handgrip strength is the greatest amount of force exerted by the hand when gripping or grasping (MacDermid *et al.*, 2015). To perform this test, participants were positioned following the standard recommendations (MacDermid *et al.*, 2015). As shown in Figure 7-4, participants were instructed to squeeze the handle bar of the MIE digital analyser as fast and as hard as possible for 3 seconds. Three maximum handgrip strength tests with 15 seconds of rest period between each were performed and the greatest maximum handgrip strength test was recorded (Samuel *et al.*, 2012). The maximum rate of grip force development, which characterises rapid force was calculated as previously published (Watanabe *et al.*, 2011; Schettino *et al.*, 2014). Using the maximum voluntary contraction, the training load used in the exercise training was also recorded.

Figure 7-4: Measuring maximum hand grip strength with the MIE digital analyser

7.3.6.3.2 Pinch Strength Testing

Pinch strength is the maximal isometric force generated by voluntary contractions of muscles of the thumb and other finger muscles (MacDermid et al. 2015). In the present study, the lateral pinch strength was measured because of its use in performing many daily activities (MacDermid *et al.*, 2015). Using the MIE digital analyser, the maximum pinch strength was measured following instructions adapted from the recommended standard assessment protocol (MacDermid *et al.*, 2015) (Figure 7-5). The best of three repeated pinch strength tests was used in the analysis.

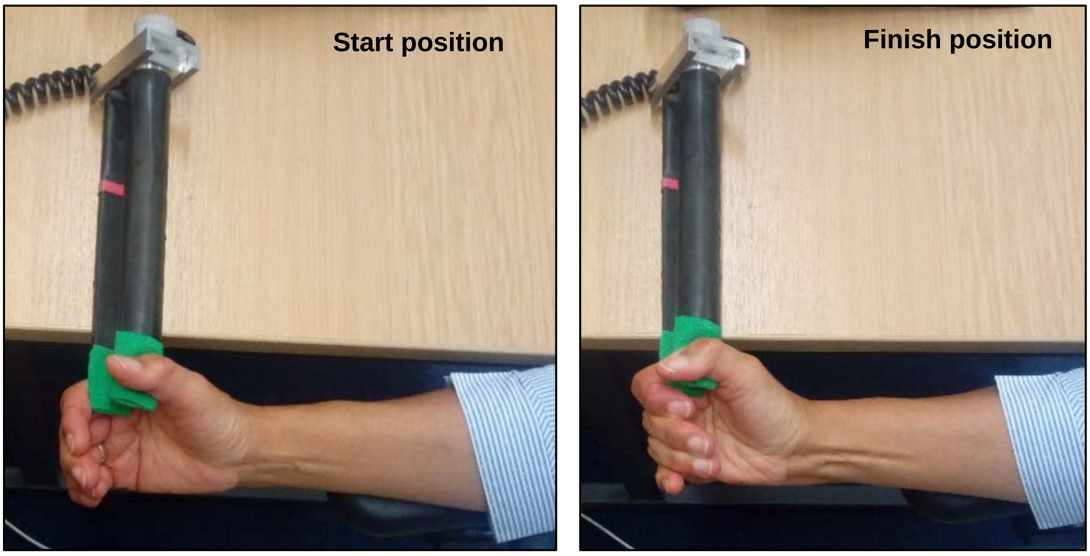


Figure 7-5: Pinch Strength Testing with the MIE digital analyser

7.3.6.4 Assessing handgrip resistance level

To select the load for the hand rapid-force exercises, participants squeezed different thera-band balls and guided by the modified Borg scale (Appendix D.3), their baseline resistance levels were determined (see section 7.3.7.4). This was performed using the non-dominant hand to avoid overloading of the dominant hand.

7.3.7 Rapid-force Hand Exercise Protocol

7.3.7.1 Exercise content

The explosive exercise protocol published by Tillin *et al.* (2014) (Table 7-1) was adapted following discussions with the authors (Folland and colleagues, University of Loughborough) to produce the rapid-force hand exercise protocol shown in Table 7-4. This exercise protocol contains two exercises targeted at hand grip (hand grip rapid-force exercises) and the lateral pinch (pinch grip rapid-force exercises).

Table 7-4: Rapid-force hand exercise Protocol (Adapted from Tillin *et al.* (2014))

Exercise Protocol	Content
1 rapid-force exercise set	1 rapid force contraction (handgrip or pinch grip) as fast and hard as possible in 1s (Each contraction last 1s followed by 5s rest)
Rapid-force exercise protocol	4 sets of 10 rapid force handgrip contractions and 4 sets of 10 rapid force pinch grip contractions Rest period of 10 seconds between each set

NB: m: minutes; s: seconds

7.3.7.2 Exercise prescription

For use of the rapid-force exercise protocol within this study, the mode of delivery previously published (Tillin *et al.*, 2014) was modified based on recommendations for hand OA exercise development (see Table 7-5). The exercise protocol (Table 7-4.) was therefore delivered to study participants at a frequency of 3 times weekly; intensity was based on participants' perception of resistance and for a duration of 6 weeks.

Table 7-5: Modification of published explosive exercise protocol prescription

Exercise dosage	**Published Exercise Protocol** (Tillin et al., 2014)	**Modified Exercise Protocol (Rapid-force hand exercise)**	**Reason for modification**
Frequency	4 times weekly	3 times weekly (Interspersed with a day of rest)	Hand strengthening programmes designed with a day of rest between sessions may produce considerable improvement in strength (Rogers *et al.*, 2009)
Intensity	No report of intensity	Exercise started at a moderate intensity and progressed accordingly (see section 7.3.7.4)	Future studies that investigate grip strength exercises should emphasise higher exercise dosage (e.g. higher intensity, fewer repetitions, more resistance) (Østerås *et al.*, 2014a)
Progression	Exercises were not progressed	Exercises were progressed every 2 weeks (see section 7.3.7.4)	Exercises were progressed using colour coded resistance balls (Rogers *et al.*, 2009). A modified Borg scale (appendix D.3) were used to set the initial load (resistance) and exercise progression (Heine *et al.*, 2012)
Duration	4 weeks	6 weeks	Significant grip strength improvement is seen in hand OA patients after a 6-week strength-training programme performed at submaximal levels (Lefler *et al.*, 2004)

7.3.7.3 Procedure for exercise training session

Each exercise training session started and ended with a warm up and ended with cool down exercises of submaximal isometric grip contractions (Katz *et al.*, 2001). The exercise protocol was performed using Thera-Band hand exerciser balls and each session lasted about 12 minutes (see Appendix D.6). For the hand grip rapid-force exercises, all participants performed exercises with their left hand with the right (dominant) hand acting a control (no exercise training). Conversely, all participants performed the pinch grip rapid-force exercises with their right hand with the left hand acting as control (no pinch exercise training.

7.3.7.4 Exercise Progression

Exercises were progressed every two weeks following the procedure previously discussed (see section 7.3.6.4). Baseline load was purposefully set at a moderate level (3 to 4 on the Borg scale) to permit subsequent exercise progression, enhance motivation and adherence, and reduce the possibility of exacerbation of symptoms (Heine *et al.*, 2012). If participants were using the maximum level of resistance at a progression point, then the number of exercises sets were increased to five. If a participant struggled with the exercises, the intensity was regressed by reducing the resistance.

7.3.7.5 Exercise Adherence

To optimise adherence to the exercise protocol, the researcher contacted the study participants once weekly via telephone or email to check on their exercise training and to discuss any challenges encountered. To monitor adherence, the researcher kept an exercise log sheet (Appendix D.9) whilst the participants kept exercise diaries which also contained adverse events reporting (Appendix D.10.1) and participant feedback (Appendix D.10.2).

7.3.8 Adverse Events and Risk Assessment

As shown in Table 7-6, the PhD researcher defined the following safety terms to guide the study as previously described (Lamb *et al.*, 2015). Participants were advised to report any of such events to the researcher for advice (Appendix D.10.1). The biomechanical assessment for this study involved the standard operating procedures routinely undertaken by staff of the University and were subjected to the University's internal risk assessment procedures, which were low risk.

Table 7-6: Adverse events descriptions

Adverse event	Definition and description
Adverse Event (AE):	Any untoward medical occurrence, unintended disease or injury or any untoward clinical signs in study participants whether or not related to the study or the exercise protocol
Adverse Response/ Reaction (AR):	All untoward and unintended responses related to the study procedure or exercise protocol, (e.g. muscle soreness, stiffness, etc.)
Serious Adverse Reaction (SAR):	Any untoward or unexpected occurrence that is life threatening, results in death, hospitalization or significant disability or incapacitation.

7.3.9 Statistical Analysis

All data were managed using Microsoft Excel and analysed using SPSS statistics version 27. Continuous data were described as means and standard deviations. A Shapiro Wilk test and visual inspection of their histograms showed a largely normally distributed data, hence the paired t-test was used to evaluate change in all strength and Myoton data [(i.e. tone (frequency), stiffness (N/m), elasticity (log decrement) and relaxation time (ms)]. Similarly, the Intraclass Correlation Coefficient (ICC) was used for the reliability testing of both outcomes.

For the intra-rater (within session) reliability for Myoton data, the ICC type; ICC (3,1) was used based on 2-way mixed-effects model (3), absolute-agreement and single measurement (1) (Koo *et al.*, 2016). For the test-retest (between-day) reliability for both strength and Myoton data, the ICC type; ICC (3,2) was used based on 2-way mixed-effects model (3), absolute-agreement and mean of two measurements (2) (Koo *et al.*, 2016). Reliability data were interpreted according to the scale described by Koo *et al.* (2016) (greater than 0.90 = excellent; between 0.75 and 0.9 = good; between 0.5 and 0.75 = moderate; less than 0.5 =poor).

7.3.10 Ethical Issues, Data Protection and Anonymity

This study was approved by the Faculty of Health Sciences, University of Southampton Ethics Committee (ERGO number: 43602). Briefing and consenting were undertaken by the researcher and study participants were educated on their participation being entirely voluntary. Appropriate actions were taken with regards to any reported adverse events. This study adhered to the European Union General Data Protection Regulation (GDPR) (https://www.eugdpr.org/). To ensure participants' confidentiality and anonymity, participants were given identification numbers unlinked to their biodata. All participants' personal and non-identifiable data were securely stored to be held for a minimum of 10 years by the University of Southampton, as per university regulations.

7.4 Results

7.4.1 Demographic data

The demographic characteristics of the study participants are provided in Table 7-7. Of the ten healthy adult volunteers recruited for the study, eight participants (6 females) completed the study with two dropouts (reasons given were rapid-force exercises were boring). The average age of participants was 32 years and all participants were right hand dominant.

Table 7-7: Baseline characteristics of the study participants

	Participants (N)	Age Mean ± SD (years)	Weight Mean ± SD (kg)	Height Mean ± SD (m)
Male	2	32.0 ± 8.5	89.6 ± 0.8	1.8 ± 0.01
Female	6	31.8 ± 4.3	61.7 ± 7.0	1.6 ± 0.05
Total	8	31.9 ± 4.9	68. 7± 14.2	1.7 ± 0.09

NB: SD-Standard. Deviation; N-number of participants; kg –kilogrammes; m – meters; all right hand dominant

7.4.2 Reliability Results

7.4.2.1 Test-retest reliability results for grip strength data

For the FCR muscles, test-retest (between-day) reliability [ICC (3,2)] for maximum grip strength data was excellent [0.95 95% (0.79 - 0.99)] for both hands (see Table 7-8). That for maximum hand grip rate was good [0.83 95% (0.36 - 0.96)] in the dominant hand and excellent [0.94 95% (0.79 - 0.99)] in the non-dominant hand.

For the thenar eminence muscles, between-day test-retest reliability [ICC (3,2)] for maximum pinch strength, reliability was excellent [0.98 95% (0.87 – 1.0)] in the dominant hand and good [0.86 95% (0.47 - 0.97)] in the non-dominant hand. Reliability for the maximum pinch grip rate was excellent [0.97 95% (0.75 - 0.99)] in the dominant hand and good [0.90 95% (0.59-0.98)] in the non-dominant (see Table 7-8).

Table 7-8: Test Retest reliability for assessing grip strength using MIE digital analyser

Flexor Carpi Radialis Muscles								
Grip Strength Measurements	**Dominant Hand**				**Non-Dominant Hand**			
	Mean ± SD	ICC (3,2)	95% CI	ICC Interpretation	Mean ± SD	ICC (3, 2)	95% CI	ICC Interpretation
Maximum hand Grip Strength								
D1	283.50 ± 98.5	0.95	0.79 - 0.99	Excellent	260.75 ± 80.77	0.95	0.79 - 0.99	Excellent
D2	287.13 ± 108.9				262.75±107.63			
Maximum hand grip Rate								
D1	884.37 ± 496.89	0.83	0.36 - 0.96	Good	712.18±359.81	0.94	0.75 - 0.99	Excellent
D2	829.54 ± 703.01				739.25±453.25	0.94	0.86 - 0.99	
Thenar Eminence Muscles								
	Dominant Hand				**Non-Dominant Hand**			
Maximum Pinch Grip Strength								
D1	73.13 ± 24.42	0.98	0.87 – 1.0	Excellent	68.38±15.91	0.86	0.47 - 0.97	Good
D2	76.00 ± 21.59				73.25 ±20.56			
Maximum pinch grip rate								
D1	179.99 ± 128.24	0.97	0.75 - 0.99	Excellent	180.26±114.67	0.90	0.59-0.98	Good
D2	202.56±133.78				179.46±87.22			

NB: D1-First assessment session; D2- Second assessment Session; CI- Confidence Interval
Data analysis was based on single baseline measurements

ICC interpretation: Excellent (≥0.9); Good (0.9 > 0.75); Moderate (0.75 > 0.5); Poor (< 0.5) (Koo et al., 2016)

7.4.2.2 Reliability results for MyotonPRO data

7.4.2.2.1 Intra-rater (within-session) reliability for assessing muscle mechanical properties with MyotonPRO device

Details of all intra-rater (within session) Myoton reliability [ICC (3,1)] results for the thenar muscles are detailed below (see Table 7-9). For the thenar muscles, within-session intra-rater reliability [ICC (3,1)] for elasticity was excellent in both dominant [0.93 95% (0.72 - 0.99)] and non-dominant hands [0.98 95% (0.88 – 1.0)]. That for tone, was excellent in the dominant hand [0.97 95% (0.85 - 0.99)] and poor in the non-dominant [0.42 95% (-0.35 - 0.85)]. Within-session reliability for relaxation time was excellent [0.96 95% (0.83 - 0.99)] in the dominant and poor [0.25 95% (-0.61 - 0.80)] in the non-dominant. Lastly, reliability for stiffness was excellent [0.93 95% (0.71 - 0.99)] in the dominant hand to poor [0.19 95% (-0.63 - 0.77)] in the non-dominant hand.

For the FCR muscles, within-session intra-rater reliability [ICC (3,1)] for decrement was good in the dominant [0.89 95% (0.53 - 0.98)] and poor [-0.16 95% (-0.42 - 0.42)] in the non-dominant hand. That for tone was excellent in the dominant hand [0.98 95% (0.92 - 1.0)] and poor [0.06 95% (-0.56 - 0.69)] in the non-dominant. Relaxation time was both excellent in the dominant [0.99 95% (0.94 - 1.0)] and poor in the non-dominant hands [-0.02 95% (-0.78 - 0.67)]. Lastly, reliability for stiffness was excellent [0.97 95% (0.85 - 1.0)] in the dominant hand and poor [0.07 95% (-0.58 - 0.70)] in the non-dominant hand.

Table 7-9: Intra-rater(within session) reliability for assessing muscle mechanical properties

Thenar Muscles						
	Dominant Hand			Non-Dominant Hand		
Muscle Mechanical Properties	**Mean ± SD**	**ICC (3,1)**	**95% CI**	**Mean ± SD**	**ICC (3,1)**	**95% CI**
Elasticity (log decrement)						
D1	1.28 ± 0.16	0.93	0.72 - 0.99	1.43 ±0 .26	0.98	0.88 – 1.0
D2	1.26 ± 0.14			1.44 ± 0.24		
Tone (Hz)						
D1	20.72 ± 2.64	0.97	0.85 - 0.99	19.86 ±2.49	0.42	-0.35 - 0.85
D2	20.50 ±2.50			19.26 ± 1.36		
Relaxation (ms)						
D1	14.16 ± 2.10	0.96	0.83 - 0.99	15.60 ± 2.16	0.25	-0.61 - 0.80
D2	14.27 ± 2.07			15.88 ± 0.95		
Stiffness (N/m)						
D1	360.10±65.83	0.93	0.71 - 0.99	321.25±70.14	0.19	-0.63 - 0.77
D2	353.53±56.86			307.91±26.57		

Flexor Carpi Radialis						
	Dominant Hand			**Non-Dominant Hand**		
Elasticity (Log Decrement)						
D1	1.05 ±0.10	0.89	0.53 - 0.98	1.43 ±0.26	-0.16	-0.42 - 0.42
D2	1.02 ±0.09			1.10 ± 0.21		
Tone (Frequency; Hz)						
D1	16.71 ±1.91	0.98	0.92 - 1.0	17.94±3.14	0.06	-0.56 - 0.69
D2	16.62 ±1.83			15.01 ± 6.28		
Relaxation (ms)						
D1	16.29 ± 2.06	0.99	0.94 - 1.0	15.11 ± 2.03	-0.02	-0.78 - 0.67
D2	16.29 ± 2.0			13.73 ± 5.81		
Stiffness(N/m)						
D1	306.70±48.84	0.97	0.85 - 1.0	340.80±60.81	0.07	-0.58 - 0.70
D2	06.80±48.17			287.40±122.38		

NB: D1-First assessment session; D2- Second assessment Session; CI- Confidence Interval
Data analysis was based on single baseline measurements.

ICC interpretation: Excellent (≥0.9); Good (0.9 > 0.75); Moderate (0.75 > 0.5); Poor (< 0.5) (Koo et al., 2016).

7.4.2.2.2 Test-retest (between day) reliability for assessing muscle mechanical properties with MyotonPRO device

For the thenar muscles, the test-retest (between-day) reliability [ICC (3,2)] for elasticity was moderate in both dominant [0.67 95% (-0.445-0.93)] and non-dominant hands [0.52 95% (0.90 -2.01). That for tone (frequency), was moderate in the dominant hand [0.65 95%(-0.49 -0.93)] and poor in the non-dominant [0.32 95%(-1.10 - 0.85)] (see Table 7-10). Relaxation time was moderate [0.67 95% (0.83 - 0.99)] in the dominant and poor [-0.60 95% (-13.07 - 0.71)] in the non-dominant hand. Stiffness was moderate for both dominant [0.59 95% (-0.63-0.91)] and non-dominant hand [0.54 95% (-0.98 - 0.90)].

For the FCR muscles, test-retest (between-day) reliability [ICC (3,2)] for decrement was poor in both dominant [0.15 95% (-2.18 - 0.82)] and non-dominant [0.11 95% (-1.85 - 0.80)] hands (see Table 7-10). Reliability for tone was excellent [0.81 95% (0.05 - 0.96)] in the dominant hand and moderate [0.55 95% (-1.46 - 0.91)] in the non-dominant. Relaxation time was moderate in the dominant [0.56 95% (-1.40 - 0.91)] and poor [-0.14 95% (-3.84 - 0.76)] in the non-dominant hand. stiffness was poor for both dominant hand [0.21 95% (-2.95 - 0.84)] and non-dominant hand [0.45 95% (-2.87 – 0.90)] in the non-dominant hand.

Table 7-10: Test-Retest (between day) reliability for assessing muscle mechanical properties

Thenar Muscles						
	Dominant Hand			**Non-Dominant Hand**		
Muscle Mechanical Properties	**Mean ± SD**	**ICC (3, 2)**	**95% CI**	**Mean ± SD**	**ICC (3, 2)**	**95% CI**
Elasticity (Log Decrement)						
D1	1.27 ± 0.15	0.67	-0.445-0.93	1.44 ± 0.25	0.52	0.90 - 2.01
D2	1.33 ± 0.13			1.33 ± 0.38		
Tone (Hz)						
D1	20.61± 2.55	0.65	-0.49 -0.93	19.56 ± 1.68	0.32	-1.10 - 0.85
D2	19.71±1.68			18.53 ± 0.97		
Relaxation (ms)						
D1	14.21 ± 2.06	0.67	-0.33 -0.93	15.74 ± 1.31	-0.60	-13.07 - 0.71
D2	15.06 ± 1.40			14.74 ± 1.40		
Stiffness (N/m)						
D1	356.81±60.36	0.59	-0.63-0.91	314.58±40.71	0.54	-0.98 - 0.90
D2	331.10±37.54			292.99±52.36		
Flexor Carpi Radialis						
	Dominant Hand			Non-Dominant Hand		
Elasticity (Log Decrement)						
D1	1.04 ± 0.09	0.15	-2.18 - 0.82	1.27 ± 0.14	0.11	-1.85 - 0.80
D2	0.93 ± 0.22			1.10 ± 0.28		
Tone (Frequency; Hz)						
D1	16.67 ±1.86	0.81	0.05 - 0.96	16.48 ± 3.63	0.55	-1.46 - 0.91
D2	16.36 ± 1.330			17.40 ± 2.90		
Relaxation (ms)						
D1	16.29 ± 2.01	0.56	-1.40 - 0.91	14.42 ± 3.04	-0.14	-3.84 - 0.76
D2	15.49 ± 3.87			16.10 ± 2.42		
Stiffness(N/m)						
D1	306.75±48.07	0.21	-2.95 - 0.84	314.10±70.79	0.45	-2.87 – 0.90
D2	282.71±58.45			307.92±66.36		

NB: D1-First assessment session; D2- Second assessment Session; CI- Confidence Interval; Hz – Hertz; ms- microseconds

Data analysis was based on single baseline measurements.
ICC interpretation: Excellent (≥0.9); Good (0.9 > 0.75); Moderate (0.75 > 0.5); Poor (< 0.5)

7.4.3 Grip strength measures before and after six weeks rapid-force exercise training protocol

7.4.3.1 Maximum Grip Strength

Hand rapid-force exercises did not have any significant effect on maximum grip strength in the left hand (p=0.38; Table 7-11), thus rejecting the research hypothesis (six weeks rapid-force hand exercises of the left hand would increase left hand grip strength). Hence, a six-week rapid force exercise training programme did not have any significant effect on left hand grip strength. Comparatively, the right hand which performed no exercises showed significant increase in the grip strength measures (p=0.03) (Figure 7-6).

Table 7-11: Maximum Hand Grip Strength Pre- to Post-training

Maximum Grip Strength	Baseline Assessment Mean ± SD (N)	Post-training Assessment Mean ± SD (N)	Mean Difference 95% CI	P-value
Right Hand (Control)	285.3 ± 102.5	325.6 ±103.3	41.1 (-74.7 - - 6.0)	**0.03***
Left Hand (Trained side)	261.8± 93.9	278.9 ±131.7	51.2 (-60 - 25.8)	0.38

NB: SD=Standard. Deviation; N = Newtons; CI = Confidence Interval; Statistical test=paired t test statistic; P= probability; * = significance. Cohen's d - (0.2: small effect size; 0.5: medium effect; 0.8: large effect)

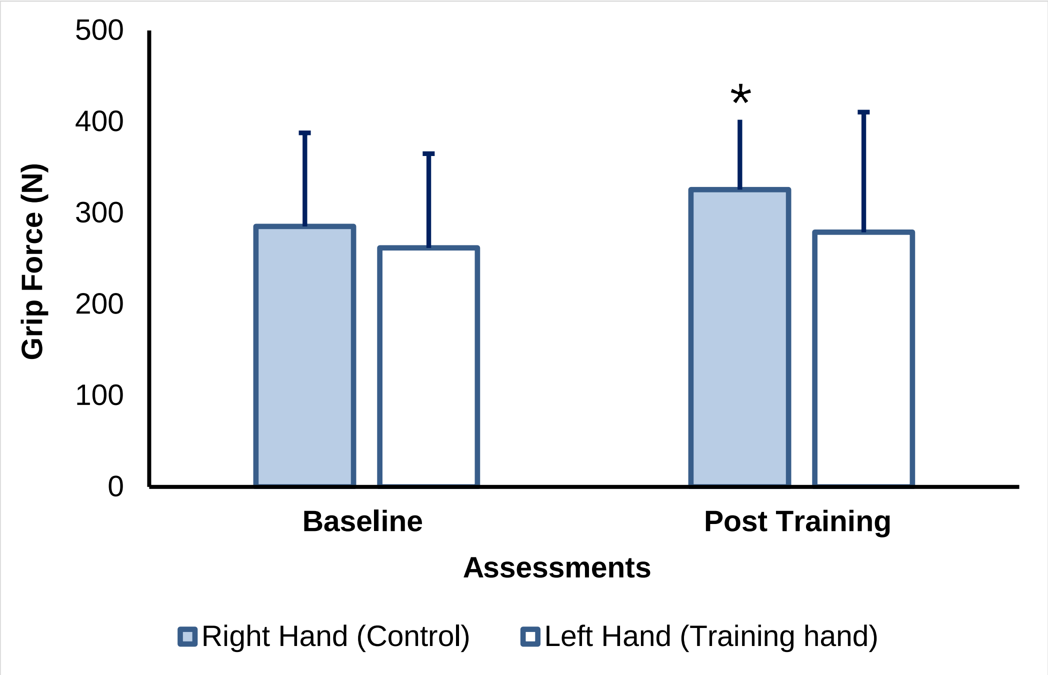


Figure 7-6: Maximum Hand Grip Strength before and after 6 weeks rapid-force exercise training protocol (*=p<0.05)

7.4.3.2 Grip Rate during maximum hand grip contractions

Grip rate for maximum hand grip increased in the left hand but this change was not statistically significant (p=0.09) (see Table 7-12; Figure 7.6). Hence, the rapid force exercise programme did not increase rate of rise of force which characterises rapid force. Comparatively, there were no significant changes (p=0.89) in right hand grip rate, serving as the control.

Table 7-12: Grip Rate for maximum hand grip contractions

Maximum Grip rate	Baseline Assessment Mean ± SD (N/s)	Post-training Assessment Mean ± SD (N/s)	P-value	Effect size (*d*)
Right Hand (Control)	857.0 ± 579.9	880.1 ± 602.7	0.89	-
Left Hand (Trained side)	725.7 ± 402.7	870.5 ± 553.0	0.09	0.4

NB: SD-Standard. Deviation; N/s – Newtons per seconds; statistical test - Wilcoxon Signed Ranks Test; P – probability
Cohen's d – Large effect (>0.8); Medium effect (0.8 > 0.5); Small effect (0.5 > 0.2)

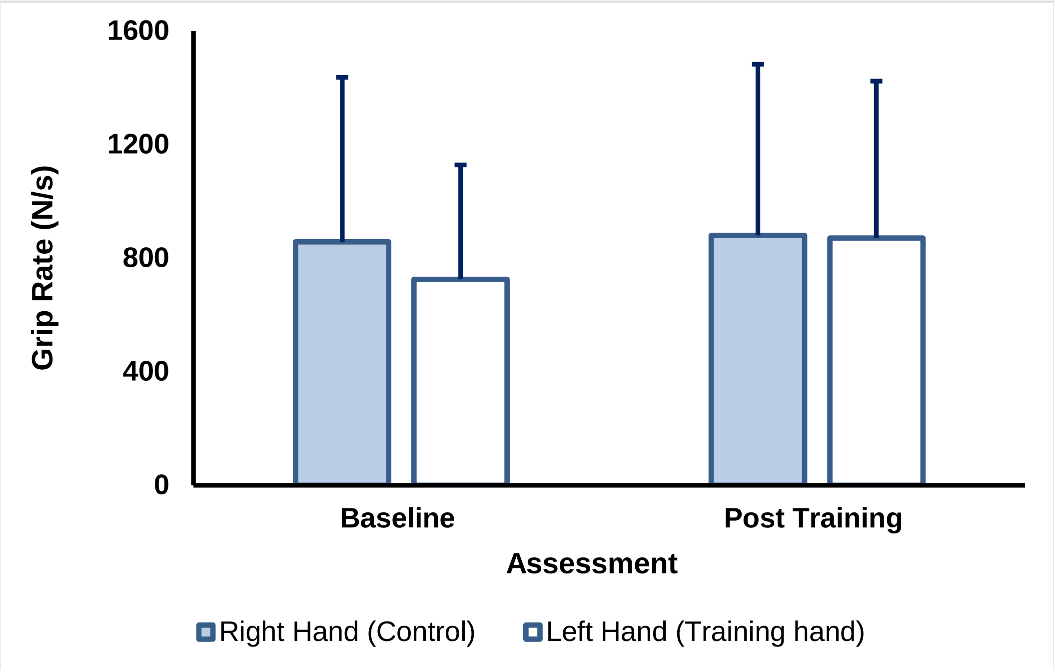


Figure 7-7: Grip Rate for maximum hand grip contractions before and after 6 weeks rapid-force exercise training protocol (*=p<0.05)

7.4.3.3 Maximum Pinch Grip Strength

There was a statistically significant increase in right pinch strength (p=0.01) (Table 7-13), thus supporting the research hypothesis (i.e. six weeks rapid-force pinch exercises of the right hand would increase right pinch grip strength). Pinch grip rapid-force exercises have a positive effect on pinch strength and may be a helpful addition to hand grip exercise programmes in healthy adults. There was no significant effect of the exercise in the left hand (see Figure 7-8).

Table 7-13: Maximum Pinch Grip Strength

Maximum Pinch Grip Strength	Baseline Assessment Mean ± SD (N)	Post training Assessment Mean ± SD (N)	Mean Difference 95% (CI)	P-value (Effect size)
Right Hand (Trained side)	74.6 ± 23.0	80.5 ± 21.0	-5.9 95%(-9.7 - -2.2)	**0.01*** (*d* =-0.3)
Left Hand (Control)	70.8 ± 17.8	77.3 ± 20.1	-6.4 95%(-14.2 - 1.3)	0.09

NB: SD-Standard Deviation; N - Newtons; CI - Confidence Interval; Statistical test -paired t test statistic; P – probability; * - significance

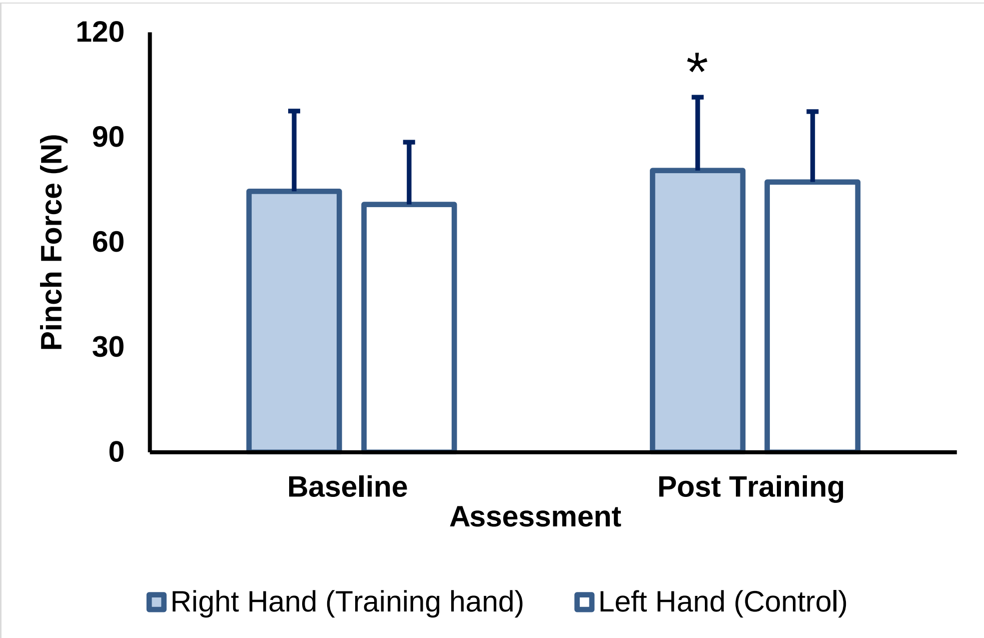


Figure 7-8: Maximum Pinch Grip Strength before and after 6 weeks rapid-force exercise training protocol (*=p<0.05)

7.4.3.4 Maximum grip rate for pinch grip contractions

An increase in grip rate for performing pinch grip was seen in both hands but more in the right which performed the pinch grip exercises than the left hand (Table 7-14; Figure 7-8). However, the observed increase was not statistically significant but was very close to significance (p=0.06) (see Table 7-14). There was no statistically significant change in the left hand.

Table 7-14: Maximum grip rate for pinch grip contractions

Maximum Pinch Grip Rate	Baseline Assessment Mean± SD (N/s)	Post training Assessment Mean± SD (N/s)	Mean Difference 95%(CI)	P-value (Effect size)
Right Hand (Trained side)	191.3 ± 130.4	227.1 ± 140.0	-35.8 (-73.4-1.7)	**0.06** (*d*=-0.3)
Left Hand (Control)	179.9 ± 99.1	199.7 ± 81.0	-19.8 (-59.9-0.3)	0.28

NB: SD-Standard. Deviation; N/s – Newtons per seconds; CI - Confidence Interval; P – probability; Statistical test -paired t test statistic

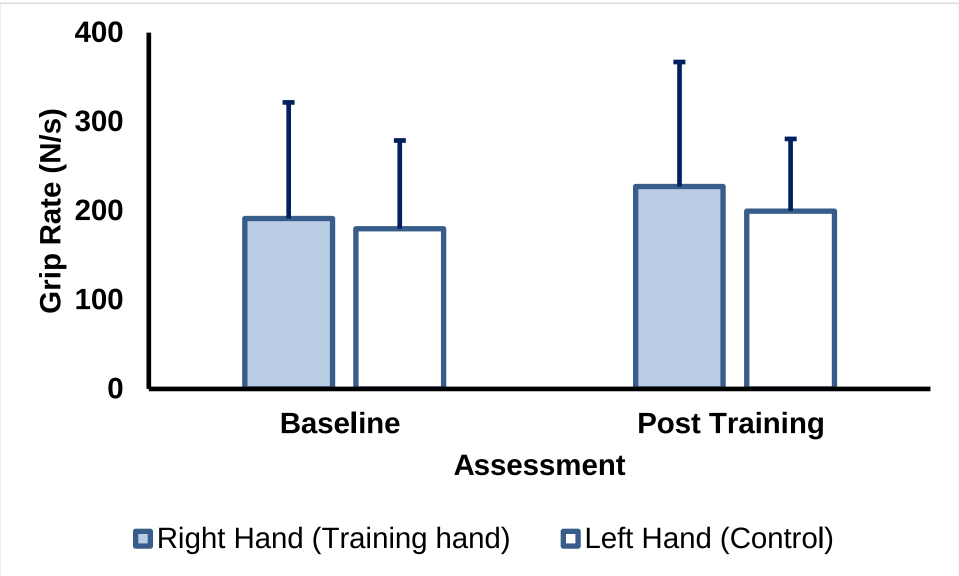


Figure 7-9: Grip Rate for Maximum pinch grip contractions before and after 6 weeks rapid-force exercise training protocol (*=p<0.05)

7.4.4 Muscle mechanical properties before and after six weeks rapid-force exercise training protocol

7.4.4.1 Muscle mechanical properties of the flexor carpi radialis muscles

Myoton elasticity, tone and stiffness decreased in the left FCR muscles however, these changes were not statistically significant (see Table 7-15). Hence, hand grip rapid-force did not have any significant effect on these three muscle mechanical properties in the left FCR muscles. An increase in relaxation time was seen in the FCR muscles of the right hand that performed the full hand grip exercises and no increase was seen in left hand. However, the observed increase in relaxation time was not statistically significant, but was very close to significance (p=0.06) (Table 7-15).

Table 7-15: Muscle Mechanical properties for Flexor Carpi Radialis Muscles before and after six weeks rapid-force hand grip exercise training protocol.

Myoton Properties	Hand Dominance	Pre-training Assessment (Mean ± SD)	Post-training Assessment (Mean ± SD)	Mean Difference 95% (CI)	P-value (paired t-test)
Elasticity (log decrement)	Right Hand	0.98 ± 0.12	0.99 ± 0.09	(-0.13 - 0.11)	0.85
	Left Hand	1.19 ± 0.16	1.06 ± 0.17	(-0.08 - 0.33)	0.19
Tone (Hz)	Right Hand	16.52 ± 1.48	16.17 ± 2.30	0.35 (-1.24 - 1.93)	0.62
	Left Hand	16.92 ± 2.71	16.34 ± 2.47	0.58 (-1.59 - 2.76)	0.55
Stiffness (N/m)	Right Hand	294.7 ± 40.0	300.6 ± 51.2	-5.9 (-58.3 - 46.6)	0.80
	Left Hand	311.0 ± 54.6	282.5 ± 59.7	28..5 (-22.6 – 79.7)	0.23
Relaxation (ms)	Right Hand	15.89 ± 2.55	16.64 ± 1.95	-0.75 (-2.70 - 1.20)	0.39
	Left Hand	15.26 ± 1.88	17.52 ± 3.11	-2.26 (-4.65 - 0.14)	0.06

NB: SD-Standard. Deviation; Hz - Hertz; CI - Confidence Interval; Statistical test -paired t test statistic; P – probability; * - significance; ms – microseconds. N/m - Newton per meter.

7.4.4.2 Muscle mechanical properties for thenar eminence muscles

An increase in Myoton elasticity (log decrement) was seen in the both left and right thenar muscles, but more in the right hand than the left (active control) (see Figure 7-10). This change was statistically significant in the right hand (p=0.02) hence supporting the research hypothesis that pinch grip rapid-force exercises significantly increases the elasticity of the thenar muscles after six weeks of exercise training. An increase in both Myoton frequency and stiffness in the right thenar muscles was observed, but these were not statistically significant [Frequency (p=0.52); Stiffness (p=0.63)]. Hence, six weeks pinch rapid-force exercise training did not have any significant effect on the Myoton frequency and stiffness of the right hand thenar muscles.

A decrease in Myoton relaxation time was seen in the thenar muscles of both hands but more in the right hand than the left hand. These changes in the hand, which were the expected outcome were, however, not statistically significant (p=0.70) (see Table 7-16).

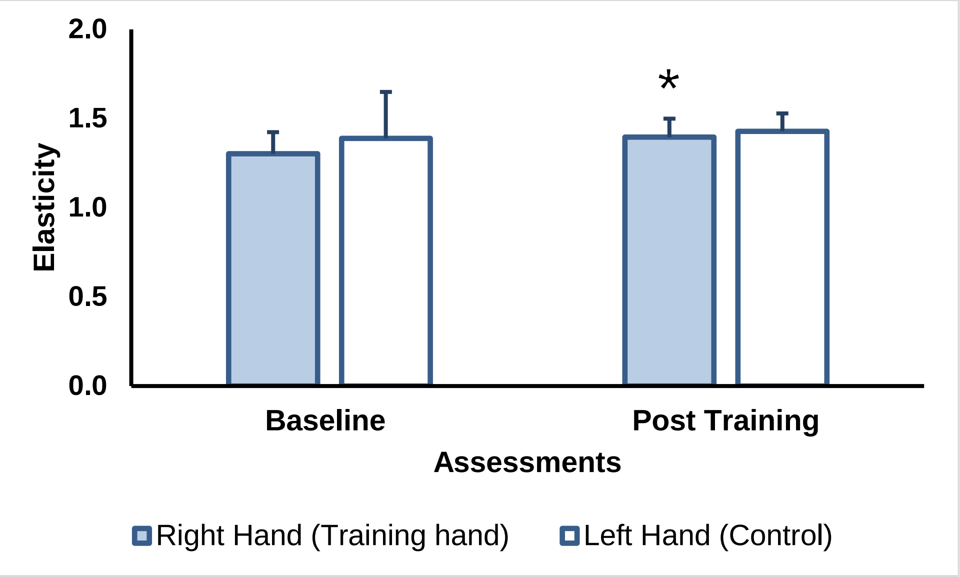


Figure 7-10: Myoton elasticity (log decrement) for Thenar muscles before and after 6 weeks rapid-force exercise training protocol (*=p<0.05)

Table 7-16: Muscle Mechanical properties for thenar muscles before and after six weeks rapid-force hand grip exercise training protocol

Myoton Properties	**Hand Dominance**	**Pre-training Assessment** (Mean ± SD)	**Post-training Assessment** (Mean ± SD)	**Mean Difference 95% (CI)**	**P-value** (paired t-test)
Elasticity (log decrement)	Right Hand	1.30 ± 0.1	1.40 ± 0.1	-0.09 (-0.17 - -0.02)	**0.02 ***
	Left Hand	1.39 ± 0.3	1.43 ± 0.1	-0.04 (-0.22 - 0.13)	0.57
Tone (Hz)	Right Hand	20.16 ± 2.3	20.71 ± 1.6	-0.55 (-2.47-1.37)	0.52
	Left Hand	19.04 ± 1.1	19.78 ± 1.0	-0.74 (-2.07-0.60)	0.23
Stiffness(N/m)	Right Hand	344.0 ± 42.7	355.5 ± 45.4	-11.6 (-66.32 - 43.21)	0.63
	Left Hand	303.8 ± 38.9	326.5 ± 25.6	-22.7 (-53.83 - 8.3)	0.13
Relaxation (ms)	Right Hand	14.69 ± 1.5	14.33 ± 1.7	0.31 (-1.52 - 2.13)	0.70
	Left Hand	15.24 ± 1.5	15.20 ± 1.2	0.04 (-2.05 -2.14)	0.96

NB: SD-Standard. Deviation; Hz - Hertz; CI - Confidence Interval; Statistical test -paired t test statistic; P – probability; * - significance; ms – microseconds; N/m - Newton per meter

7.4.5 Adverse events and participants feedback on the rapid-force exercises

7.4.5.1 Adverse events

Adverse events associated with the hand rapid-force exercises were mild and reported by few participants (n=3). These are:

1. Slight discomfort in third week of exercise which eased over time
2. Feeling of tiredness after first session
3. Pain in both hands in the 5th week of the performing the exercise
4. Mild discomfort in metacarpophalangeal joint of index finger (hand for pinch exercises)

7.4.5.2 Participant feedback on Hand rapid-force exercises

Participants were asked to share their experience and views on the hand rapid-force exercises using the participant feedback sheet attached to the exercise diary. Below are the views of the participants regarding the exercise content, its description and performance

7.4.5.2.1 Views on hand rapid-force exercise content

Regarding the exercise content (see Table 7-17), participants described the hand rapid-force exercise protocol as broadly easy, simple, and beneficial. Whilst some participants thought the exercise protocol was useful and brought about some benefits in their hands, one however hinted that she did not feel any marked changes in her hand. Below they commented:

> *"I feel the exercise was effective. My forearms feel stronger, it will be interesting to see if this is shown in the findings or just in my mind" (beneficial).*

> *"Personally, I did not feel differences. Not sure if more repetitions could help, e.g. doing the exercises twice daily, I do not know" (no effect)*

Majority of the participants also commented on how uncomfortable the pinch rapid-force exercises were, but this did not hinder their exercise performance and adherence. One participant stated

> *"It [pinch exercises] was only uncomfortable during the exercise, no lasting discomfort continued after finishing the exercise session. It was not severe enough to make me consider stopping at any point".*

See Table 7-17 for full details of participants feedback on the hand rapid-force exercise content.

Table 7-17: Participant feedback on Hand rapid-force exercise content

Participant Feedback	Evidence
1. Exercises easy and simple	"The exercises were okay and easy to carry on" "The exercises weren't difficult; I prefer the blue ball because its less easy to perform compared to the green and the black" "Exercises are boring, easy but not uncomfortable". "The exercises are simple, and the future patients should be able to do it"
2. Exercises are beneficial	"I enjoyed it and believe the exercises to have been effective. I intend to try and buy some of those balls to continue to use" "I'm not feeling any pain after performing the exercises compared to my initial sessions" "I feel the exercise was effective. My forearms feel stronger, it will be interesting to see if this is shown in the findings or just in my mind". **No effect** "Personally, I did not feel differences. Not sure if more repetitions could help, e.g. doing the exercises twice daily, I do not know"
3. Uncomfortable pinch exercises	"I found the pinch exercise to be mildly uncomfortable in my metacarpophalangeal joint of my right index finger" "It *[pinch exercises]* was only uncomfortable during the exercise, no lasting discomfort continued after finishing the exercise session. It was not severe enough to make me consider stopping at any point". "Pinch exercises are difficult to perform"

7.4.5.2.2 Views on exercise description and performance

A few participants thought the exercise descriptions in the exercise diaries were clear, but the instructions were confusing, and this affected exercise performance. One participant stated:

> *"Although the descriptions were clear, but I used to get confused with counting the repetitions. I tried to count using the other hand, but by reaching to the third/fourth repetition, I lose my concentration"*

Other comments on the exercise description and performance are detailed below (Table 7-18). Participants therefore made three clear recommendations to improve the rapid-force exercises: use clear exercise descriptions and instructions (e.g. photos and possible a video), review the exercise diary presentation and use balls with sensors for future studies to help with counting exercise repetitions.

Table 7-18: Views on exercise Description and performance

Views on exercise Description and performance	
Exercise description	**1. confusing instructions** "Instructions were confusing, sometimes I forget which arm to do. I suggest we do each exercise singly on each arm rather jumping to each arm intermittently". **2. Difficulty with counting** "Although the descriptions were clear, but I used to get confused with counting the repetitions. I tried to count using the other hands, but by reaching to the third/fourth repetition, I lose my concentration" **3. Clear and easy instructions** "Combined with the instruction given during the face to face sessions the movements were clear and easy to follow". The description of exercises together with practice at the beginning of the training were clear
Exercise performance	**1. Forgetfulness** "On occasions I had to remind myself that the movement was intended to be explosive rather than gradual" **2. Less time consuming** "I think the intensity of the exercise and the short duration they take would allow more frequent use" "The exercise was easy and did not take much time"
Suggestions for future	**1. Use balls with sensors** "It would be good if there were sensors in the ball to count the repetitions" **2. Clear exercise descriptions and instructions** "I would suggest a video demonstration" "Photos and descriptions in different planes (e.g. from lateral side of hand) might be helpful" "Add photos of the grip exercises. It would be useful to have both photos on the diary". **3. Review exercise diary presentation** "I think you should review the structure and presentation of the diary e.g. use thicker borders or different colours to separate grip and pinch details"

7.5 Discussion

7.5.1 Overview

A before and after experimental study was conducted to establish the proof of concept of hand rapid-force exercises which was delivered as a six-weeks exercise protocol: handgrip rapid-force exercises performed by the non-dominant hand (left hand) and pinch grip rapid-force exercises performed by dominant hand (right hand). In a sample of eight healthy volunteers, the proof of concept was established by investigating the effect of the hand rapid-force exercise protocol on muscle rate of rise of force, hand and pinch strengths, and mechanical properties of the thenar and FCR muscles. Findings from the proof of concept study showed positive trends towards the use of rapid-force exercises in the hand which were found to be easy to perform, tolerable, and beneficial in healthy volunteers. The literature asserts that measurements would be meaningless if there are no agreements between repeated measurements, particularly intra-rater and test-retest agreements (Koo *et al.*, 2016). Good reliability reports are available on grip strength (Bohannon, 2017; Bobos *et al.*, 2020) and muscle mechanical properties (Aird *et al.*, 2012; Agyapong-Badu, 2014) in different populations. However, it cannot be assumed that such will be case for the studied sample hence reliability tests were conducted to establish the robustness of the measures before use within the present study as recommended (Chuang *et al.*, 2012). Below, details of the reliability tests are discussed followed by the pre-post study results.

7.5.2 Reliability of grip strength and Myoton mechanical properties

Findings from the reliability studies showed largely good to excellent (ICC 3,2 > 0.83) test-retest (between day) reliability for all grip strength and grip rate data. Test retest reliability was excellent (ICC 3,2 > 0.95) for hand grip strength and good to moderate (ICC 3,2 0.85 - 0.98) for pinch grip strength. These results are consistent with previous studies that reported excellent intra-rater reliability for grip strength in healthy participants (ICC 0.92 95% CI 0.88- 0.94) (Bobos *et al.*, 2020) and in non-paretic hand of stroke survivors [(0.95 – 0.99 95% CI (0.87 – 0.99)] (Aguiar *et al.*, 2016). Reliability results for grip rates were also largely good to excellent for both hand grip rate (ICC 3,2 0.83 – 0.94) and pinch grip rates (ICC 3,2 0.90 – 0.97). Therefore, the good to excellent grip strength and grip rate test retest reliability result recorded within the present study suggests strong agreement between the repeated measures taken. This therefore influenced the decision to use the digital grip and pinch analyser in assessing grip strength and grip rate within the present study as the researcher was confidence in its ability to produce consistent results and detect change between the baseline and post- training measures (Koo *et al.*, 2016).

The test retest (between day) reliability for all four muscle mechanical properties studied (elasticity, tone, stiffness, and muscle relaxation time) was generally moderate to poor (ICC 3,2 -0.6 – 0.67) in the thenar muscles. Moderate reliability (ICC 3,2 0.59 – 0.67) was recorded in the dominant hand and poor to moderate (ICC 3,2 -0.6 – 0.52) in non-dominant hand. The latter suggests a reduced ability of the Myoton device to produce consistent measures in the thenar muscles of the left hand which might affect its ability to detect change. Whilst this was acknowledged, the better reliability results in the dominant hand influenced the use of the MyotonPro device as that hand performed the pinch grip rapid-force exercises. Hence, the researcher was confidence in the ability of the Myoton device in producing consistent before and after training values of all Myoton data within the dominant hand. Although slightly lower values were recorded within this study, the moderate test retest reliability are consistent with previously reported between day reliability (ICCs 3,1 > 0.72 – 0.87) for biceps femoris and rectus femoris muscles in young males (20-35 years) (Mullix *et al.*, 2012).

The test retest reliability for FCR muscle relaxation time was moderate (ICC 3,2 0.56) in the dominant hand and poor (ICC 3,2 –0.14) in the non-dominant hand. That for FCR muscle tone, stiffness and elasticity was poor to good (ICC 3, 2 0.15 - 0.81) in the dominant hand and poor to moderate (ICC 3,2 -0.11 - 0.55) in the non-dominant hand. The non-dominant hand performed the hand grip rapid-force exercises within the present study hence the modest test retest reliability suggests a less likely ability of the Myoton to produce consistent repeated measures compared to the dominant hand. This may influence the ability of the Myoton to detect change between the baseline and post-training Myoton measures in the non-dominant FCR muscles tone, stiffness, and elasticity and a weaker ability for the muscle relaxation time. Despite the modest reliability of the Myoton device within the studied population, notably observed were the lower values compared to the published high test-retest reliability for FCR muscle tone, stiffness and elasticity (ICC > 0.92) in non-paretic hands of stroke survivors (Chuang *et al.*, 2012) . A standardized approach was followed during measurements, however, some participants fidgeted during measurements which may have minimally influenced the results as previous authors have reported that movement of the probe from the muscle midline can significantly alter muscle stiffness and tone (Agyapong-Badu, 2014; Agyapong-Badu *et al.*, 2018).

Compared to poor values in the non-dominant hand (ICC 3,1 0.19 – 0.42), intra-rater (within session) reliability for thenar muscle tone, stiffness, elasticity and muscle relaxation time was excellent (ICC 3,1 > 0.93) in the dominant hand which performed the pinch rapid-force exercises.

This suggests strong agreement between the repeated Myoton measures taken by the researcher and increased the use of the device and its ability to produce consistent measures within a measurement session. The reliability results within the present study are consistent with previously reported excellent within-session reliability in the biceps brachii of young adults (ICCs 3,2> 0.95) (Mooney *et al.*, 2013) and quadriceps muscles of older males (ICC 3,2 > 0.90) (Aird *et al.*, 2012). Unlike the thenar muscles, poor (ICC 3,1 -0.16 – 0.07) intra-rater within session reliability for all four Myoton parameters were recorded in the FCR muscles of the non-dominant which performed the handgrip rapid-force exercises. The FCR muscles contribute to hand gripping action and from the literature, dominant hands are 10% stronger in gripping than the non-dominant hands (Roberts et al., 2011). Hence, the study participants who were all right-hand dominant may have been less strong in their non-dominant hand and this may have contributed to the poor reliability results recorded in that hand. This reliability result therefore indicates the poor repeatability of the Myoton device to produce consistent repeated results in the FCR muscle properties and invariably the limited ability to detect change. These findings are divergent from previous studies that studied a similar cohort of young adults with excellent within session reliability (ICC 3,2 > 0.99) (Mullix *et al.*, 2012).

Of importance to clinicians is the ability of outcome measures to provide results that are reproducible (Syczewska *et al.*, 2009). Despite some variations in the Myoton reliability results in the non-dominant hand, the moderate to excellent agreement in the dominant hand established the researcher’s confidence in the use of the device. The excellent reliability results advanced the certainty of the researcher that the use of the MIE digital analyser and the MyotonPRO device will yield similar results with repeated measures as asserted in literature (Agyapong-Badu, 2014). This established the stability of the devices in measuring both strength and muscle mechanical properties on different days, which informed their use to evaluate before and after training measurements within the study.

7.5.3 Grip strength and rate measures before and after rapid-force exercise training

The study results showed no significant effect of the hand grip rapid-force exercise protocol (performed on the left hand) on maximum hand grip strength. A similar effect of no change has been reported in a previous study that investigated a hand OA exercise programme with an intensive strength training component (Østerås *et al.*, 2014a). In addition to specific instructions given, participants within the present study also exercised at an intensity of 70% of their maximal effort; an intensity level within the recommended level for both healthy adults (60%-70%) (Garber *et al.*, 2011) and people with arthritis (30%-75%) (Katz *et al.*, 2001).

The non-significant quantitative results therefore suggest that perhaps the intensity of the exercise was not sufficiently high enough to increase maximal force contractions to bring about change in hand grip strength. This is corroborated by the qualitative feedback (section 7.4.5.2.1) where some participants reported of not feeling any differences in their hands and wondered whether more repetitions would have shown better effects. Additionally, both in person and written exercise instructions (Appendix D.10) were given, however some participants reported that this was unclear and got them confused with counting their exercise repetitions. Such irregularities in exercise frequency coupled with low intensity due to lack of focus during exercise performance (e.g. some participants reported exercising whilst browsing their phones or watching television) may have influenced the non-significant hand grip strength results in the participants. Most participants performed the exercises as a home programme hence future exercises should combine both home and supervised exercise delivery as recommended from the scoping review (Chapter 5) to achieve the desired results.

Comparatively, the dominant hand (right hand), which performed no whole hand exercises (performed pinch grip training), showed significant increase in the grip strength measures (p=0.03). Such significant results in the right hand (control-no hand grip exercise training) may be attributed to the fact that the right hand was not a true control as it underwent pinch grip exercises which might also influence whole hand grip test results. As previously mentioned, participants were all right hand dominant and as such, cross-over effect of the training (Doix *et al.*, 2013) with better motor control and skill acquisition on the dominant side, may have also contributed to the significant results in the control hand. Similar findings of improved maximum pinch strength have been reported in an ambitious exercise programme intended for people with hand OA that involved key pinch and fingertip pinch exercises with thera-band exerciser balls similar to those used within the current study (Rogers *et al.*, 2009). All participants performed the pinch grip rapid-force exercises with their right hand (left hand acted as control). Contrary to the maximum hand grip strength, statistically significant increase in right pinch grip strength (p=0.01) was recorded. Whilst this shows the benefits of the rapid force exercises on pinch grip strength, similar to previous reports (Roberts *et al.*, 2011), the PhD researcher acknowledges that the participants were right hand dominant and may be stronger in their right hand, hence the better results. Nonetheless, this proved the concept that pinch grip rapid-force exercises can be beneficial in the hand and may be a helpful addition to hand grip strengthening exercise programmes.

Grip rate signifies the rate of rise of force which also characterises rapid-force. Hence, significant increase in hand grip rate signifies a positive effect of the rapid-force exercises in both hand and pinch grip rapid-force.

The study results demonstrated that rapid-force exercise training did not have any significant effect on both hand grip rate (p= 0.09) and pinch grip rate (p=0.06). These results contrasts previous studies on lower limb explosive strength training programmes in a similar cohort were significant effect on explosive (rapid-force) force production was reported (Tillin *et al.*, 2014). Such divergent results may be attributed to the exercise intensity (75% MVC) which was lower than that of the previous study (90% of the MVC) (Tillin *et al.*, 2014). However, the p-values within the present study almost reached significance (p= > 0.06). The effect size for pinch grip rate was small (Cohen's d= -0.27) thus suggesting slight effect of the pinch grip rapid-force exercises on pinch grip rate. Contrary to the pinch grip rate, the estimated effect size for hand grip rate was small (Cohen's *d*=0.4) and probably fell short of the significant level due to the small sample size (8 study participants). These quantitative results are corroborated by the qualitative feedback responses where study participants thought the exercise were effective and improved the strength of their forearms (see Table 7-17). The above discourse suggests that hand grip rapid-force exercises is a promising dynamic hand strength exercise protocol to consider, may have significant effect with an adequate sample size, so warrants further study with a larger sample. Rapid-force exercises may therefore be a feasible strength training concept to explore for improving rapid-force contractions in the hands for possible inclusion in hand strength training programmes.

The absolute measures and precision of grip strength can be influenced by the aspects of protocol such as hand size, posture, effort and hand dominance to mention a few examples (Roberts *et al.*, 2011). It was observed that before and after training grip strength and grip rate data were generally higher in the dominant hand compared to the non-dominant, which may also suggest the increased values in the dominant hand. Findings are consistent with previous literature which stated that the dominant hand has a 10% stronger grip than the non-dominant (Roberts *et al.*, 2011). However, this was not the case for the Myoton values as no such trends or characteristics were observed within the population studied. These findings are comparable with previous research that investigated the symmetry and within session reliability of the biceps brachii in a similar young adult population using the MyotonPRO device (Mooney *et al.*, 2013). Below the Myoton parameters are discussed.

7.5.4 Muscle mechanical properties before and after rapid-force exercise training

The results showed that hand grip rapid-force exercises did not have any significant effect ($p>0.05$) on the FCR muscle elasticity, frequency, stiffness, and relaxation time of both hands. The lack of changes may be due to the inability of the Myoton device to monitor changes between the baseline and post- training measures or evaluate the effect of the hand grip rapid-force hand due to the poor to moderate (ICC 3,2 -0.11 - 0.55) test-retest reliable results previously discussed (section 7.5.2). In addition, the no effect of the exercise protocol can also be attributed to the low level of specificity regarding the rapid-force exercise performance.

For instance, findings from the qualitative feedback indicated that some participants performed the exercises sub-optimally as one participant commented on how she had to remind herself to exercise rapidly rather than use low contractions (see Table 7-18). However, of note was the near significant ($p=0.06$) increase in FCR muscle relaxation time observed in the non-dominant hand that performed the hand grip rapid-force exercises. Mechanical stress relaxation time is the time for a muscle to restore its shape from deformation after a voluntary contraction or an external force is removed (Schneider *et al.*, 2015). Hence, a significance increase in the non-dominant FCR muscles would have indicated a longer recovery time in the left FCR muscles after the performance of the exercises, a negative effect contrary to the expectation of the exercise protocol. However, the magnitude of the estimated effect size (d = - 1.2) was not large enough to inform the exercise development within the present PhD or future work.

Similar to the FCR muscles, rapid-force exercises did not produce significant changes in the thenar muscle tone, stiffness and relaxation time in both hands. Such findings may be due to: i) lack of effect of the pinch grip rapid-force exercises on these Myoton parameters; or ii) limited ability of the Myoton device to detect real change in the thenar muscles due to the moderate test retest reliability (ICC 3,2 0.59 – 0.67) (see section 7.5.2). However, significant increase ($p=0.02$) in thenar muscle elasticity (log decrement) was recorded in the dominant hand that performed the pinch grip rapid-force exercises. Elasticity is the ability of the muscle to restore its initial shape after a contraction or the removal of an external force (Schneider *et al.*, 2015). Hence, significant increase in elasticity indicates that the pinch grip rapid-force exercises made the thenar muscles of the dominant hand: (1) more elastic (2) reduced their ability to fatigue quickly and (3) increased the speed of movement, relevant factors needed for functional activity performance (Gapeyeva *et al.*, 2008; Maffiuletti *et al.*, 2016).

Previous research suggests that mechanical characterisation of the skeletal muscle properties using the Myoton provides new insights into the muscle function (Roja *et al.*, 2006). With the exception the dominant hand thenar muscle elasticity, the above pre to post Myoton results suggest the inability of the MyotonPRO device in identifying the mechanical changes within the thenar and FCR muscles investigated.

Based on the moderate to excellent reliability scores (section 7.5.2), the Myoton device was used as a robust measure of assessing the mechanical properties in the hand of the healthy volunteers. However, the statistically non-significant effect obtained from pre and post training exercises suggests the limited relevance in its use in future studies investigating rapid-force exercises as the device was not able to sufficiently detect change in the muscles measured. It has been documented that the exact location of the Myoton probe, the length of the muscles being assessed, the contractile state of the muscle and prior activity affects Myoton measures and limits accurate measurements (Agyapong-Badu, 2014; Agyapong-Badu *et al.*, 2018). Within the present study, the standardised testing approach was followed and specific instructions for participants to relax before measurements were given (Chuang *et al.*, 2012; Agyapong-Badu, 2014). However, the researcher suspects that some Myoton measures may have been affected as some participants (the majority of whom were from the university community) attended some assessment sessions after using the computer (typing) and despite instructions to relax, perhaps the muscles were not fully relaxed during measurements.

Previous authors have recommended the use of high-force contractions in strength training programmes (Aagaard *et al.*, 2010) as they are more logically relevant to daily functional tasks performance (Balshaw *et al.*, 2016; Maffiuletti *et al.*, 2016). The positive effect of hand rapid-force exercises on hand and pinch grip rate (i.e. rapid-force), pinch strength and thenar muscle elasticity has been established within the present study. These quantitative results were corroborated by the qualitative reports as study participants found the exercises to be effective with beneficial effects in improving upper limb strength. A few adverse events (e.g. slight discomfort, pain in the hands) were reported however, these were not serious enough to prevent the exercise training as participants noted that discomforts were only temporary and did not persist after exercise training (see Table 7-18). Based on the quantitative and qualitative findings as well as the mild adverse events, the use of the concept of rapid-force exercises was demonstrated in the hand.

Given that such dynamic strength training have been reported to provide highly efficient means of increasing function and may be well tolerated in people with OA (Balshaw *et al.*, 2016), exploration of rapid-force exercises in future strength training programmes targeted at hand OA should be considered.

7.5.5 Study limitations

Firstly, a sample size of 8 is insufficient for reliability studies as a minimum sample of 20 is required for such purposes (Atkinson *et al.*, 2001). However, the reliability studies were not the main focus of the present study but rather to proof the concept of the rapid-force exercises, which informed the sample size choice. The reliability studies were conducted as part of the proof of concept study to confirm the robustness of the MIE digital grip analyser and MyotonPro device in producing consistent repeated measures before use within the group studied. The sample size of 10 (eight remained after two dropouts) for this study was therefore chosen because the rapid-force exercises were new and the PhD researcher was uncertain regarding its impact in the hand, hence a small sample size was deemed a realistic choice. From the literature, a few studies of this nature have used similar samples for reliability studies (n=11 and 10) (Aarrestad *et al.*, 2004; Schneider *et al.*, 2015) and pre to post dynamic exercise training studies (n=9 and 10) (Tillin *et al.*, 2011; Tillin *et al.*, 2013; Tillin *et al.*, 2014) with favourable results. However, the PhD researcher acknowledges that the small sample size used within the present study may have produced some of the low reliability results and invariably the lack of significant changes in some of the intervention effects, as such, the generalization of the study results should therefore be done with caution.

Secondly, the control side in each training scenario was not a true control, as both hands underwent training of one form or other (i.e. whole hand grip or pinch grip) and this could have influenced testing, as some muscles contributed to both activities. Whilst the use of the Myoton device is emerging, several reliability studies have been conducted in different populations and on different muscles. Commonly investigated muscles are extensor digitorum, FCR (Chuang *et al.*, 2012), trapezius (Viir *et al.*, 2006); gastrocnemius, erector spinae, Achilles (Schneider *et al.*, 2015); rectus femoris and biceps femoris (Mullix *et al.*, 2012; Agyapong-Badu, 2014) and biceps brachii (Aarrestad *et al.*, 2004; Mooney *et al.*, 2013). Thirdly, to the best of the researcher’s knowledge, this is the first time thenar muscles mechanical properties have been investigated hence there was no comparable published data to facilitate a discussion. The need for future studies on establishing the psychometric properties of the thenar muscles properties in healthy individuals to obtain normative data as well as in different populations is warranted.

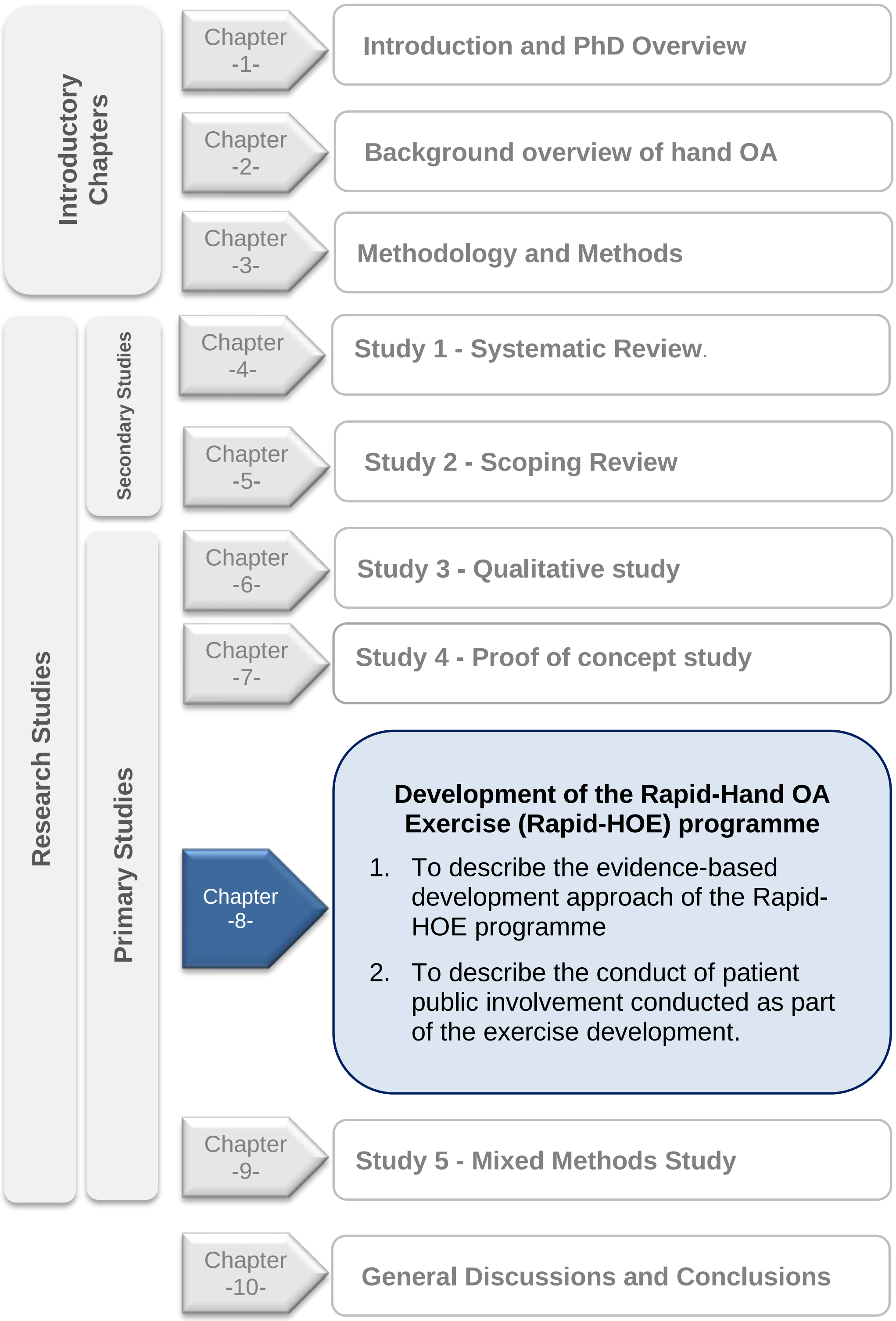
7.6 Conclusions

1. Rapid-force exercises significantly increased pinch grip strength, which suggests that rapid-force exercises are beneficial in improving pinch grip and may be a helpful addition to hand grip strengthening exercise programmes.
2. No changes were observed for hand grip strength. It would be useful to examine whether a longer duration exercise programme (between 6 weeks and three months), that is more comparable with previous studies may show increased grip strength, or that targeting isometric strength as well as rapid-force, would have a positive effect on grip strength.
3. The study showed a near significant effect of rapid-force exercises on hand grip rate ($p = 0.06$) and pinch grip rate ($p = 0.09$) with small estimated effect sizes (Cohen's $d = 0.4$ and -0.3). Possible significant effects may be reached with an adequate sample size, so warrants further study with a larger sample.
4. The concept of hand rapid-force exercises has been demonstrated in the hand of healthy volunteers. These exercises were found to be easy and simple, tolerable, and beneficial in improving hand rapid-force in the non-dominant hand and pinch rapid-force, maximal pinch strength and thenar muscle elasticity in the dominant hand.
5. Whilst several reliability studies have been conducted in different muscles, this is the first time thenar muscles mechanical properties have been investigated. The need for future studies to establish the psychometric properties of the thenar muscles properties in healthy individuals to obtain normative data, as well as in different populations, is warranted.

7.7 Chapter summary

This chapter has described Study 4 which has demonstrated the feasibility and established the use of the concept of rapid-force exercises in the hand. These exercises were found to be easy, tolerable and feasible in healthy volunteers and based on this, rapid force exercises were incorporated into an exercise programme with other hand exercises recommended from the literature to produce a novel hand exercise programme for hand OA (Chapter 8).

Location in thesis



Chapter 8 Development of the Rapid-Hand Osteoarthritis Exercise Programme

8.1 Introduction

This chapter is presented in two sections. Section-1 describes the evidence-based development of the Rapid-force Hand Osteoarthritis Exercise (Rapid-HOE) programme (consolidation of evidence from all preceding research works; studies 1-4). Section 2 describes a Patient Public Involvement (PPI) activity conducted as part of the exercise development process, to explore relevant stakeholders' (patients, clinicians, and researchers) views on the developed Rapid-HOE programme (see Figure 8-1).

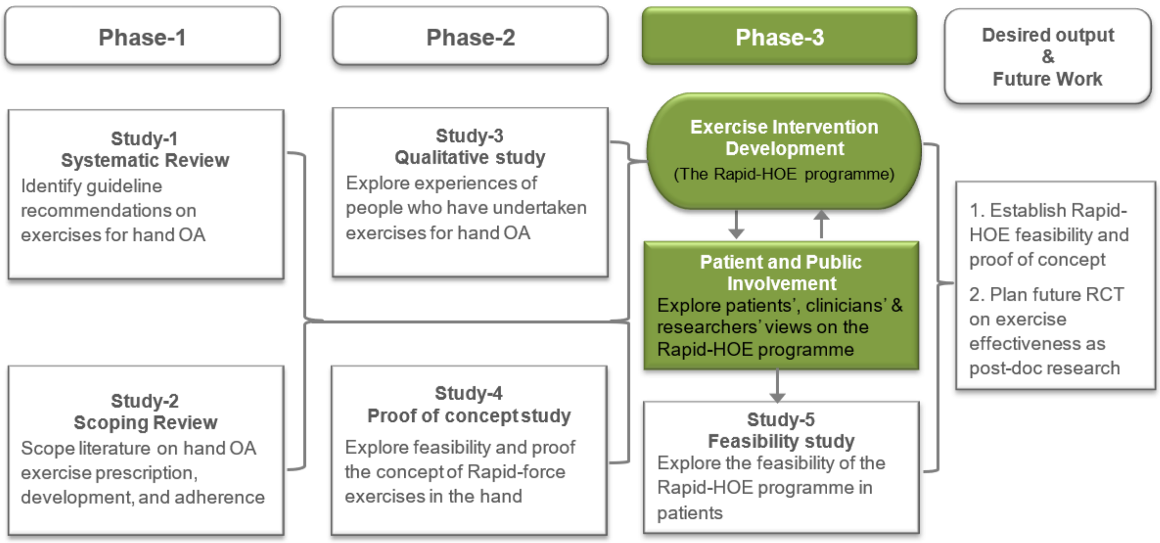


Figure 8-1: Exercise development and patient public involvement location within the overall PhD research

Section 1 - Evidence-based development of the Rapid-HOE programme

8.2 Brief background

The need to identify the optimal hand exercise programme that is beneficial for people with hand OA, was warranted due to: i) limited quality research; and ii) disagreement amongst researchers on existing exercises (Kloppenburg *et al.*, 2018). This, therefore, formed the basis of the PhD research with the aim to develop and propose an exercise programme to improve pain, hand function and quality of life in people with hand OA.

In Chapter 7, the concept of hand rapid-force exercises was established in the hands of healthy volunteers, these exercises were found to be simple, tolerable, and beneficial in improving hand and pinch rapid-force, maximal pinch strength and thenar muscle elasticity. These findings identified hand rapid-force exercises as a promising dynamic hand strength exercise protocol, which can be considered for possible inclusion in hand OA strengthening programmes. Based on this recommendation, an exercise programme for people with hand OA was developed with the inclusion of the feasible hand rapid-force exercises investigated in Chapter 7 and other hand exercise recommendations from the scoping review (Chapter 5) and qualitative study (Chapter 6). This section presents the evidence-based exercise development process.

8.3 Method

From the literature, evidenced-based interventions should be developed systematically using the best available evidence sources: i) research evidence, ii) clinical expertise; and iii) patient and client evidence (Rappolt, 2003). In addition, the development process must adhere to an appropriate theory-based intervention development framework, after which the intervention must be tested through a series of a carefully phased approaches (see Figure 8-2) (Craig *et al.*, 2013). As proposed by the Medical Research Council (MRC) guidance for the developing and evaluating complex interventions (Craig *et al.*, 2013), the development phase includes three stages: i) identifying the evidence base; ii) identifying or developing theory and; iii) modelling process and outcomes (see Figure 8-2). The three developmental phases as followed in the development of the hand OA exercise programme, are discussed below.

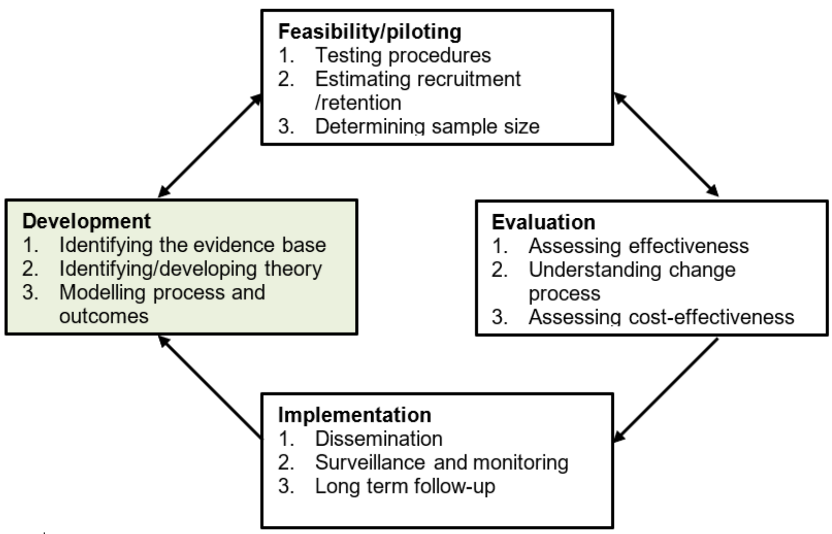


Figure 8-2: Key elements of intervention development and evaluation process (Craig *et al.*, 2013).

8.3.1 Developing the Rapid-HOE exercise programme

8.3.1.1 Stage 1 - Identifying the evidence base

The first step in the development process is to identify what is already known about similar interventions, and if there is no current, high quality systematic review of the relevant evidence, one should be conducted (Craig *et al.*, 2013). A few systematic reviews have been conducted but none have focussed on hand OA exercise management. Due to the lack of available evidence, a systematic review of clinical practice guidelines and consensus recommendations on exercise management for hand OA was conducted (see Chapter 4).

8.3.1.2 Stage 2 - Identifying/developing theory

This stage involves the development of a theoretical understanding of the process of change, based on existing evidence and theory, or new primary research. During this stage, three key studies (scoping review, qualitative and proof of concept studies) were conducted to understand and establish the rationale to develop the hand OA exercise programme. A scoping review provided evidence on how existing exercises for hand OA are developed, prescribed, and adhered to (see Chapter 5). A qualitative analysis study identified the views of hand OA patients on an existing hand OA exercise programme (see Chapter 6). Findings from an RCT (Østerås *et al.*, 2014a) recommended the need to enhance strength training components of hand OA exercises due to limited beneficial effects of existing programmes. Informed by this, the PhD researcher adopted the emerging rapid-force muscle strength training concept used in the lower limbs (Tillin *et al.*, 2013; Maffiuletti *et al.*, 2016) for the hand and investigated it in a proof of concept study (see Chapter 7). Relevant findings from these studies were consolidated to produce the new hand OA exercise programme (see sections 8.4.1).

8.3.1.3 Stage 3- Modelling process and outcomes

This stage involves the modelling of the developed intervention to provide information about the design and evaluation before running a full-scale evaluation. A Patient Public Involvement (PPI) project to seek the views of hand OA patients, clinicians and researchers on the developed Rapid-HOE programme content was conducted for this stage (see section 8.5).

8.4 Results

8.4.1 Developing the Rapid-HOE exercise programme

Figure 8-3 shows all underlying research studies and the relevant findings from this PhD project that contributed to the Rapid-HOE programme content. From the systematic review, scoping review, and qualitative study, relevant exercises beneficial for people with hand OA were identified (see Chapter 4 - Chapter 6). These exercises were added to the rapid-force exercises investigated in the proof-of-concept study (Chapter 7) to produce the Rapid-force Hand Osteoarthritis Exercise (Rapid-HOE) programme.

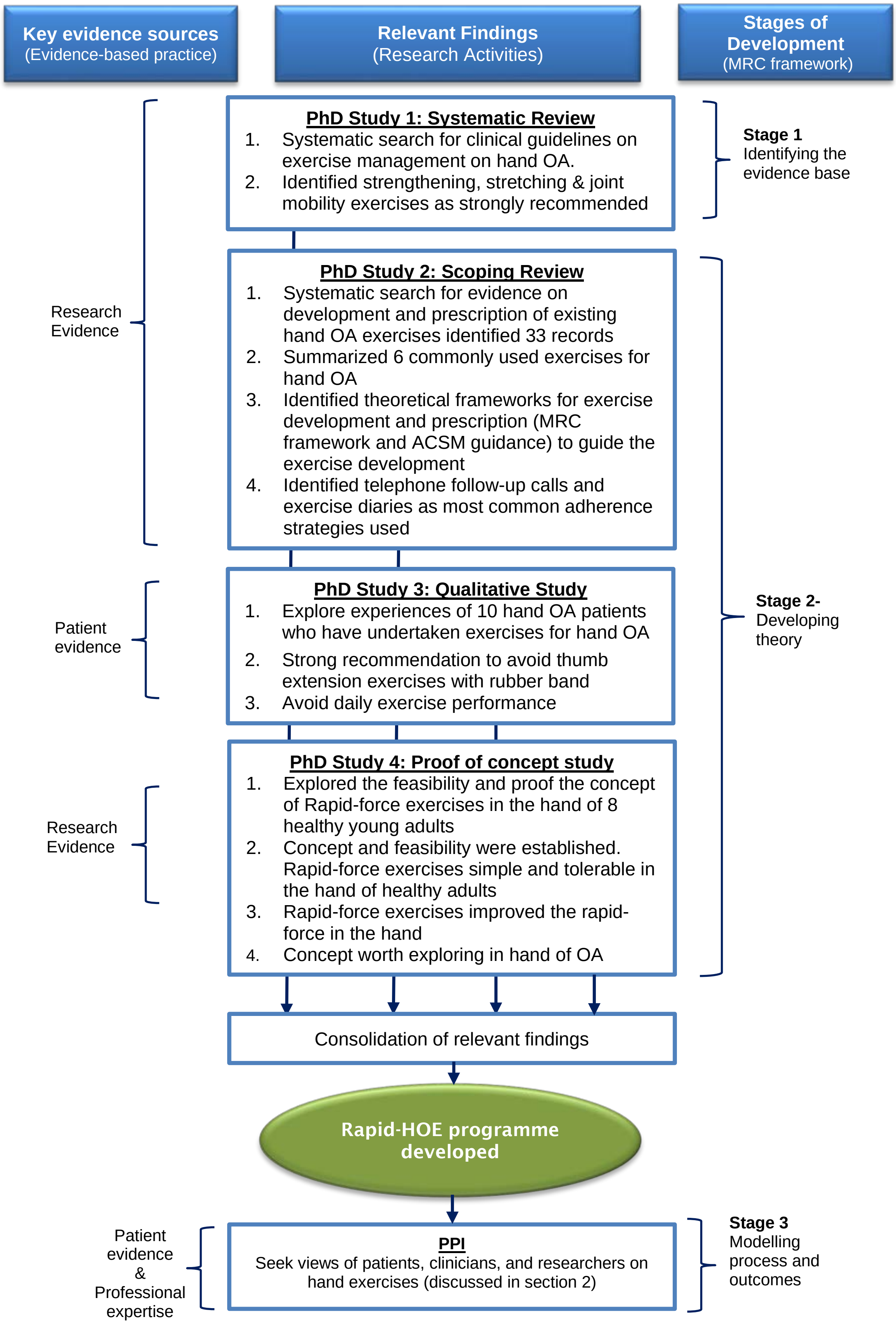
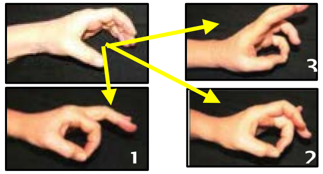
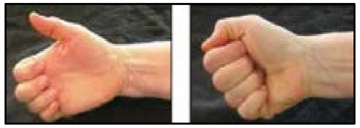


Figure 8-3: Development of the Rapid-HOE programme

8.4.2 The Rapid-HOE programme: content and prescription

Table 8-1 describes the exercise components of the developed Rapid-HOE programme (Version-1). The Rapid-HOE programme includes exercises to both increase, and maintain ROM, and to increase strength and endurance as recommended by the ACSM exercise development guidance (2011).

Table 8-1: The Rapid-HOE Programme content

Exercise Type and description	Exercise illustration	Aim of Exercise
1. Making an "O" sign Bring the index fingertip to the thumb tip, keeping the finger joints bent (flexed). Repeat with other fingers as shown in picture] *[repeat 6 times]*		Increase finger joint flexibility
2. Roll into a fist First, bend (flex) the finger DIPs and PIPs only and then later bend the MCPs, hold for 5 seconds and later extend in this order: MCPs, PIPs and DIPs *[Repeat 6times]*	 **Start position** **Finish position**	1. Maintain finger joint flexibility 2. Increase joint flexibility
3. Static hand grip strength Squeeze as hard as you can and hold 10 seconds *[Repeat 6times]*		1. Increase hand grip strength 2. Increase endurance
3. Hand Rapid-Force exercises **4a**. Handgrip rapid-force contractions Hand grip ball as fast and hard as possible in 1s, followed by 5 seconds rest *(repeat 6times)* **4b**. Pinch grip rapid-force contractions Pinch ball as fast and hard as possible in 1seconds, followed by 5seconds rest *(repeat 6times)* *[Perform 3 sets of each 6 grip and pinch contractions].*	  **Start position** **Finish position**	1. Increase Rapid hand force 2. Increase grip ability

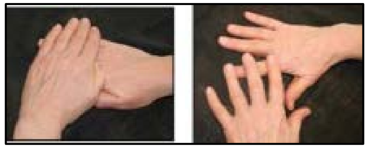
Exercise Type and description	Exercise illustration	Aim of Exercise
4. Finger stretch/stretches Place hand on a flat surface, use other hand to apply firm pressure to stretch the 2nd to 5th PIP and DIP joints *[Press and hold for 30 seconds; repeat two times for each hand or each finger if finger is painful]*	 **Group stretch** **Single stretch**	Increase finger joint flexibility

Table 8-2 describes the prescription of the Rapid-HOE programme following the ACSM guidance for exercise prescription in people aged 50 years or older (Garber *et al.*, 2011).

Table 8-2: Rapid-HOE exercise prescription

Exercise components	Component details
Frequency	Week 1 to 2: 6 reps of each exercise, 3 days per week Week 3 to 4: 8 reps of each exercise, 3 days per week Week 5 to 6: 10 reps of each exercise, 3 days per week
Exercise Intensity	Start with moderate resistance exercise balls (investigator help choose). Exercise performed at 75% of MVC Exercise progressed every 2 weeks (changing balls to higher resistance balls).
Exercise duration	15 - 20 minutes
Exercise training period	6 weeks

NB: Exercise balls are colour-coded Nuosen, gel hand balls, with three levels of resistance [yellow (easy) = 15kg; orange (medium) = 25kg, and blue (heavy) = 30kg].

MVC= Maximum voluntary contractions; reps=repetitions

Section 2 - Exploring stakeholders' views on the Rapid-HOE programme in a virtual Patient Public Involvement project

8.5 Background

After the development of the Rapid-HOE programme (section 8.1), it was necessary to explore the views of relevant stakeholders on the exercise programme using the Patient Public Involvement (PPI) approach. PPI is defined as "research being carried out 'with' or 'by' members of the public rather than 'to', 'about' or 'for' them" (Turk *et al.*, 2017). It is an important activity in the research process where potential stakeholders are involved in the planning, development, and dissemination of research to ensure acceptability, relevance, and quality of research. Based on the relevance of PPI in research, a number of UK national bodies, such as the Centre for Sport, Exercise and Osteoarthritis Research Versus Arthritis at University of Southampton, have taken a national approach to embedding PPI in all its research (Adams et al., 2014). This PPI project was therefore conducted based on its relevance within the research process, and its beneficial contribution in addressing the overall PhD aim, which was: to develop an exercise programme to improve pain, function and QoL of people living with hand OA.

There are three approaches to the involvement of stakeholders in PPI activities, these are consultation, collaboration, and user control involvement activities. Within this PPI project, the first two approaches were employed. Therefore, this PPI project was conducted to consult with hand OA patients and rehabilitation experts to seek their views on the developed Rapid-HOE programme.

8.6 Aims

The specific aims were:

1. To consult with people with hand OA, clinicians, and researchers on the Rapid-HOE programme
2. To develop ideas to co-design the study to test the feasibility of the Rapid-HOE programme

8.7 Methods

8.7.1 Reporting Guideline

The conduct and reporting of PPI in research are quite poor and inconsistent, and the field is really criticised for this (Staniszewska *et al.*, 2011). To help improve the quality, consistency, and completeness of PPI reporting, the Guidance for Reporting Involvement of Patients and the Public (GRIPP) checklist was developed (Staniszewska *et al.*, 2011). There are two versions of this checklist, the GRIPP2-SF (short form) and GRIPP2-LF (long form) (Staniszewska *et al.*, 2017). The GRIPP2-SF is recommended for studies where PPI is a secondary, or tertiary focus, such as those conducted as part of other studies. The GRIPP2-LF is for studies with PPI as the primary focus (Brett *et al.*, 2017). This PPI was conducted as part of the experimental research process to develop the Rapid-HOE programme, and for this reason, the GRIPP2-SF (Table 8-3) was used in its planning and reporting.

Table 8-3: The Guidance for Reporting Involvement of Patients and the Public GRIPP2-SF (short form) checklist (Staniszewska *et al.*, 2017).

Section and topic	Item
1: Aim	Report the aim of PPI in the study
2: Methods	Provide a clear description of the methods used for PPI in the study
3: Study results	Outcomes—Report the results of PPI in the study, including both positive and negative outcomes
4: Discussion and conclusions	Outcomes—Comment on the extent to which PPI influenced the study overall. Describe positive and negative effects
5: Reflections/ critical perspective	Comment critically on the study, reflecting on the things that went well and those that did not, so others can learn from this experience

NB: PPI- Patient Public Involvement

8.7.2 Training on the PPI approach

The concept of PPI was new to the PhD researcher and to understand the approach to its conduct, the researcher completed a 5-Course series skills training on PPI by the Southampton Academy of Research (SOAR) to be trained as a PPI facilitator (see Appendix E.1).

8.7.3 Recruitment of PPI partners

Seven PPI stakeholders (referred as partners from hereon) were approached and invited to participate in the PPI discussion using existing university staff networks, emails, and social media (twitter). These were people living with hand OA (n=3), and expert clinicians, and researchers who manage, and investigate people living with hand OA respectively (n=4). Table 8-4 shows brief details of the PPI partners involved in the PPI activity. These partners were verbally consented via telephone conversations and involved in the PPI discussion.

Table 8-4: Demographic data

PPI Partners	Demographic data
Patients	
PP1	Golfer Living with hand OA (20 years)
PP2	Widow, Farmer, dog agility handler Living with hand OA (20 years)
PP3	Support worker Living with hand OA (15 years)
Clinician and researchers' partners	
CP	Occupational therapist (7 years clinical experience; 3 years in hand OA management) Education level - BSc
RP	Physiotherapist Researcher in movement mechanics (10 years; 3 years in hand OA research) Education level - PhD
C/RP1	Physiotherapist (Teaching; research; clinician) Research interest: hand OA, upper limb, complex regional pain syndrome, Educational level - PhD
C/RP2	Physiotherapist (about 20 years clinical experience in hand therapy; 13 years in hand OA management) Researcher (research interest in CMC1 OA) Educational level (PhD candidate)

PPI: Patient Public Involvement; PP: patient partner; CP: Clinician Partner; RP: Researcher Partner; C/RP: Clinician and Researcher Partner; m: minutes; MS: Microsoft teams video conferencing tool

8.7.4 Procedure for Virtual PPI Activities

8.7.4.1 Pre-meeting activities

PPI discussions were organised (via email) and held online using Microsoft Teams (n=1) and Zoom (n=6). All sessions were facilitated by the PhD researcher with an occasional observer present (PhD supervisor-MS). One week prior to the PPI meeting, all partners were sent the PPI project information sheet (Appendix E.2), and the Rapid-HOE exercise programme (Table 8-1). This was done to allow partners to familiarise themselves with the exercise programme and review its content in preparation for the scheduled discussion. Partners were sent reminders a day before and approximately 2 hours) prior to the scheduled discussion via email (included a statement on the option to reschedule if their plans changed).

8.7.4.2 The PPI meetings

The PPI was conducted on a one-to-one basis and each discussion sessions lasted between one and 1.5 hours. At the start of the discussion, the procedure for the session was briefly explained, consent was reiterated verbally (to confirm consent received via email), a confidentiality statement was read out to them, and permission for audio recording of the sessions were sought. After this, a 7-minute Power point presentation explaining the background of the research, purpose of the PPI project and the expected scope of contributions from the partners was presented (see Figure 8-4).

Figure 8-4: Snapshot of the virtual Patient Public Involvement meeting

Image showing expert PPI partner (left) and PhD researcher (right). Image of expert PPI partner included with her permission.

PPI partners were engaged in discussions facilitated by the PhD researcher, and guided by a semi-structured topic script designed for patients (Appendix E.3) and experts (Appendix E.4). Three main discussion points were generally explored with all partners during the PPI meetings (see Table 8-5). Whilst notes were taken, discussions were also video recorded to corroborate the information gathered (videos later deleted).

Table 8-5: Discussion points explored during PPI activity

Discussion points	Aim
Theme 1 Views and experiences with hand OA exercise	Explore partners' general views of, and experiences with existing hand OA exercises
Theme 2 Views of Rapid-HOE the programme	Explore partners' thoughts on the Rapid-HOE programme and its potential usability amongst people with hand OA
Theme 3 Co-designing next phase of the project)	Explore partners' expert opinion, lay perspectives, and recommendations on the feasibility research strategy (i.e. research methods, recruitments, and qualitative interview guides).

NB: Rapid-HOE- Rapid hand osteoarthritis exercise programme; OA- osteoarthritis

8.7.4.3 Post-meeting activities and information management

All partners were sent brief discussion summaries after the PPI meetings. This was to corroborate what was discussed, include further comments, and feedback where necessary, in case of any omissions (see Appendix F.5 for a snapshot of a PPI partners' feedback summary). Relevant information from all discussions were reviewed by the PhD researcher and common themes (comments, suggestions, points of feedback and recommendations) were synthesized to inform the modification of the earlier version of the Rapid-HOE exercise programme. In keeping with good practice (Turk *et al.*, 2017), an audit trail of all PPI activities was documented (see Appendix E.5).

8.7.5 Ethical Considerations

This is a PPI exploratory consultation and engagement project, as such clinical research ethics approval was not required (Turk *et al.*, 2017). However, the project was designed along the framework of good clinical research governance as employed in a similar PPI project (Algeo *et al.*, 2015).

8.8 Study Results

This PPI activity involved discussing three main themes (section 8.7.4.2), the results of which are discussed in this section.

8.8.1 Theme-1: General views and experiences of/with hand OA exercises

All PPI partners had experiences with exercises for hand OA either as: i) patients living with the condition, ii) researchers investigating different exercises for hand OA management, or iii) clinicians managing patients with exercises. The patient partners thought that existing exercises were generally good, had beneficial effects and should be encouraged for hand OA management. Amongst the three patient partners, only one was using an exercise programme prescribed by her physiotherapist to self-manage her hand OA. For the other two, one commented that she just grew to live with her hand OA, and the other mentioned that her GP advised on pain and steroid medications, as hand OA was part of her aging process, and nothing could be done about it.

Table 8-6 shows brief details from the discussion with the expert PPI partners (clinicians and researchers) regarding their general experience with existing hand OA exercises. Two key points were identified. The first was the need for tailored intervention programmes (including exercises) for hand OA management, due to the different hand OA phenotypes (CMC1 and hand OA or OA of the fingers), which is currently lacking in literature. The second was the higher exercise intensity prescription for hand OA exercises as some existing ones are performed at sub-optimal levels to produce any meaningful benefits to patients (Appendix E.7 documents full details of the expert PPI discussion).

Table 8-6: Key findings from experts PPI partners relevant to the views on existing exercises

Expert PPI partners	PPI Responses
Researcher (RP1)	1. Some patients do not know much about exercises for hand OA 2. Most use different self-management approaches, which are not often helpful in improving their symptoms 3. Lack of education on the importance of exercise in managing symptoms, hence low reliance on it
Researcher and Clinician & Researcher (RP1& C/RP2)	1. Based on personal views, existing hand OA exercises are not pushing patients enough to exercise at sub-optimal levels as recommended by the ACR guidelines 2. This may have resulted in the lack of positive results reported within literature

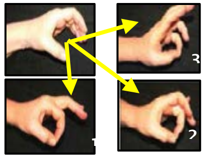
Expert PPI partners	PPI Responses
Clinician partner (CP1)	1. Discussed their use of tailored intervention programmes (including exercises) for managing CMC1 and hand OA (OA of the fingers) differently 2. Cited the content of the Rapid-HOE programme (excluding the rapid-force contraction exercises) as some of exercises usually used by clinicians

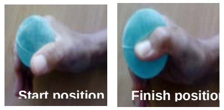
NB: Full details of discussion and responses is documented in Appendix E.7
CP: Clinician Partner; RP: Researcher Partner; C/RP: Clinician and Researcher Partner

8.8.2 Theme-2: Views and usability of the Rapid-HOE programme

Views of PPI partners on the Rapid-HOE programme are presented in Table 8-7. Both patient and expert partners thought the Rapid-HOE programme was simple, straight-forward, and feasible. However, two key challenges with its usage were discussed: i) lack of clarity with the exercise description; and ii) perceived difficulty with performing rapid-force exercises. These challenges are discussed below in reference to patients (sections 8.8.2.1) and experts (section 8.8.2.2).

Table 8-7: Views of patient PPI partners on Rapid-HOE programme

Exercise content and description		PPI comments
1.Make an "O" sign Bring the index fingertip to the thumb tip, keeping the MCP, PIP and DIP joints flexed. Repeat with other fingers as shown in picture] *[repeat 6 times]*		-PP1 thought exercise was good but disliked the presentation (e.g. pictures too small; illustrations over complicated). Suggested the following: 1. use only 2 pictures instead of the 4, leave out arrows and numbers 2. make picture bigger for better clarity 3. revise description for clearer understanding 2.Suggested adding a strengthening component to exercise (touch tip to tip and hold a few counts, then release)
2. Roll into a fist First, flex the DIP and PIPs only and then later flex the MCPs, hold for 5 seconds and later extend in this order: MCPs, PIPs and DIPs *[Repeat 6times]*		-All patient partners commented that PIPS, DIPS and MCPs terminologies used in descriptions were confusing. -Suggestion to use top and middle finger joints was made -Exercise description should include "roll into a fist" for better clarity - Show exercise illustration in sideways view for better clarity of presentation
3.Static hand grip strength Squeeze as hard as you can and hold 10 seconds *[Repeat 6times]*		- Suggestion to merge static and rapid force grip exercises was made as all are strengthening exercises - Suggestion to rename exercise as ball exercises or strength exercises (do not understand why the exercise 3 and 4 should be divorced from each other) - PP1 thought the number of repetitions of rapid force exercises was too much (suggested the gradual progression of the exercises from perhaps from 3 reps and later 6 reps)

Exercise content and description		PPI comments
5. Hand Rapid-Force exercises **a. Handgrip rapid-force contractions** Hand grip ball as fast and hard as possible in 1s, followed by 5s rest (repeat 6times) **b. Pinch grip rapid-force contractions** Pinch ball as fast and hard as possible in 1s, followed by 5s rest (repeat 6times) *[Perform 3 sets of each 6 grip and pinch contractions].*	  	- Exercise description text, not consistent and should be revised - Exercise repetition (6reps) too much to perform as anticipated of its difficulty - reduce repititions from 6reps to 2 or 3 repetitions initially with progression made over time.
5.Finger stretch/stretches Place hand on a flat surface, use other hand to apply firm pressure to stretch the 2nd to 5th PIP and DIP joints *[Press and hold for 30 seconds; repeat two times for each hand or each finger if finger is painful]*	 	All partners - commented on the difficulty in understanding exercise description and illustration (one stated that the NHS exercise explanation of a similar exercise was better) - agreed that the three times weekly exercise performance was good and should be a minimum requirement. -Advised that exercises should be tailored to individual preferences and lifestyle if everyone does the minimum set - PP1 suggested the use of an OA hand in exercise illustrations instead of the non-OA hand (volunteered to support research with photos of her hand for illustrations)

NB: PP - patient partner

8.8.2.1 Views of Patient Partners on the Rapid-HOE programme

All patient partners commented that the use of medical terminologies; PIPS, DIPS and MCPs for describing exercises 1, 2 and 5 were confusing and should be changed to non-medical terms. When asked to suggest possible descriptors, one patient partner (PP1) suggested the use of middle finger joint for PIPs, top middle finger joints for DIPs and knuckles for the MCPs, which were agreed by other patient (PP2) and expert partners (CP; C/RP2). With the illustrations, some commented on the difficulty in understanding the presentation of the exercises and felt it could be improved. Partner-PP1 commented on exercises 1 and 5:

> *"the pictures were too small; illustrations were over complicated [..], even the NHS exercise explanation of similar exercise was better". (**PP1)***

Suggestions to use larger pictures for clarity, as well as revised descriptions for clearer understanding were made. Regarding the perceived difficulty with the rapid-force grip exercises, patient partners felt the number of repetitions (6reps) was too much and suggested a reduction from six to two or three repetitions initially with gradual progression made over time.

8.8.2.2 Views of Expert Partners

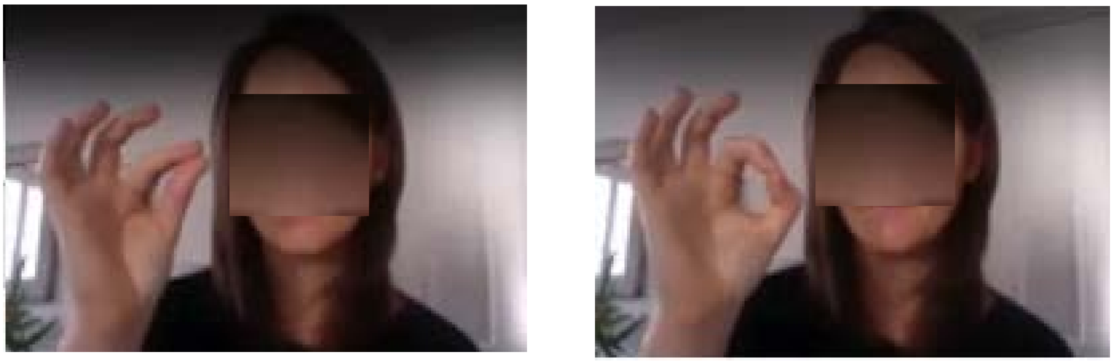
Most expert partners commented that it had a good balance between flexibility and strengthening exercises and contained some recommended exercises from literature. In agreement with patient partners, expert partners also suggested the need to improve the description of some of the exercises with emphasis on two areas. The first was making the description more patient-user friendly, as would be communicated by a therapist in clinical practice. For example, with Exercise 2 (roll into a fist), one expert partner suggested changes from option (A) to (B):

> *(A) "First, flex the DIP and PIPs only and then later flex the MCPs, hold for 5 seconds and later extend in this order: MCPs, PIPs and DIPs"*
>
> *(b) "Start with your (fingers) straight; bend the top finger joints only into a hook position; bend the knuckles into a full fist; hold for 5 seconds; straighten the knuckles fist first before straightening the top two finger joints to the start position'(**CP)***

The second was the use of descriptors that ensure the quality of exercise performance, such as providing correct and wrong exercise positions. Clinician partners thought this was relevant for the exercise programme, particularly as it would be used as a home programme. One commented on Exercise 1 (making an O sign):

> *"Photos are good. Sometimes patients touch pad to pad instead of pinch to pinch. So have a photo showing the wrong way of doing the exercise also" (**CP)***

Figure 8-5 shows snapshot of the recommendations made during the PPI discussion with the clinician partner.



Wrong exercise position　　Correct exercise position

Figure 8-5: Clinician PPI partner demonstrating correct and incorrect ways of performing Exercise 1 (making an O sign).

Image included with permission from PPI partner.

Regarding the anticipated problems with the performance of Rapid-force grip exercises (Exercises 5a and 5b), the views of expert partners were conflicting. Two partners thought it was important to have included high intensity exercises (i.e. rapid-force exercises), as it brings a new perspective to existing hand OA exercises. One commented:

> *"…clinicians think very differently from researchers, they think patients should not do high intensity exercises which in my view has not been proven, hence such exercises must be explored".* **(RP)**

Another researcher PPI partner expressed similar views:

> *"…I feel these patients are underestimated when it comes to exercise, what type and how they should be performed and purely based on my opinion, I think some of the poor results in hand OA research are due to low optimal level exercises available…"* **(C/RP1)**

Conversely, two clinicians raised concerns over the inclusion of high intensity exercise, due to the potential harm it may cause patients, based on available literature and from their personal clinical experience (CMC joint instability and subluxation, trigger finger and Carpal tunnel syndrome). For Exercise 5a (Handgrip rapid-force contractions) for instance, one partner commented:

> "…*we don't usually use our hands for rapid force productions, rather for high sensibility-controlled function. Rapid grip risks developing Carpal tunnel syndrome, trigger finger". **(C/RP2)**

For the Exercise 5b (pinch grip rapid-force contractions), two partners commentated,

> *"My potential concern with the OA thumb patients is that hyperextension of the MP joint will cause CMC instability and from a joint protection point of view, we advise patients to avoid the lateral pinch as this position translates forces into the base of thumb"* **(CP)**

> *"…the thumb pinch exercise illustrates forceful adduction, which is counterproductive for the CMC joint, often involved in hand OA. Contributes to subluxing forces and dominance of adductor pollicis which is often already overly active".* **(C/RP2)**

From the above comments, two recommendations were suggested: (1) Hand rapid-force exercise may be worth exploring, if care is taken to ensure the MP joints are protected and (2). exercises should be excluded from the programme based on the potential detrimental effects (e.g. trigger finger, CMC joint subluxation).

8.8.3 Theme-3: Co-designing next phase of the project

This section presents the results from co-production phase of the PPI discussion, where three aspects of the planned feasibility study to test the Rapid-HOE programme were explored. These were the proposed research method (i.e. mixed methods study), participant recruitment, and the interview guides designed for the qualitative aspect of the study. Table 8-8 shows key responses from all PPI partners on this discussion and with the research method. All partners thought the mixed methods research was the right approach to use. In addition, partners also suggested the inclusion of three key aspects: i) participant education on exercises; ii) clearly defined hand OA population; and iii) video illustrations of the exercises. These are discussed below (section 8.8.3.1 - 8.8.3.4).

Table 8-8: Key responses on the Aspects of Feasibility Study discussed

Aspects discussed	PPI Expert Responses	PPI Patient Responses
Research design (Mixed methods study)	1. Mixed methods is the right approach 2. Suggestions made a. Educate patients on the benefits of exercises (can use video or pre-study workshop) b. Encourage participants on exercising and its importance on improving symptoms c. Explore exercise confidence level in participants • use confidence questionnaire • include question in interview d. Clearly define hand OA population e. Explore online participant screening process and data collection (include hand photos in screening) f. Add videos for additional illustration	1.All thought it was a good idea and made sense 2.Suggested the need to a. Educate patients on the benefits of exercises as it works b. Encourage patients to exercise to a routine c. Advise participants to link exercises to something important in their life to enhance exercise performance
Participant Recruitment (during COVID-19 pandemic)	Partners suggested use of 1. Social media (i.e. Facebook, twitter, etc.) 2. first contact professionals e.g. GPs; PTs, etc. 3. Other researchers within the field to contact people from their pool of volunteers 4. Charities and organizations (e.g. Arthritis UK; University of the 3rd Age)	Partners suggested 1. Use the internet i.e. social media 2. Doctor's surgery 3. Speaking to friends of friends, gatekeepers of organizations 4. Organizations and charities (e.g. OA support groups, elderly homes, etc) 5. Two partners offered to help with recruitment
Interview guide	1. No input from one partner (lack of qualitative expertise) 2. Others thought questions were clear 3. Include question on exercise confidence level of patients	Thought the questions were clear and understandable

PPI: Patient Public Involvement; PP: patient partner; CP: clinician partner; RP: researcher partner; C/RP: Clinician and Researcher Partner; m: minutes; MS: Microsoft teams video conferencing tool

8.8.3.1 Participant education on exercise

Both partner groups highlighted the importance of educating and encouraging participants on the benefits of exercises, as part of the study as it ensures exercise participation and adherence. One patient partner, a farmer with 20 years history of hand OA commented:

> *"Exercise is not magical, people should be encouraged to perform them and although, it may be difficult, it works"* **(PP2**).

An expert partner (RP), a physiotherapist with 3 years history in hand OA research, also advised on the importance of having conversations with participants through pre-study workshops or PPI activities on exercises and its role in hand OA management. She suggested the inclusion of such an approach in the feasibility study, as this will help create positive mindset in participants, develop their trust in the exercises and be a source of motivation for them.

8.8.3.2 Targeted hand OA population

Having been informed of the targeted population to be studied in the feasibility study (i.e. hand OA in general), expert partners advised on the need to clearly define the target population. Reasons given were the challenges in studying such populations due to the differences in their aetiologies and the reported poor study outcomes in research that studied different hand OA phenotypes together. One expert partner, a physiotherapist with 20 years clinical experience in hand therapy, and 13 years in hand OA management, after acknowledging the challenges of researching hand OA due to the heterogeneity of the condition, also advised:

> "…*it is necessary to characterise the population of hand OA patients for any study which might help achieve better research outcomes than studying a population of different hand OA phenotypes together. I suggest you consider the use of an algorithm to tailor the exercise programme to different hand OA phenotypes (CMC or nodal) if you can..."* ***(*****C/RP2).**

8.8.3.3 Video illustrations of the exercises

Some PPI partners recommended the inclusion of exercise videos to complement the illustrations. One patient partner (PP3), remarked that videos will serve as a reference to practice the skills taught and help people not to forget their exercises. In addition, two expert partners (RP; C/RP1) commented that exercise videos will ensure the quality of exercise performance to achieve better outcomes.

Suggestions included creating videos using Microsoft Sway App or locked YouTube videos, which only the study participants can access to ensure data protection.

8.8.3.4 Participant recruitment and interview guide

Several recruitment strategies were suggested, but common amongst both PPI groups were the use of social media, and contacting charities and organizations, such as Versus Arthritis and University of the Third Age. In addition, two patient partners **(PP1 and PP2**) offered to help with participant recruitment.

Regarding interview guides, all patient partners, and expert partners (except one with limited qualitative study expertise) commented on the clarity of the interview questions.

8.9 Discussion and Conclusions

8.9.1 Discussions

A PPI project was conducted to consult with patients and experts with two broad aims: i) to seek their views on the developed Rapid-HOE programme, and ii) to discuss ideas to co-design a study to test the feasibility of this programme. Regarding the views of the PPI partners on the Rapid-HOE programme, many aspects were discussed (full details in Appendix E.9). Key points were:

- the limitations in the presentation of the exercise programme, and
- potential problems with the rapid-force exercise content.

For the exercise presentation, comments on the need for better clarity of presentation, and understanding of the exercise description, and illustrations were made. Suggestions to use non-medical terms, bigger pictures with less complicated illustrations and exercise descriptions that highlight the quality of exercise performance were considered and integrated into the Rapid-HOE programme.

Discussions on the rapid-force exercise content were centred around its potential harm and benefits, with opposing views between experts on its inclusion in the rapid-HOE programme. For the rapid handgrip exercises, whilst some clinical partners supported its inclusion, others advised against it largely, because the perception of the irrelevance of rapid-force use in the hands and the potential harm it may cause.

Whilst the PhD researcher agrees that the hands are usually used for controlled functions, she also recognizes the potential benefits in rapid-force productions in the hands such as those theorized by Schettino et al. (2014) (rapid-force production in the hand supports legs and trunks during falls by grabbing supports). Regarding the concerns raised, it is unclear the potential harm the rapid-hand grip exercises might cause in the hand of hand OA patients, but the PhD researcher author is confident in its non-harmful effect in the hands of healthy individuals based on the proof-of-concept study (Chapter 7). Although participants in that study commented on how difficult the performance of the rapid grip exercises were (especially, the rapid pinch exercises), no serious adverse effects in the hands were reported. Based on the research evidence and views of both patients and some expert partners, a decision to maintain the rapid handgrip exercises in the Rapid-HOE programme was made, since the concept was worth exploring.

For the rapid-pinch exercises, a strong argument against its inclusion in the Rapid-HOE programme was made. This was due to the potential harm to the CMC joint, and literature supporting these claims (Lockard, 2000; Neumann *et al.*, 2003). Researchers reported that exercises to improve pinch strength, as well as excessive movements to achieve full thumb opposition, or flexion, can cause increased subluxation, pain and functional limitations in unstable CMC joints (Lockard, 2000; Neumann *et al.*, 2003). The lateral pinch employed in the rapid-pinch exercise, has been reported to encourage thumb adduction, which may increase CMC instability risk (Lockard, 2000). Since the PhD researcher could not segregate patients with stable, or unstable CMC1 joint, and by extension those who may, or may not be as risk, the rapid-pinch exercises were excluded from the Rapid-HOE programme to avoid potential harm to participants with thumb OA patients.

Regarding the planned feasibility study, three key considerations submitted by most partners were: (1) the inclusion of participant education on exercises; (2) video illustrations of the exercises; and (3) clearly defined hand OA population. The PhD researcher acknowledged the importance of participant education and use of exercise videos and integrated them into the feasibility study. Participant education was integrated into the pre-training assessment session with a video session organized through Microsoft teams to teach the exercise programme. As previously indicated, expert PPI partners also strongly encouraged the need to clearly define the hand OA population to be studied in the feasibility study. According to experts, defining the patient specifications yields better research outcomes than studying different populations together with the foreknowledge of its potentially poor outcomes. These views reflect the findings of a Cochrane review on exercises in hand OA (Osteras *et al.*, 2017) which attributed the small reported exercise benefits to the possible heterogeneity of the hand OA population reviewed.

Whilst such suggestions are sound, the MRC guidance for developing complex interventions (Craig *et al.*, 2013) advise to allow some degree of adaptation in the intervention protocol development as ensuring strict standardization at this stage may be inappropriate. Based on this, a decision to maintain a less specific hand OA population for the feasibility study was made. The PhD researcher anticipates that this will help identify which hand OA phenotype may benefit from the Rapid-HOE programme. Also, based on the feasibility study findings, a more defined hand OA population will be considered in future studies to test the exercise effectiveness.

Lastly, many strategies were suggested for participant recruitment but common amongst both PPI groups was the use of social media, which was considered useful, especially during the COVID-19 pandemic. Noteworthy amongst the suggestions was the use of the patient partners themselves as recruiting agents, as two partners offered to help with recruitment by reaching out to family, and friends with hand OA within their circles. In addition to the planned recruitment strategies (emails, university patient pool and word of mouth), social media and the PPI recruiting agents were added to the feasibility study's participant recruitment strategy.

In summary, the relevant feedback and recommendations from the PPI discussions informed the revision of the earlier version of the Rapid-HOE programme (Table 8-1) to produce the final version below (Figure 8-6). This final version contains four exercises: (1). Making an "O" sign; (2). Rolling fingers into a fist; (3). Hand Grip contractions (static and rapid-force contractions) and (4). Straightening stretches (ironing out exercises).

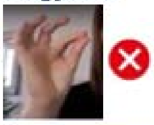
The Rapid-HOE programme

Exercise 1: Making an "O" sign

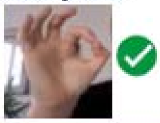
Bring the index fingertip to the thumb tip, keeping the finger joints bent. Hold for 5 seconds and then straighten the fingers. Repeat with other the fingers *[repeat 6 times]*

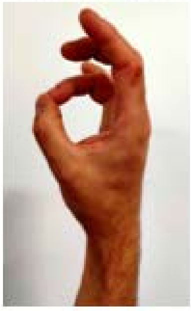
Please see the wrong & correct way of making an "O" sign

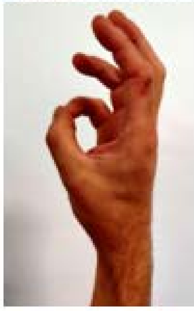
Wrong position



Correct position







See here, a link to the video showing the exercise performance: *(yet to be included)*

Exercise 2: Roll into a fist

Start exercise with your fingers straight (1); bend the top two finger joints only into a hook position (2); bend the knuckles into a full fist (3); hold for 5 seconds; straighten the knuckles first (2) before straightening the top two finger joints (i.e. hook fist) back to the start position (1). *[Repeat 6times]*

(1)

(2)

(3)

See here, a link to the video showing the exercise performance: *(yet to be included)*

Exercise 3: Hand Grip contractions (3a & 3b)

3a. Static handgrip contractions

Squeeze as hard as you can and hold 10 seconds, followed by 5 seconds rest
[Repeat 6times]

See here, a link to the video showing the exercise performance: *(yet to be included)*

3b. Hand grip Rapid-Force contractions

Grip ball with hand as fast and hard as possible for one seconds, followed by 5 seconds rest. Please *repeat 6times.*

Perform 3 sets of each 6 grip contractions for the first two weeks. Progress to 6 sets in week 3 to 6 if you can.

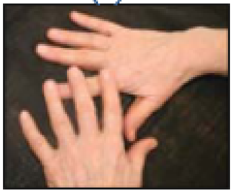
See here, a link to the video showing the exercise performance: *(yet to be included)*

Exercise 4: Straightening stretches (ironing out exercises)

Place OA hand on a flat surface, use other hand to apply firm pressure to stretch the top two finger joints and knuckles at the same time (1)

[Press and hold for 30 seconds; repeat two times]
You can either do this for the individual fingers (1) or all fingers together in a group (2).

(1)



(2)

See here, a link to the video showing the exercise performance: *(yet to be included)*

Attached to this exercise booklet is a hand Osteoarthritis leaflet; a written information for people with hand Osteoarthritis for your information (An online version can be found here: (https://jigsaw-e.com/wp-content/uploads/2019/10/OA-Hand-Leaflet-v.0.10-02.02.18-LC-FINAL.pdf)

Figure 8-6: The Rapid-HOE programme (Final Version following PPI project discussion)

8.9.2 Conclusions

This PPI project was successful and achieved the purpose for which it was designed, which was to seek hand OA patients' and experts' (clinicians and clinically-active researchers) views on the Rapid-HOE programme. The PPI partners consulted brought a wealth of knowledge to improve the content, presentation, and description of the Rapid-HOE programme and the planned feasibility study. Based on relevant recommendations from the discussions, as well as evidence from a brief literature review on some concerns raised, the Rapid-HOE programme was revised. Additionally, suggestions to improve the feasibility study were embedded into the design and conduct of the as far as possible.

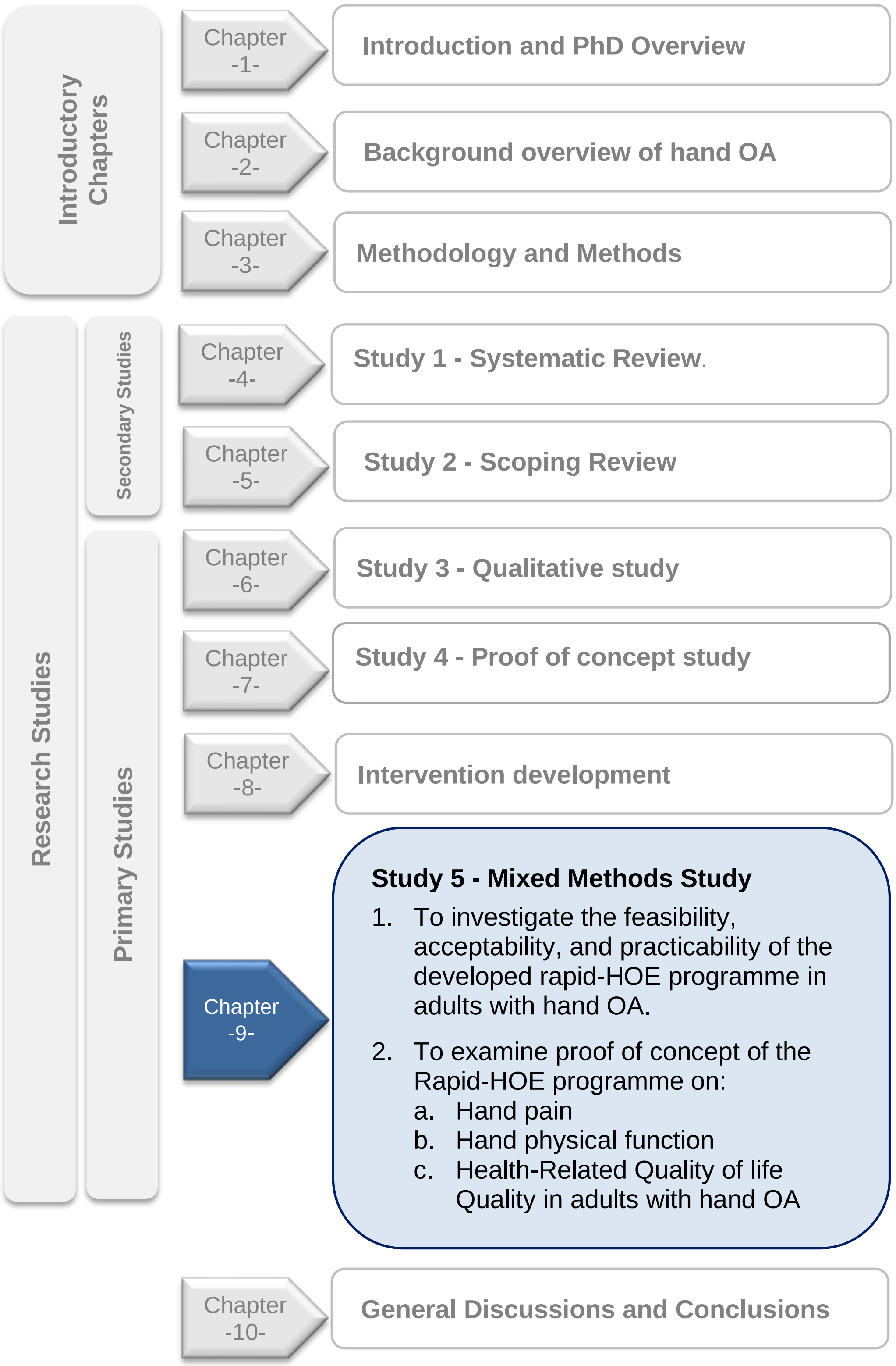
8.10 Reflections and critical perspectives

This PPI project was initially meant to be a face-to-face interaction with identified partners, but plans changed abruptly due to the COVID-19 pandemic in March 2020. Due to lockdown restrictions, the PPI project was delayed for three months (March – June 2020), as the potential patient partners were older adults (above 50 years) of whom the majority were within the high-risk population for COVID-19. During this period, contingency measures of reaching and engaging potential partners using existing university staff networks were employed successfully, that enabled virtual interaction with PPI partners in July (6-27th) 2020. Whilst a few technical challenges were encountered during the virtual discussions, all sessions were successfully conducted with minimal impact on the information discussed and gathered.

8.11 Chapter summary

The Rapid-HOE programme was developed systematically following the best practice approach to exercise development and PPI stakeholder involvement. This exercise programme includes exercises to both increase and maintain ROM, and to increase strength and endurance. The next chapter introduces the final study within this PhD, to test the proof of concept and the feasibility of the Rapid-HOE programme.

Location in thesis



Chapter 9 Study 5 - Feasibility of the Rapid-Hand Osteoarthritis Exercise programme in People with Hand OA: A Mixed Methods Study

9.1 Introduction

Following the development of the Rapid-HOE programme, based on evidence provided from Chapters 4, 5, 6 and 7, the proof of concept and feasibility of the programme in people living with hand OA required investigation. This chapter therefore describes the final study within the PhD (Figure 9-1), An mixed methods study with the aim to explore the feasibility and proof of concept of the Rapid-HOE programme in people living with hand OA.

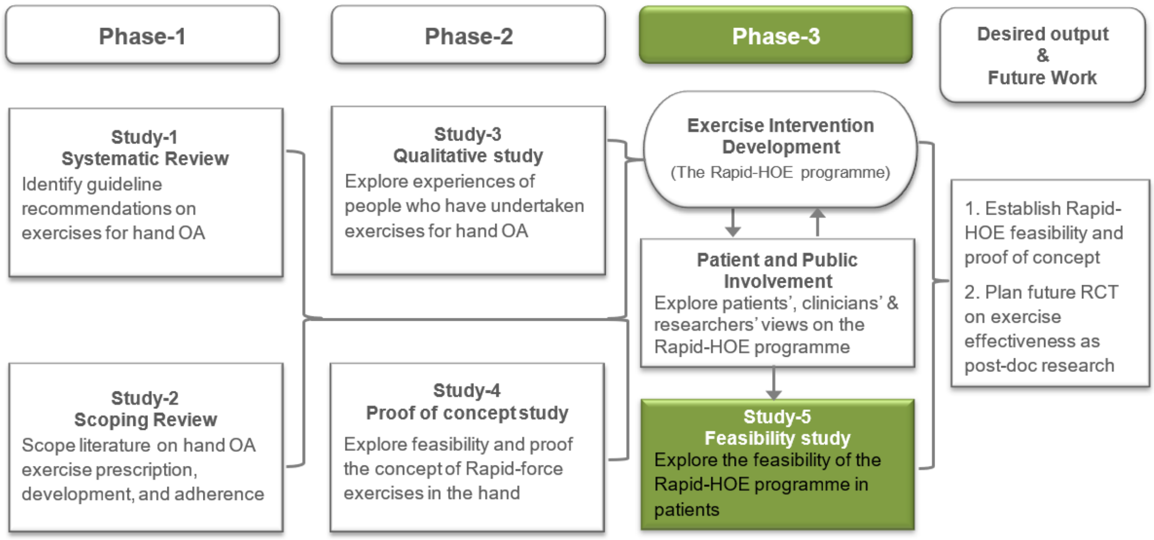


Figure 9-1: Mixed methods study location within the overall PhD research

9.2 Background

The aim of this PhD is to develop an exercise programme to improve pain, hand function and QoL in people with hand OA. Having established the concept and feasibility of the hand rapid-force exercises (Chapter 7), recommendations for its potential use in hand OA strength training programmes was made (Katz *et al.*, 2001) based on the benefits for dynamic strength exercises in people with OA. Another recommendation from Chapter 7 was the need to establish the feasibility and potential effectiveness of such an exercise programme within this population.

Hence, following the development of the Rapid-HOE exercise programme (Chapter 8), the next phase was to test its feasibility in the patient population. To achieve this, a feasibility study approach was deemed necessary. Feasibility studies are described as pieces of research conducted before a main study in order to answer the question; "Can this study be done?" (Arain *et al.*, 2010). Such research designs are reported to provide findings that help ascertain whether an intervention is worth recommending for efficacy testing (Bowen *et al.*, 2009). To propose the Rapid-HOE programme for the management of hand OA, it was necessary to test and establish its feasibility, safety, and tolerability in the people with hand OA, using the feasibility research design, as well as explore their exercise experiences. The overall aim was to establish the feasibility and prove the concept of this exercise programme in people living with hand OA, and to form preliminary data for a future RCT aimed at establishing its effectiveness.

9.3 Objectives and hypothesis

9.3.1 Primary objective

To investigate the feasibility, acceptability, and practicability of the Rapid-HOE programme in people living with hand OA.

9.3.2 Secondary objectives

To examine proof of concept of the Rapid-HOE programme on:

1. Hand pain in adults with hand OA
2. Hand physical function in adults with hand OA
3. Health-Related Quality of life Quality (HRQOL) in adults with hand OA

9.3.3 Research hypotheses

1. Six weeks Rapid-HOE programme is feasible and acceptable in adults with hand OA.
2. Six weeks Rapid-HOE programme would reduce hand pain in adults with hand OA.
3. Six weeks Rapid-HOE programme would improve hand physical function in adults with hand OA.
4. Six weeks Rapid-HOE programme would improve HRQOL in adults with hand OA.

9.4 Methods

This study was conducted during the COVID-19 pandemic (December 2020 to March 2021). Whilst this allowed recruitment of study participants across the UK and facilitated the recruitment process, it also limited the measurements of physical measures such as hand grip strength due to restrictions on person-to-person contact.

9.4.1 Study design

A feasibility study design was used to assess participant recruitment, acceptability and adherence (Arain et al., 2010). The feasibility study employed the explanatory sequential mixed methods research design approach: a two-phase mixed methods design in which a quantitative phase is conducted, followed by a qualitative phase, to help further explain the quantitative results in more depth (Doyle *et al.*, 2016).

9.4.2 Study setting

The study took place in participants' homes, connecting virtually with the PhD researcher. Recruitment was intended to be in the Southampton area, but the virtual study enabled participants from other regions to take part (Hampshire, Sussex, Chichester, greater London, midlands, and Ayrshire).

9.4.3 Sample size

Formal sample size calculations are not always appropriate for feasibility studies. The studies should be large enough to provide details about the aspects assessed for feasibility (Thabane et al., 2010). An audit of sample sizes for ongoing feasibility and pilot trials conducted in the United Kingdom (UK) revealed that feasibility studies had sample sizes ranging from 10 to 300 participants per arm (Billingham *et al.*, 2013). Other guidance recommends that a minimum sample size of 12 participants per group is appropriate for feasibility studies based on three rationales (i.e. feasibility; precision about the mean and variance; and the regulatory considerations) (Julious, 2005). In our previous proof of concept study (Chapter 7), a sample size of eight showed positive findings (some significance results) despite being a small number. This number is similar to physiological studies in the literature, which typically range from 6-12 participants. Therefore, based on the previous proof of concept study's sample size (n=8) and the present study's rationale for feasibility (i.e. testing feasibility of Rapid-HOE programme and the study design processes), a sample size of 20 participants was deemed appropriate for the present study.

9.4.4 Participants

9.4.4.1 Participant characteristics and recruitment

Study participants were community dwelling older adults living with hand OA. A purposive sample of 20 participants were recruited from the general population using:

1. Study poster (Appendix F.1).
2. Social media advertisement on the researcher's personal twitter and Facebook pages (Appendix F.2).
3. Patient partners from the virtual PPI activity who offered to help with participant recruitment (see Chapter 8, section 8.8.3.4)
4. Word of mouth through recruited participants who mentioned the study to other friends and family (i.e. snowball effect).
5. Osteoarthritis charities and groups.

All potential participants were invited to participate in the study via email and interested individuals were invited to contact the researcher via email or telephone (invitation letter - Appendix F.3). The recruitment process is described as follows. At least one week before data collection, interested volunteers were sent the Participant Information Sheet (Appendix F.4) via email to afford them sufficient time to consider taking part in the study (minimum of about 24 hours to decide). Those who agreed to take part were screened against the inclusion and exclusion criteria (see Table 9-1) on the telephone (or Microsoft Teams) to ensure eligibility. Eligible volunteers were provided with a 5-10-minute telephone briefing on the study description and possible adverse events associated with data collection. Finally, arrangements were made with volunteers who agreed to proceed with their participation to collect their baseline assessment via Microsoft Teams to start of their exercise training.

9.4.4.2 Eligibility criteria

Participants were recruited according to their eligibility in meeting the selection criteria stated in Table 9-1.

Table 9-1: Details of the eligibility criteria

Inclusion criteria	Exclusion criteria
Male and female community dwelling older adults (≥ 50 years) with 1. Pain, aching or stiffness in the hand (in addition to three of the ACR[1] criteria) 2. Either doctor diagnosed or self-reported or researcher identified hand OA 3. Self-reported hand pain with osteoarthritic changes (i.e. aches or stiffness) in any hand joint 4. Clinical presentation of tenderness, soft tissue swelling, joint deformity and finger nodes (Heberden's & Bouchard's nodes) in two or more hand joints	Hand OA volunteers (≤ 50 years) with: 1. Upper limb injuries within six months prior to the study 2. Recent trauma (previous 2 months), painful sequelae from a fracture or upper limb surgery 3. Hand impairments that will prevent them from performing hand assessments and the exercise programme (i.e. orthopaedic; neurological disorders, etc). 4. Inflammatory arthritis (e.g. psoriatic, rheumatoid arthritis, scleroderma, etc) 5. Volunteers who perform athletic sports or active exercise with their hands (to avoid bias due to differences in physical activity levels).

9.4.5 Investigated intervention: The Rapid-HOE programme

The Rapid-HOE programme developed in Chapter 8 was used (see Figure 8-6). The ROM exercise components were progressed every two weeks by increasing the number of repetitions (Garber *et al.*, 2011). The level of resistance at baseline, and person-specific exercise progression for the muscle strengthening component of the exercise programme, were determined as previously discussed using the Borg scale and different resistance exercise balls (Figure 9-2). These balls were also used for performing the grip exercise components of the Rapid-HOE programme.

[1] American College of Rheumatology criteria for hand OA (Hard tissue enlargement involving at least 2 of 10 selected joints; Hard tissue enlargement of at least two DIP joints; Less than 3 swollen MCP joints and Deformity of at least 1 of the 10 selected joints)

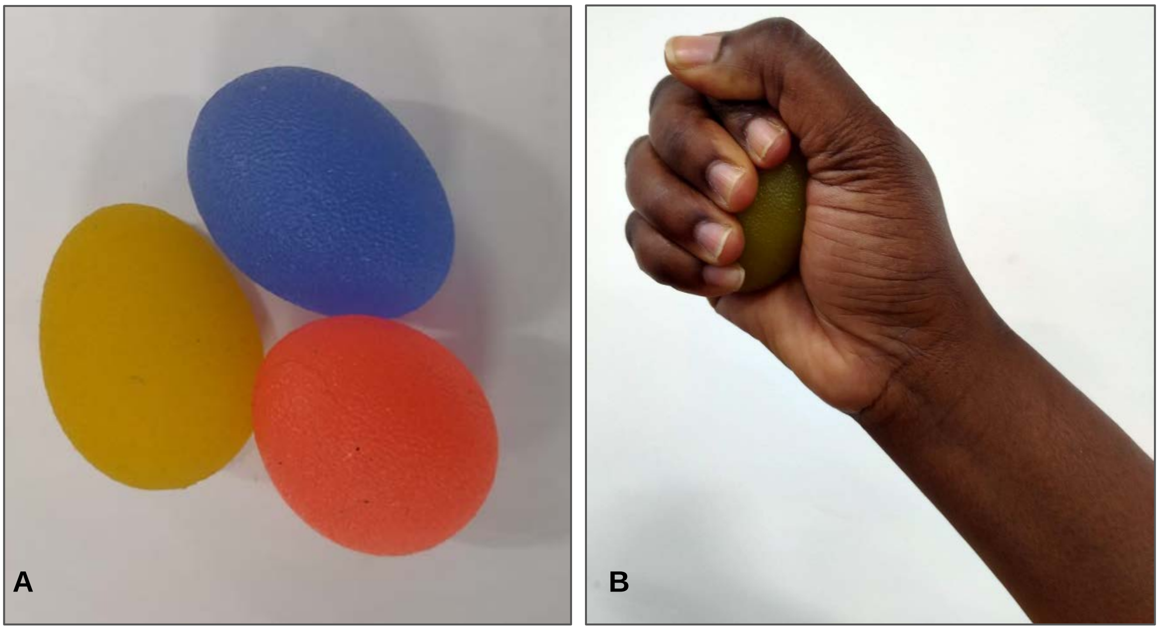


Figure 9-2: Resistance balls for hand grip exercises and setting the load for Rapid-HOE exercise performance.

[Image A: showing the colour coded Nuosen gel hand balls with three levels of resistance: yellow- (easy; 15kg); Orange= (medium; 25kg) and blue = Heavy; 30kg); Image B: Showing hand grip activity using the exercise ball]

9.4.6 Outcomes and outcomes measures

9.4.6.1 Primary outcomes

9.4.6.1.1 Acceptability

Acceptability is the extent to which a new idea, programme or measure can be judged as suitable or attractive to intended users and involves satisfaction, perceived appropriateness and intent to continue use (Bowen *et al.*, 2009). In the present study, acceptability was assessed with semi-structured interviews (Appendix F.2) after the exercise training programme and adverse events reporting were documented with adverse event form (Appendix F.6).

9.4.6.1.2 Practicability

Practicability is the extent to which an intervention can be delivered when resources, time, commitment, or some combination thereof are constrained in some way. It involves the evaluation of the positive or negative effects on target participants, the ability of participants to carry out intervention activities and sometimes cost analysis.

The first two components were assessed in the present study using exercise diaries and semi-structured interviews.

9.4.6.1.3 Recruitment and retention

Recruitment is defined as the ratio of invited people with hand osteoarthritis who agree to participate in the study to those who do not. Retention was determined by the proportion of patients who completed the intervention programme (Bower et al. 2014).

9.4.6.1.4 Adherence

Study participants was contacted once a week by the researcher via telephone or email to remind them to perform their exercises. The Exercise Adherence Rating Scale (EARS) was used to evaluate the adherence to the Rapid-HOE programme after the six weeks training (see section 9.4.6.2.6; Appendix F.8). Additionally, participants were given exercise diaries to document times they performed their exercises (Appendix F.7).

9.4.6.1.5 Limited-efficacy

This concept measures how an intervention shows promise of being successful with the intended population, and usually explores intermediate, rather than final outcomes with shorter follow-up periods (Bowen *et al.*, 2009). In the present study, the limited-efficacy (i.e. intended effects of the Rapid-HOE programme) will be evaluated using the secondary outcome measures discussed below.

9.4.6.2 Secondary outcomes and Outcome measures

The Outcome Measures in Rheumatology (OMERACT) Hand OA working group aimed to define a set of core domains for hand OA assessments and recommended pain, physical function, HRQOL, hand strength, joint activity, and patient global assessment as a core set of preliminary domains for hand osteoarthritis studies (Kloppenburg *et al.*, 2015). In the present study, the first three domains were assessed. Hand grip strength could not be measured due to the COVID-19 restrictions on person to person contacts.

9.4.6.2.1 Hand pain

The OMERACT Hand OA working group strongly supported (88% agreement) the use of the VAS or NPRS as preliminary self-reported pain outcome measures for hand OA (Kloppenburg *et al.*, 2015). The choice to use the NPRS for pain evaluation in the present study was made due to its comparatively stronger psychometric properties, simplicity of use and better research usability (Appendix F.9).

9.4.6.2.2 Physical function (patient/self-reported functional measures)

Functioning represents the positive interaction between an individual (with a health condition) and that individual's contextual factors (environmental and personal factors) (World Health Organization, 2013). In the present study, the physical function of patient volunteers was assessed with the Functional Index for Hand Osteoarthritis (FIHOA) and the Patient Specific Functional Scale (PSFS) based on expert recommendations.

9.4.6.2.3 Functional Index for Hand Osteoarthritis (FIHOA)

The FIHOA is a valid and reliable 10-item instrument self-reported scale to measure physical hand function in people with hand OA (Dreiser *et al.*, 2000; Moe *et al.*, 2010). The OMERACT therefore supports the use of the FIHOA as a good feasible physical function outcome measure for hand OA (Kloppenburg *et al.*, 2015). The FIHOA (Appendix F.10) was used in measuring physical function in the present study, as employed in other hand OA studies (Østerås *et al.*, 2014a; Hennig *et al.*, 2015).

9.4.6.2.4 The Patient Specific Functional Scale (PSFS)

The PSFS is a valid, reliable, and responsive outcome measure to measure patient activity limitations and changes in activity over time (Stratford *et al.*, 1995) (Appendix F.11). In its use, patients identify up to five activities that they have difficulties performing as a result of their current physical condition and rate their perceived activity limitation using an 11-point numerical scale (0 to 10; 0 = impossible, 10 = unhindered performance) (Stratford *et al.*, 1995). Contrary to above, patient volunteers in the present study were asked to state only three activities of importance to them for the purposes of brevity as reported in a previous study of hand OA patients (CMC OA) (Rosengren *et al.*, 2013).

9.4.6.2.5 Quality of Life measures

The Arthritis Impact Measurement Scales (version 2) (AIMS2) is an arthritis-specific health status measure that assesses physical functioning, pain, psychological status, social interactions and support (Meenan *et al.*, 1992; Guillemin *et al.*, 1997). The shortened version of the AIMS2 questionnaire; the AIMS2-SF was used within the present study (Appendix F.12).

It is a valid and reliable 26 item questionnaire with five scales: (1) physical function, (3) symptoms (pain), (3) affect (tension, mood, psychological status), (4) social interaction (social activity, family support) and (5) role (work) (Guillemin *et al.*, 1997; Gignac *et al.*, 2011). Within the present study, only the first four scales were assessed, the fifth AIMS2-SF scale (Role) was not assessed since majority of the study participants were older adults and retirees.

9.4.6.2.6 Exercise Adherence Rating Scale (EARS)

The Exercise Adherence Rating Scale (EARS) is a validated six-item unidimensional scale that was developed to measure adherence to prescribed home exercises (Newman-Beinart *et al.*, 2017). The EARS is a validated scale with a high test retest reliability (ICC = 0.97; 0.94 to 0.98) and would be used to evaluate the study participants' adherence to the Rapid-HOE exercise programme (Appendix F.8).

9.4.7 Data collection procedure

Following the study recruitment and screening process described, all study materials were provided in the participant study pack and posted to each of them at home. Included in the study pack were the exercise balls (Figure 9-2) and printed copies of the following:

1. Study questionnaires (Appendices F.8 - F.12)
2. Consent form (Appendix F.14)
3. Exercise diaries (Appendix F.7)
4. Adverse event form (Appendix F.6)
5. Information and exercise booklets (Figure 9-3)
6. Hand OA information leaflet

   Leaflet source: (https://jigsaw-e.com/delivery-toolkit/hand-osteoarthritis-education/). Reproduced with permission from Primary Care Centre Versus Arthritis, February 2021.
7. Pre-stamped envelopes (to return the consent forms and completed outcome measures to the researcher)

The study involved 18 exercise training sessions of the Rapid-HOE programme to be performed 3 times weekly for 6 weeks in the comfort of the participants' home. One assessment was performed at baseline and the other at the end of the six weeks exercise training period via Microsoft Teams App.

On average, pre-baseline and baseline data collection activities lasted about 30 minutes, the exercise training lasted between 15 and 20 minutes, and the post-training assessment lasted about 50 minutes (Appendix F.13).

As a reminder, the data collection procedure was guided by the data collection checklist to limit the errors of missing any assessments (Appendix F.15). Since the exercises were performed at home, periodic follow ups by the researcher were conducted (via telephone or Microsoft Teams) to check accuracy of exercise performance and exercise adherence.

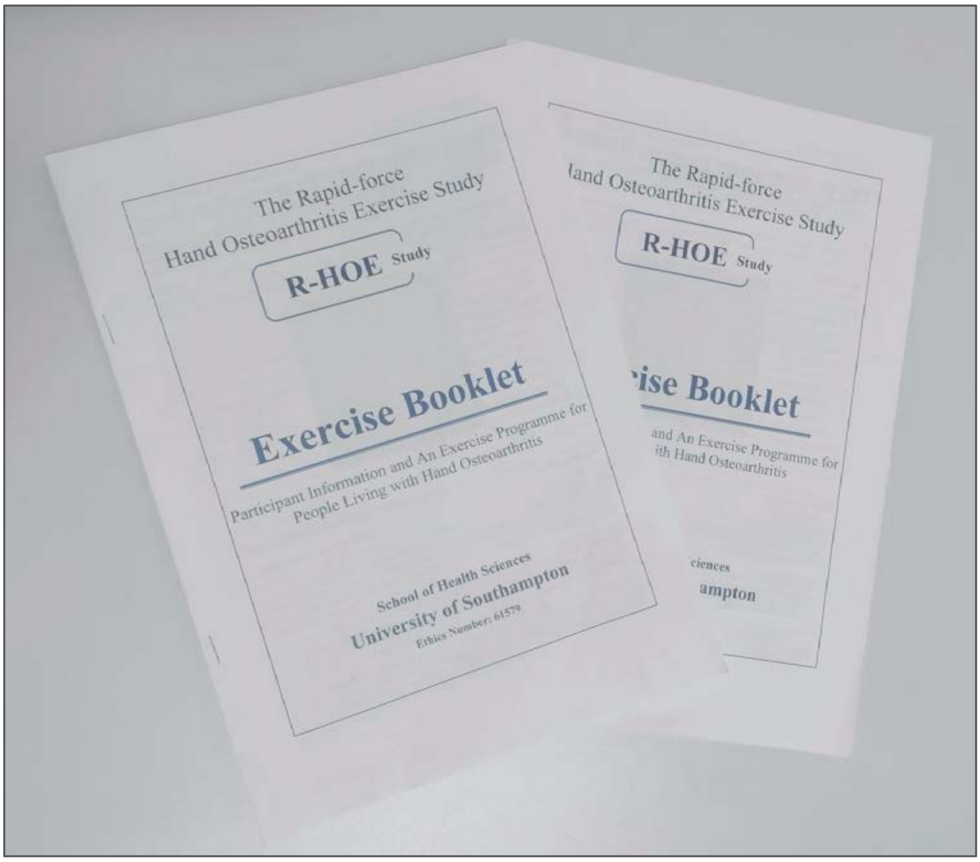


Figure 9-3: Study participant information and exercise booklet.

This booklet contains information on i) hand OA, ii) benefits of exercise on hand OA iii) pain and mild discomfort associated with exercising, iv) the Rapid-HOE programme and instructions on exercise performance, v) additional hand OA information from Primary Care Centre Versus Arthritis.

9.4.8 Assessment procedure

9.4.8.1 Pre-baseline assessment activities

Data collection was conducted remotely via Microsoft teams. On the first day, participants were guided to sign the consent form (Appendix F.14) previously sent to them (via SafeSend, Email or Post). Consenting was video recorded and stored separately from other research data, whilst the PhD researcher awaited the arrival of participants' signed paper copies (after which video consents were destroyed).

Participants were also guided to select the load (i.e. resistance) of the exercise balls to start the exercise training for the first two weeks using the Borg scale (Appendix D.3). Following the above pre-baseline assessment activities, the main baseline assessment was measured.

9.4.8.2 Baseline assessment

An initial physical testing of hand and pinch grip strengths were planned but these objective measurements were taken out of the earlier versions of the protocol due to: (1) Government COVID-19 rules and restrictions, (2) the university enforced restrictions on all face-to-face human study interactions across the university, and (3) the safety of both the researcher, and the participants, as the potential participants were older adults (above 50 years), of whom the majority are within the high risk population for COVID-19. Hence, only patient-reported measures were assessed. These assessments were conducted in three steps and performed in the same order each time.

First, the participants' self-perceived hand pain was assessed using the NPRS as previously described (see section 9.4.6.2.1). Secondly, the two functional measures; the PSFS and FIHOA questionnaires were completed (PSFS first before FIHOA). This was done so that participants' activity choices for completing PSFS will not be influenced by the documented activities in the FIHOA questionnaire if the FIHOA was completed first (Rosengren *et al.*, 2013). Thirdly, the AIMS2-SF questionnaire was completed (instructions for data collection in Appendix F.16).

9.4.8.2.1 Post-training assessment

Following the six weeks exercise training, all outcomes assessed during the baseline assessment were reassessed. The EARS questionnaire was also completed to evaluate adherence to the exercise programme. A virtual interview lasting about 30 minutes was conducted with all study participants using Microsoft Teams. Interview sessions were guided by an interview topic guide (Appendix F.5) to explore their experience, adherence, acceptability and practicability of the Rapid-HOE programme.

Study participants were invited to the online meetings by their personal email address, with the researcher sending from their university email address. They received a copy of the joining URL with which they joined the meeting using any web browser. All interviews were audio and video recorded (using the "Start Recording" meeting controls' function on Microsoft Teams App) and stored in a password protected device. All recordings were transcribed within one week of data collection and then destroyed after the completion of study's data collection (31/03/2021). This was done by deleting all recordings on University of Southampton's OneDrive and SharePoint where recordings are automatically saved by the Microsoft Teams App.

9.4.8.2.2 Exercise training procedure

Exercise training sessions according to experts should have three phases; i) warm up, ii) the main exercise training, and iii) a cool down phase (Katz *et al.*, 2001). Figure 9-4 shows the three phases to be followed for the Rapid-HOE programme in the present study. Exercises were performed with the hand affected by hand OA. Where participants had OA in both hands, they were advised to carry out the exercises with both hands.

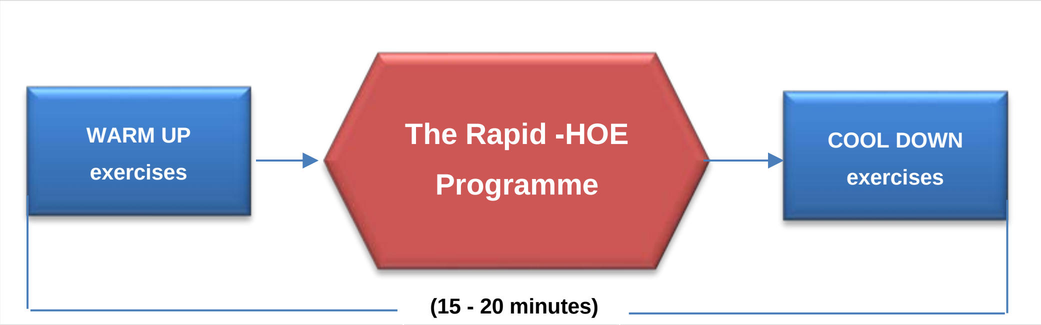


Figure 9-4: Exercise training procedure for the Rapid-HOE programme for people with hand osteoarthritis.

9.4.9 Risk assessment

The assessment for this study involves the standard operating procedures routinely undertaken by staff of the University which have been subject to the University's internal risk assessment procedures. The exercise programme was carefully and systematically developed. However, in the unlikely event of any serious adverse reaction; participants were advised to stop the exercise training and to see their general practitioner. As accurate and timely reporting of adverse events is a requirement of Good Clinical Practice, researchers would additionally document the adverse event using the adverse events form (Appendix F.6), and report any serious adverse events to the ethics committee.

9.5 Data analysis

All quantitative data were managed and analysed as previously described (see Chapter 7, Section 7.3.9). Based on a largely normally distributed data from the Shapiro-Wilk test, pre and post training data for all clinical outcome measures were analysed using the paired t-test. The research hypotheses were accepted if an alpha value of less than 0.05 was achieved.

The effect sizes were estimated to determine the magnitude of the experimental effect using Cohens d (d = 0.2 represents 'small' effect size, 0.5 is 'medium' effect size and 0.8, 'large' effect size) (Kazis *et al.*, 1989). All qualitative data from the interviews, exercise diaries and adverse events forms on acceptability, practicability and adherence were analysed using the thematic analysis approach previous discussed (Chapter 6; section 6.3.7.1). Details of the NVivo analysis is provided in Appendix F.18.

9.6 Integration of Quantitative and Qualitative data

The “mixing” of quantitative and qualitative data is a critical component of mixed methods research and from the literature (Zhang *et al.*, 2013), the three approaches used are the integration, connection or embedding techniques. Within the present mixed methods study, the integration approach (also referred as “merging”) was employed as recommended by Creswell *et al.* (2011). With this approach, the results of the quantitative and qualitative analysis were conducted and reported separately in the results section (sections 9.10 and 9.11). The mixed methods merging analysis occurred in the interpretation phase of the study (discussion section) where a side by side comparison of both relevant quantitative and qualitative analysis results was done.

9.7 Ethical issues, data protection and anonymity

All ethical considerations and data protection approach previously discussed (Chapter 7; section 7.3.10) were adhered to. Due to the virtual nature of this study, briefing and consenting were conducted virtually, and were confirmed with signed paper or electronic versions at later dates. Additionally, all participants’ personal information collected during the interview sessions were pseudonymised as soon as practicable for electronic storage.

9.8 Data management plan

The data management plan previously discussed were followed for this study (see 7.3.10). In addition, all transcribed interview data, videos, and audio files were managed with the NVIVO software package (Silver *et al.*, 2014).

9.9 Results

9.10 Quantitative Results

9.10.1 Participant characteristics

Twenty community dwelling individuals living with hand OA were recruited for this study, however eighteen participants (females=15) completed the study as there were two dropouts (i.e. one gave no reason for stopping the rapid-HOE programme, another had a fall unrelated to the Rapid-HOE exercise performance). Participants were largely right-handed (n=17) between the ages of 59 to 85 years (70.33±7.42 years) (Table 9-2). The number of years participants lived with their hand OA since diagnosis varied widely between 1 and 50 years (13.00±12.28 years). The number of painful hand joints also varied widely between both hands, this ranged between no joints to nine joints (4±2.81) in the right hand, and between one to 10 joints (4±3.19) in the left.

Table 9-2: Baseline characteristics of the study participants

Participants	Age (yrs) Mean ± SD	Disease Duration (yrs) Mean ± SD	Symptom Duration (yrs) Mean ± SD	No of Painful Joints (0-15)	
				Right hand	Left hand
Female (n=15)	70.53±7.65	13.87±13.26	9.73±8.56	4±2.98	4± 3.40
Male (n=3)	66.44±18.62	11.01±12.26	8.16±5.59	4± 2.83	4 ±2.86
Total (n=18)	70.33±7.42	13.00±12.28	9.61±7.93	4±2.81	4 ± 3.19

NB: N-number of participants; SD-Standard deviation; kg –kilogrammes; m – meters; Handedness (17-right handed); yrs- years

9.10.2 Feasibility of Rapid-HOE programme and outcome measures

9.10.2.1 Effect of Rapid-HOE programme on hand pain (NPRS)

A reduction in hand pain was observed in participants after the six weeks Rapid-HOE training (Table 9-3; Figure 9-5). This change was not statistically significant (p=0.06), thus rejecting the research hypothesis. However, the change was close to significant (p=0.06) with a medium estimated effect size (Cohen's *d*=0.5).

Table 9-3: Hand pain before and after 6-weeks of Rapid-HOE programme training.

Assessments	NPRS scores (mean± SD)	Mean difference (CI)	P-value	Effect size (*d*)
Pre-training (week- 1)	4.28 ± 1.96	1.00 (-0.07 - 2.07)	0.06	0.5
Post-training (week- 6)	3.28±2.24			

NB: SD-Standard. Deviation; N – Newtons; CI - Confidence Interval; Statistical test - paired t test (2-tailed); P – probability; * - significance; NPR Scale (0 to 10; 0=no pain)

Cohen's d - (0.2: small effect size; 0.5: medium effect; 0.8: large effect)

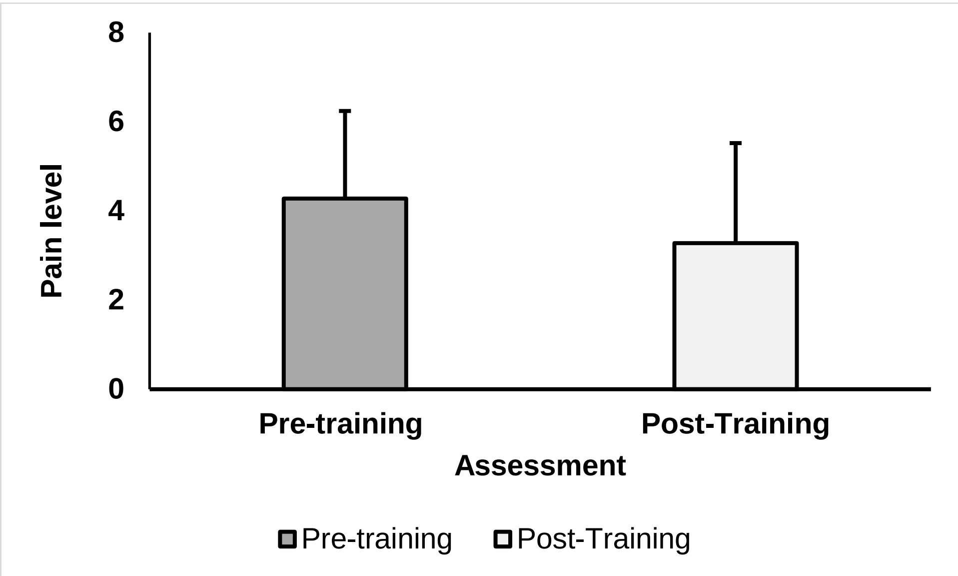


Figure 9-5: Hand pain assessment before and after 6-weeks of Rapid-HOE programme training for people with hand OA

Hand function measured on a scale of 0 to 10 (0=no pain; presented as SD bars with mean values).

9.10.2.2 Effect of Rapid-HOE programme on hand function

9.10.2.2.1 Functional Index for Hand Osteoarthritis (FIHOA)

There was significant reduction in FIHOA scores (p=0.003) after six-weeks of Rapid-HOE training (Table 9-4; Figure 9-6), thus supporting the research hypothesis that six weeks Rapid-HOE programme would improve hand physical function in adults with hand OA. The estimated effect size was large (Cohen's *d*=0.8), suggesting a clinically important effect of the Rapid-HOE programme.

Table 9-4: Hand function (FIHOA) before and after 6-weeks of Rapid-HOE programme training

Assessments	FIHOA scores (mean± SD)	Mean difference (95%CI)	P-value	Effect size (*d*)
Pre-training (week- 1)	10.78 ± 5.17	2.89 (1.09 - 4.69)	0.003*	0.8
Post-training (week- 2)	7.89 ± 7.00			

NB: SD-Standard. Deviation; CI - Confidence Interval; Statistical test -paired t test statistic; P – probability; * - significance; FIHOA scores – scale of 0 to 30; lower scores represents better function). Cohen's d - (0.2: small effect size; 0.5: medium effect; 0.8: large effect)

Figure 9-6: Hand function (FIHOA) assessment before and after 6-weeks of Rapid-HOE programme training for people with hand OA.

Hand function measured on a scale of 0 to 30 (lower scores=better function); presented as means and standard deviations; * indicates significance between pre-post training (p<0.05).

9.10.2.2.2 Patient Specific Functional Scale (PSFS)

There was a statistically significant increase in PSFS scores (p=0.00) after the six weeks of Rapid-HOE training (Table 9-5; Figure 9-7), thus supporting the research hypothesis. The estimated effect size was large (Cohen's *d* = -1.0), suggesting a clinically important effect of the Rapid-HOE programme. A six weeks Rapid-HOE programme therefore improved activity performance in study participants.

Table 9-5: Hand function (PSFS) before and after 6-weeks of Rapid-HOE programme training

Assessments	PSFS scores (mean± SD)	Mean difference (95%CI)	P-value	Effect sizes (*d*)
Pre-training (week- 1)	3.28± 1.24	-1.78 (-2.63 - -0.92)	0.00*	-1.0
Post-training (week- 1)	5.06±1.96			

NB: SD - Standard deviation; CI - Confidence interval; Statistical test - paired t test statistic; P – probability; * - significance.
Cohen's *d* - (0.2: small effect size; 0.5: medium effect; 0.8: large effect size).
PSFS scores = (Scale of 0 to 10; higher scores = better activity performance)

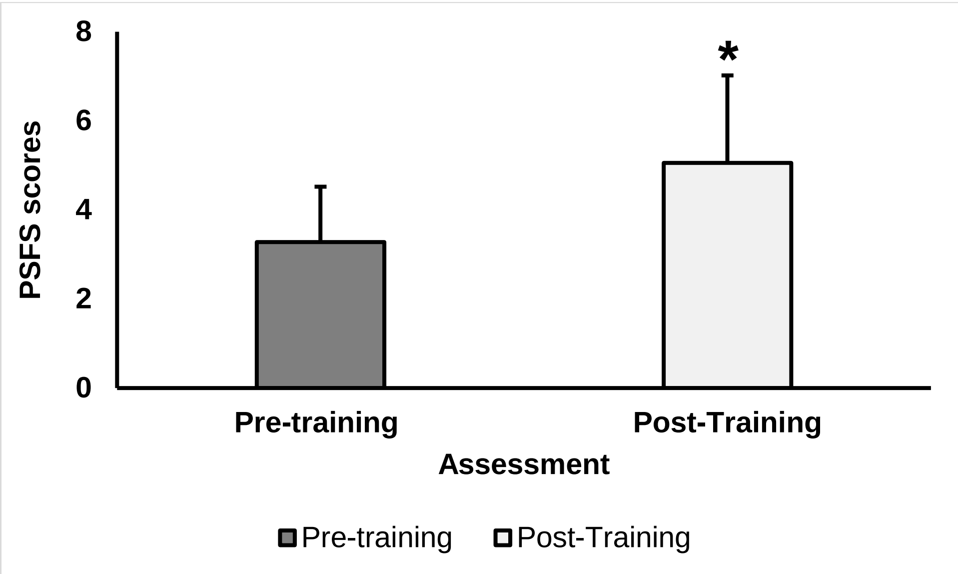


Figure 9-7: Activity limitations (PSFS) assessment before and after 6-weeks of Rapid-HOE programme training for people with hand OA.

Activity limitations measured with PSFS (scale of 0 to 10; higher scores = better activity performance]; presented as means and standard deviations; * indicates significance between pre-post (p<0.05).

9.10.2.3 Effect of Rapid-HOE programme on HRQOL (AIMS2-SF questionnaire)

The results of the four AIMS2-SF scales are presented below (physical functioning; OA symptoms (pain); psychological status and social interaction).

Physical scale: A significant reduction in the AIMS physical scale was shown after training (p=0.01), thus supporting the research hypothesis that a six weeks of Rapid-HOE programme improves physical functioning of the HRQOL in adults with hand OA (see Table 9-6). There was a moderate positive effect (Cohen's *d* = 0.67) of the Rapid-HOE programme in reducing the difficulty in performing upper limb activities.

Symptom scale: There was no significant change in the AIMS symptom scale. The research hypothesis that a six-week training of Rapid-HOE programme would improve hand OA symptoms in adults with hand OA was rejected.

Affect scale: A statistically significant increase in the AIMS Affect scale (p=0.03) was observed contrary to the expected outcome, thus rejecting the research hypothesis (i.e. Rapid-HOE programme would improve psychological status of hand OA patients). Hence, a six weeks Rapid-HOE programme did not improve the tension, mood, and psychological health statuses within the study participants. The estimated effect size was small (Cohen's *d* = 0.43) and despite the significant change observed, this change is clinically unimportant.

Social Scale: No significant change in the AIMS Social scale (Figure 9-6) A six weeks Rapid-HOE programme did not improve the social interactive ability of the study participants.

Table 9-6: Health-related quality of life before and after 6-weeks of Rapid-HOE programme training

AIMS Scales	Pre-training Assessment Mean ± SD	Post-training Assessment Mean ± SD	Mean difference (95%CI)	P-value	Effect sizes (*d*)
Physical	2.73±1.88	1.47±1.57	1.66 (0.43 - 2.08)	**0.01***	0.67
Symptom	3.66 ± 2.02	3.05±2.30	0.60 (-0.65 - 1.85)	0.33	-
Affect	3.25±1.99	4.11±1.21	-0.86 (-1.65 - -0.07)	**0.03***	-0.43
Social	1.35±1.62	1.39±1.90	-0.03 (-0.94 -0.87)	0.94	-

NB: SD - Standard deviation; CI - Confidence interval; Statistical test - paired t test statistic; P – probability; * - significance; *d* - Cohen's D (Kazis *et al.*, 1989); Cohen's *d* - (0.2: small effect size; 0.5: medium effect size; 0.8: large effect size). AIMS2-SF - (Scale (0-10; lower scores=better the health state).

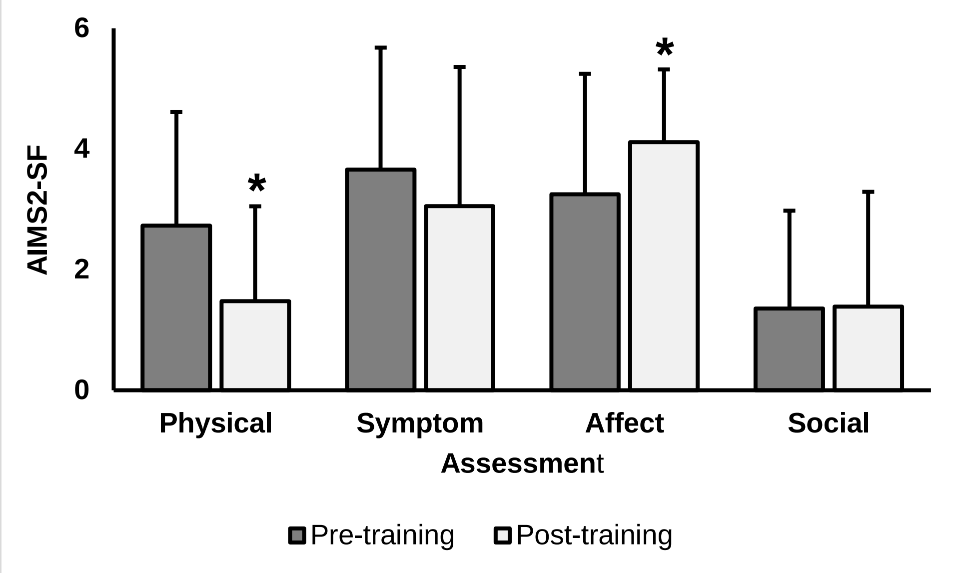


Figure 9-8: Quality of life assessment (AIMS) before and after 6-weeks of Rapid-HOE programme training for people with hand OA.

AIMS measured on a scale of 0 to 10 (0=better health); presented as means and standard deviations; * indicates significance between pre-post (p<0.05)].

9.10.2.4 Exercise Adherence Rating Scale (EARS)

Total EARS scores range from 0 and 24 (see Table 9-7). A high EARS score (22.4±3.9) was recorded for all participants showing high adherence (93.5%). Of the six questionnaire items, the highest scored items were items 4 and 6 with a mean score of 3.89 ± 0.32 out of a maximum item score of 4. All exercise diaries were completed and returned (see Appendix F.17).

Table 9-7: Exercise Adherence Rating Scale (Post-training)

Questionnaire items	EARS scores (Mean ± SD)	Max expected EARS scores	Level of adherence (%)
1. I do my exercises as often as recommended*	3.56 ± 0.98	4	88.9
2. I forget to do my exercises	3.61 ± 0.78	4	90.3
3. I do less exercise than recommended by my healthcare professional	3.72 ± 0.75	4	93.1
4. I fit my exercises into my regular routine*	**3.89 ± 0.32**	4	97.2
5. I don’t get around to doing my exercises	3.78 ± 0.73	4	94.4
6. I do most, or all, of my exercises*	**3.89 ± 0.32**	4	97.2
Mean total score of all participants	22.44±3.89	24	93.5

NB: *reversed scored

9.10.2.5 Adverse events

Three adverse events related to the Rapid-HOE exercise were recorded, one from the adverse events form and two during the weekly follow up communications (via emails). These were:

1. Pain in her left finger (lasted a week) and right thumb (lasted a month) during training (Participant reported this did not affect exercise training but thought to report them).
2. Minor pain in right finger during ironing out exercises which did not interfere with exercising.
3. Strong electrical twinges in left ring and last 3 fingers (participant reported of having carpal tunnel syndrome and explained that it might have caused this event. She eventually dropped out of the study due to a fall unrelated to the Rapid-HOE exercise programme).

9.11 Qualitative Results – Participant interviews

9.11.1 Participant views on Rapid-HOE programme

This section presents the views of study participants on the Rapid-HOE programme, first on the exercise programme content followed by the exercise presentation.

9.11.1.1 Participant views on the exercise content of Rapid-HOE programme

For the content, three themes emerged. The Rapid-HOE exercise programme was described as good and tolerable, beneficial, and easy and convenient (see Table 9-8).

Table 9-8: Summary of themes and supporting references for participant views on Rapid-HOE exercise content and presentation

<table>
<tr><th></th><th></th><th>Themes</th><th>No of Participants</th><th>No of References</th></tr>
<tr><td rowspan="6">Exercise content</td><td rowspan="3">Positive feedback</td><td>Good and tolerable exercises</td><td>7</td><td>10</td></tr>
<tr><td>Exercises are beneficial</td><td>9</td><td>25</td></tr>
<tr><td>Easy and convenient</td><td>7</td><td>10</td></tr>
<tr><td rowspan="3">Less desirable feedback</td><td>Exercises were boring</td><td>2</td><td>3</td></tr>
<tr><td>Too many repetitions for rapid-force exercise component</td><td>1</td><td>1</td></tr>
<tr><td>Ironing out exercises are not helpful</td><td>1</td><td>1</td></tr>
</table>

NB: Complete reporting of all participants views on the Rapid-HOE content and presentation (description and illustration) is reported in Appendix F.19.

9.11.1.1.1 Exercises are good and tolerable

Some participants (n=7) described the Rapid-HOE programme as good as they noticed the positive effects with the progression of the exercise training which encouraged them to continue. One participant commented:

> *"…it (exercises) was surprisingly good and I'm sorry that sounds disrespectful but I didn't really think that I will get a benefit but I have, I really have and I've been continuing to use the little balls as well. I think they were good exercises"* ***(P-115)***

Others, although they reported experiencing some hand pain, first understood the essence of exercise and were also aware that exercise are sometimes associated with muscle soreness and hence, continued the exercise training as the pain was manageable. Participant P-122 commented:

> *"I knew that it (exercise) was essential to do it in order to benefit from the exercises. At first, I found it difficult because it was painful, and [..] awkward to do. As the weeks went by, I realized that it became easier…".* ***(P-122)***

9.11.1.1.2 Exercises are beneficial

Nine of the 10 sampled participants thought the Rapid-HOE programme was beneficial for their hand OA as it improved their hand OA symptoms and ability to perform some hand functional activities. Two participants commented:

> *It's (exercises) made a big difference to my life [..] You know those round cabbages? I used to have terrible trouble holding them while I did the first cut. If it was starting, it was fine. If I did the first cut, it was just awful. And I had one the other day and I literally just picked it up, cut it and I probably having done that in two years"* ***(P-129)***

However, two participants with over eighteen years history of hand OA, suggested that although the Rapid-HOE programme was relevant and useful, it may not be of benefit to them since their hand OA was advanced. Below they commented:

> *"I would say that the exercise of the hands is probably going to be very helpful. But I do not feel that possibly for me, it was a little bit too late.[..] I mean, I feel that had I had something like this, maybe five or 10 years ago, it could well have been very beneficial. But I feel that they've (hand OA) progressed to such a state that it's not much. Although I will continue to exercise my hands because I think it's important".*
>
> ***(P-112;*** *27 years history of hand* ***)***

"...I think if you had somebody with no complete stiffness, it would be more helpful than somebody who[..] have already got the deformity so it's too late to do anything with that now. I just wish, I'd had it when my hands weren't in such a bad state"

(P-120; *18 years history of hand**)***

9.11.1.1.3 Easy and convenient

Seven participants also found the Rapid-HOE simple and easy to perform, and convenient as it could be performed anyway, which was helpful to them. One commented:

"…I like the fact that it's very easy to do [..] and that's very convenient. It's not as though you have to get dressed up[..] wear your leggings and make that". ***(P-127)***

9.11.1.1.4 Less desirable feedback on Rapid-HOE programme

Two participants described the Rapid-HOE as boring (n=2) and suggested that perhaps, it would be more enjoyable when delivered in a group session.

"My first thought was it was very boring []. You know sitting there and doing: 1, 2, 3, 4 [..] I was just thinking if you had a class full of people, you could, you know, jolly it up a bit and even sing along" ***(P-120)***

One participant was of the view that the rapid-force exercise component had too many repetitions.

*" …I think if I did nothing else at all, I might not have had the pain, but[..]I'm not just sitting doing nothing all day, my hands are being used constantly and so to add 120 squeezes on the top of that, it's just too much. It's probably too much even if I were doing nothing anyway. But otherwise, I thought it was fine. (**P-120)***

9.11.1.2 Views on structure and presentation of Rapid-HOE programme

Three main themes emerged regarding the views on structure and presentation of the Rapid-HOE programme (see Table 9-9). Participants thought the structure of the exercise programme was appropriate and the exercises were well-structured, and thoroughly developed. Others thought that exercise instructions, exercise booklet and researcher support was good, which facilitated their exercise adherence. On the structure, one participant noted:

"You know, we don't perform life at 1 speed, everything is at different speeds and I think you covered that nicely with weekly exercises because that made the muscles work in a variety of different ways. You know from a physio point, that's really functional" ***(P-115)***

Table 9-9: Participant views on Rapid-HOE programme structure and presentation

Themes on exercise presentation	Participant evidence
Appropriate content	"I think you covered the fine aspect and you covered the power and you covered the speed as well" **(P-115)** "…they *(exercises)* were holistic, the whole hands with the ball. I thought that was a really nice way of mobilising." **(P-125)**
Well-structured and thoroughly developed	"It (exercises) was very well structured. And it was just about the right length of time [..] and I, I found it easy" **(P-112)** "I saw it *(exercises)* was well thought through and my hands are definitely become stronger as a result of it…" **(P-115)**
Good instructions and researcher support	"…the actual setup of the booklet and the patient information leaflets and going through it all with you. And I always read the instructions for each exercise before I did it, even though I'd only done it two days before. I thought the booklet and the information stuff was excellent". **(P-129)** "The follow up messages do help because again, it focuses your mind back on it (exercises) and if you've forgotten to do it for a few days, it just gives you that jolt, that I better catch up and start doing it []. I thought it all went very well. **(P-118)**

NB: Complete reporting of all participants views on the Rapid-HOE presentation (description and illustration) is reported in Appendix F.19.

9.11.1.3 Acceptability of Rapid-HOE programme

The Rapid-HOE programme was judged as acceptable as it met the three requirement for acceptability of a new intervention: satisfaction, perceived appropriateness, intent to continue use (see Table 9-10). Participants expressed their satisfaction with Rapid-HOE programme regarding: i) the exercise content, ii) duration, iii) structure and presentation, iv) encouragement and researcher support and v) the online approach to the exercise delivery. Some also thought the individual exercise components were appropriate, benefited their hand OA symptoms and were pleased to have undergone the training and indicated their continued use even after completing the six weeks training programme.

Table 9-10: Acceptability of Rapid-HOE programme

Acceptability requirements	Evidence
1. Satisfaction	"I'm impressed actually because I didn't think I was gonna notice too much difference, but my hands are definitely much stronger, and my wrists haven't been aching anywhere near as much as they used to" **(P-115)** "it's much easier to be negative about something than the other way around. But no, I've obviously benefited from it. So no, all praise for it*(exercises)"* **(P-120)** "…I've been really happy to do it *(exercises)."* **(P-115)**
2. Perceived appropriateness	"…I feel that if I had something like this, maybe five or 10 years ago, it could well have been very beneficial" **(P-112)** "..it was very well structured. And it was just about the right length of time" **(P-112)** "I did not really have a like or dislike it was. It was a necessary thing to do, right, in order to improve my hands." **(P-122)**
3. Intent to continue use	"…I will continue to exercise my hands because I think it's important. I will continue to do that". **(P-112)** "I should definitely do it but not as a counting []. When I'm waiting for the kettle to boil, I shall do some exercises[..] or if I'm waiting at the bus stop or [..] train..." **(P-120)** "As long as you're not going to ask me for those eggs back, I should carry on doing the exercises, because it certainly has improved my pain" **(P-115)**

NB: Full details of results is reported in Appendix F.20

9.11.1.4 Practicability of the Rapid-HOE exercise

The Rapid-HOE programme met the first two requirement to classify an intervention as practicable: evaluation of the positive or negative effects on target participants and the ability of participants to carry out intervention activities (see Table 9-11).

9.11.1.4.1 Positive effects of Rapid-HOE programme

Both positive physical and psychological effects of the Rapid-HOE programme were reported by study participants. For the physical, the programme improved participants': i) hand pain, iii) handgrip strength, iii) functional task performance iv) hand joint flexibility and ROM and v) fine motor skills. For the psychological, participants also reported how the Rapid-HOE programme improved their self-efficacy and changed their negative hand OA beliefs (n=3). For instance, one recounted both experiences:

> *"…by the end, I feel I can [..] clench my fists really quite hard. And it feels good. It feels strong [...]. The way the exercises progress has trained my mind to understand the way my hands can work [..].*

It's a nice way of educating us into the potential of our hands because joint pain in the hands makes you stop using them a bit. And so, it's a good way of retraining your brain to go, ***No! I am dexterous and I can do things!*** *Here are the things that helped me".* ***(P-125).***

9.11.1.4.2 Negative effects of Rapid-HOE programme

Three negative effects were reported: muscle spasm in the last two weeks of the training (n=1) (see Table 9-11), one episode of challenges with MCP and IP extension during isometric gripping (participant has history of claw hand) and sore fingers with the handgrip exercises. Participants however, reported that these three negative effects did not hinder their exercise performance.

9.11.1.4.3 Ability of participants to carry out Rapid-HOE programme

All the study participants carried out their exercises, as they found it easy to perform (section 9.11.1.1.3), acceptable (section 9.11.1.3) and did not encounter severe challenges (section 9.11.1.1.4). Based on the marked positive effects (minor and manageable negative) of the Rapid-HOE programme and participants' ability to perform it, the Rapid-HOE programme was judged as a practicable exercise intervention for hand OA.

Table 9-11: Practicability of Rapid-HOE programme

Practicability components	Evidence
1. Positive effects reported by participants	
Pain reduction	"I think the exercise program is good, [..] you found that as you carried on during the exercises, your ability was better, instead of hurting so much, it didn't hurt so much." **(P-122)** "… I should carry on doing the exercises, because it certainly has improved my pain" **(P-115)**
handgrip strength improvement	"…by the end, I feel I can[..]clench my fists really quite hard. And it feels good. It feels strong" **(P-125)**
Improved functional task performance	"…I definitely do think that doing exercises has helped. I've got a lot more. I can grip things; I can pick things up better than I did before" **(P-116)**
Improved hand joint flexibility and ROM	"I think the exercise program is good, [..] it enables you to loosen your fingers during the exercises, whereas they were stiff before." **(P-122)** "My hand has become for the first time, flexible whereas I used to find it was stiff and painful. Now I find that, [..] the palm of my hand doesn't hurt [..] and my fingers moved a lot more freely. When I'm preparing meals or doing things in the kitchen, it's a lot easier than it was." **(P-122)**

Practicability components	Evidence
Improved fine motor skills	"… before I was having trouble with actually holding a sewing needle, because it was hard, but I can do that a little bit better" (P-129)
Improved psychological health	**Improved self-efficacy/ changed beliefs on OA** "… when you make time for yourself, it repays you, and because of my life at the moment, that is a bit of a blur[..] So actually, [..] it's been the only times I spend time just for myself" **(P-125)** "I think it was really good because it gave you something positive to try and help yourself. And I definitely do think that doing exercises has helped." **(P-116)**
2. Negative effects on target participants	
Muscle spasm	"…mainly the last two weeks with using the ball, sometimes my hand would go into a spasm and I would just have to give it a rest then and go back to it later. But apart from that no I didn't have any problems at all". (P-116)
Challenges with MCP and IP extension	"once I've done the exercises *(isometric handgrip exercises),* I found that I had difficulty actually opening my hand". **(P-122).** NB: This patient reported of having a claw hand ("I'm still slightly concerned that my left hand still resembles sort of a claw. Whereas my right hand will stay flat. But I don't know if there's any way of improving that")
Sore fingers	"…exercises 3a and b where I found to begin with my finger got really sore because, I squeezed [..] but that wasn't a problem" **(P-129).**
3. Ability of participants to carry out Rapid-HOE programme	
Ease of performance	"*That (rapid-force exercises*) was quite easy to do? No problem. No, its fine" **(P-118)** "I think[..] I'll do it the same way because it worked, and I managed to achieve doing all the exercises as a result of it" **(P-115)**

NB: Full details of results is reported in Appendix F.20.

9.11.1.5 Adherence to the Rapid-HOE programme

As previously mentioned (section 9.11.1.2), participants indicated that researcher support through weekly follow up communications ensured their exercise adherence. In addition, participants also mention the following as the adherence strategies that facilitated their adherence to the Rapid-HOE programme: i) fitting exercise into daily life, ii) making personal efforts and adjustments, iii) developing a routine and personal motivation (see Table 9-12).

Table 9-12: Participant reported adherence to Rapid-HOE programme

Adherence Strategies	Participant evidence
Fitting exercise into daily life	"Well, the foundation of this, of course, is that you can sort of do it while you're watching television or something like that, which tended to be when I did it." **(P-118)**
Making personal effort and adjustment	"…I think that if you're doing them say, between 11 and 12, every day. Like my brother knew, that's when I was going to be doing them *(exercises)* and not to disturb me. [..] You could tell friends or family, don't ring me or contact me between 11 and 12 because that's what I've done to set time aside for my exercises. "… when you make time for yourself, it repays you, and because of my life at the moment, that is a bit of a blur[..] So actually, [..] it's been the only times I spend time just for myself" **(P-125)**
Developing a routine	"….my advice would be, because it really doesn't take that long to do the whole set of exercises to just pick a time, [..]. Just say, right, I've got a window here, I'm gonna sit and do my exercises **(P-116)**
Motivation	"… to know that there was going to be an end of session assessments, that kept me going". If it was just do this for six weeks, and then nothing happens. [..] it would be so much easier to give up. **(P-120)**
Weekly follow up/ Support	"I found it helpful that you did an email every week, just to remind me and I could feel it was easy to communicate with you to say, if I was having any problems or not [..] that kept me going". (P-120)
Previous exercise knowledge and experience	"So, had to do various other exercises during my lifetime and I know that they do help, so [..] I guess I have found it easier than a lot of people would have. **(P-129)**

NB: Full details of results is reported in Appendix F.21

9.11.1.6 Participant recommendations for Rapid-HOE programme modification

Some participants suggested the need to maintain the current form of Rapid-HOE programme as it has worked for them. Others made recommendations to enhance the programme regarding the content, presentation and delivery which are presented below (Table 9-13).

For exercise content, participants advised the need to:

1. Maintain the current exercise duration (15-20 minutes),
2. Adapt the exercise programme to patient specific needs and preferences and
3. Increase weekly exercise frequency from three to four repetitions, and duration of training from six to eight (Table 9-13).

Regarding exercise presentation, participants advised the following:

1. Make instructions for grip exercise repetition clearer
2. The option to exercise both hands together and a caution note on extreme hand stretching during ironing out exercises should be added.
3. Include exercise videos to improve the quality of exercise performance
4. For the exercise booklet, include CMC joint descriptor on hand diagram (not included in study version) and add a statement to encourage exercise performance.

For the Rapid-HOE programme delivery, participants suggested group exercise sessions and the inclusion of an additional visual check during exercise training. Three interactive video sessions were advised for future exercise delivery:

1. First session - interact, conduct pre-training assessment, and teach programme.
2. Second session – conducted a week after teaching programme to check on the quality of exercise performance, repetition, and adherence to programme content
3. Third session for post training assessment.

Details of the recommendations from participants are shown in Table 9-13.

Table 9-13: Participants' recommendations for modification of Rapid-HOE programme

Suggestions		**Evidence**
Exercise content	Maintain exercise duration	"… it was just about the right length of time. [..] what I found as I progressed, and I had to move to doing 10 and eights and six repeats, it took a little bit longer. That was okay, but I think you don't want to go any further than that. That's not because of the pain or anything like that. But because it gets boring. **(P-112)**
	Increase exercise duration and frequency	**Adapt exercises to meet patient needs** "doing it three times a week [..] do that, then you can do it more often if you want to. "You can adapt it [..] I suppose [..] the most severe would still stay at three times, but you could actually improve it and maybe add another day, four days a week" **(P-125)** **Increase duration from 6 to 8 weeks** "…maybe 8 weeks rather than 6 weeks because I think a lot of people may find the first couple of weeks difficult or they can't get into the routine. So then maybe weeks 3, 4, 5 and 6 they begin to do the routine and then by week 7 and 8, they are into it, and that may encourage them [..] to continue it afterwards" **(P-127)** "…I think in a way, I might have been better if I done the exercises every day [..] I did think that when I did them on the Friday and then again, on the Monday, I'd almost lost something". **(P-129)**
Exercise presentation	Additions for exercise instructions	**1. Describe exercise frequency clearer** "I didn't find it (exercise instructions) a problem, although I had to revert back to[..]have a look to see how many[..]repetitions I was supposed to be doing. I suppose, if anything, you could have made that a little bit clearer **(P-116)** **2. Include a statement that both hands can be exercised together** "…and perhaps, if you're happy with that, a mention could be made that you can do both hands together, especially for the squeezing" **(P-120)**. **3. Add a caution on hyperextension of fingers** "Pressing the hand flat *(ironing out exercises),* I think that needs to come with a warning" **(P-120)**.

Suggestions		**Evidence**
	Include exercise videos	1. "if you had the video with somebody actually taking the class, making jokes and doing some encouragement that I could put on there. And I could do it with you. And that would, you know, liven it up a bit". **(P-120)**. 2. "Only the repetition of the squeezing, having to count, I found that boring. Whereas if you somebody had been leading it (in a video), then I could have just[..]concentrated on the squeezing and not on the counting. Person on the screen would say right, would do five more or something like that. That would have been more enjoyable than just doing". **(P-120)**.
	Additions for exercise booklet	**Include descriptor for CMC joint on hand diagram** "I thought the book was helpful and I did refer to that, especially in the beginning, []. But there was one slight disappointment. There's was a picture of a hand with what you were calling all joints[..]but there was nothing for the base of thumb and I'm sure, I'm not the only one who gets pain down there" " **(P-120)**. **Include statements to encourage and boost patient confidence** "…put something in *(exercise booklet)* that encourages people. "..I wonder whether that's where you say, you know, we've observed that for many people, pain can result in people stopping doing things, the exercise programme is sort of trying to open out what might have closed down and words to that effect". Participant quoted this example ("some people will live with it, and they won't let it constrain them, other people quite quickly respond to pain or to disfigurement and stop doing things") **(P-125)**.
Exercise delivery	Once weekly visual check	"I wonder whether a visual check after a week would be a good idea because I know from past experience, that you teach somebody an exercise and you think you've done it properly; you think they understand it? And when they come back the following week, they're doing something completely different which isn't what you said at all and may be causing harm" **(P-120)**.
	Group exercise sessions	"My first thought was it was very boring []. If you had a class full of people, you could, you know, jolly it up a bit and even sing along" **(P-120)**.

9.11.2 Impact of project (Rapid-HOE programme)

9.11.2.1 Impact feedback-1

One participant who had reservations about the Rapid-HOE programme (too many repetitions for the Rapid-force exercises in the programme), emailed the researcher PhD three weeks after completing her programme with the positive trigger finger feedback. She reported:

> *"You might be interested to know that before I started the exercises I had a trigger finger - my ring finger of my left hand. It only bothered me doing certain movements when it locked and I had to use my other hand to release it.*
> *BUT I have realised that it has disappeared! I googled trigger finger and it recommended rest and NOT doing repetitive gripping and squeezing! But doing the opposite cured mine.*
> *I thought you would like to know-*
>
> *With best wishes"*
>
> ***(P-120)***

9.11.2.2 Impact Feedback-2

Another participant also emailed several days after completing her training and shared her satisfaction with study project, the professionalism of the PhD researcher (during researcher-participant interactions) and her involvement in research. She reported:

> *"I just wanted to say how happy I was to take part in this study.*
>
> *It gave me hope and satisfaction that I was doing something to help myself and others. My experience of being involved was very positive as it was run so efficiently. I felt I had support every step of the way and a very friendly co-ordinator who kept in contact and quickly responded to any queries I had. After completing the six weeks I am confident I will be kept up to date with the results and further trials. It is so reassuring that there is more to do after the doctor just told me to keep warm, keep moving and take paracetamol!"*
>
> ***(P-130)***

9.12 Discussion

A mixed methods study was conducted to establish the feasibility and proof of concept of the novel Rapid-HOE exercise programme in 18 community dwelling older adults with hand OA. The concept of the Rapid-HOE programme was shown by establishing its feasibility and limited-effect in improving hand pain, self-reported hand function, and the HRQoL (physical health component) in people living with hand OA. Qualitatively, the Rapid-HOE programme was described as easy to perform, well-tolerated, and demonstrated both physical and psychological benefits for people living with hand OA.

Established evidence suggests that hand exercises have small, but beneficial effects on joint stiffness, grip strength, self-reported pain, and function with few and non-severe adverse effects (Osteras *et al.*, 2017; Kloppenburg *et al.*, 2018). Whilst joint stiffness and grip strength were not assessed within the present study, the current findings contrast previous reports as the self-reported pain and function improved after 6-weeks training to great effect with non-severe adverse events that were short-lived and manageable. The exercises investigated in previous studies did not contain a dynamic strength training component, and indeed one of the underpinning RCTs reported that perhaps a more ambitious exercise programme may have produced the expected results of improved grip strength within the population studied (Østerås *et al.*, 2014a). Exercise prescription guidelines for older adults with OA recommend that, the isotonic dynamic training has more relevant daily functional benefits, than isometric training (Katz et al., 2001) and can be tolerated in OA patients (Balshaw *et al.*, 2016). The explosive strength training concept for the lower limbs, from which the hand rapid-force exercise component (Chapter 7) of the Rapid-HOE programme was adapted, is an isotonic dynamic strength training concept (Tillin *et al.*, 2013; Tillin *et al.*, 2014; Maffiuletti *et al.*, 2016). It can therefore be argued that the beneficial results of improved self-reported function and pain recorded within the present study may be attributed to the complementary benefits of the rapid-force hand exercises within the Rapid-HOE programme.

The use of high intensity and resistance strength training in hip and knee OA has been reported with positive benefits on pain and function (Lockard, 2000; Neumann *et al.*, 2003). However, the evidence for hand OA is divided regarding its safety, tolerability, and benefits particularly for CMC OA patients. Whilst some have argued that high intensity exercises should be avoided for people with hand OA due to the detrimental effects on hand joints (e.g. CMC subluxation, trigger finger), others have reported that these exercises are safe and well tolerated and have notable benefits on pain, grip strength and function (Hennig *et al.*, 2015; Nery *et al.*, 2015).

Of note, such divergent views on rapid-force exercises (high intensity exercise) were echoed during the PPI discussions conducted as part of the exercise development (Chapter 8; section 8.8.2.2). Whereas some experts (clinicians) raised concerns due to the potential harm to hand joints, others (researchers) advanced its exploration and potential use provided its benefits are proven. Regarding the former, one of the concerns was the possible development of trigger finger and whilst the researcher acknowledges such possibility based on reported expert opinions, these are yet to proven. It was therefore noteworthy that one participant reported of a complete disappearance of her trigger finger three weeks after completing the rapid-HOE programme (see section 9.11.2.1) despite advice she had seen on the internet recommending rest and NOT doing repetitive gripping and squeezing exercises when you have trigger finger! Whilst conclusions cannot be drawn on this single case, it is a notable benefit, which has highlighted the positive effect of high intensity exercises in hand OA, and therefore requires further investigation. Regarding the exploration of high intensity exercises beneficial for hand OA, the feasibility and proof of concept of the novel Rapid-HOE programme have been established within the present study. Further investigations to demonstrate its effectiveness for possible use in people with hand OA is proposed (see section 10.2.6). Below, the effects of the programme in the study participants are discussed.

9.12.1 Acceptability, practicability, and retention of the Rapid-HOE programme

The qualitative interviews provided evidence to establish that the Rapid-HOE programme was acceptable and practicable within the study participants. Compared to previously published high intensity hand OA exercises where considerable pain and high dropout rates were reported (Rogers *et al.*, 2009; Hennig *et al.*, 2015), only a few participants reported minor pains and non-severe adverse events in the present study, which were manageable and did not interfere with the exercise training. The present findings therefore suggest that compared to other high intensity exercises, the novel Rapid-HOE programme is comparatively well-tolerated, and acceptable, and thus establishes its feasibility. Similarly, an intervention is judged as feasible when it is found to be practicable (Bowen *et al.*, 2009), that is an evaluation in favour of the positive effects and the ability of the target users to carry out the intervention under limited resources. The present participants' qualitative results demonstrated overwhelming positive effects compared to the negative effects (minor and manageable). From previous qualitative findings (Chapter 6), participants described a hand OA exercise programme as difficult and painful to perform and would only continue exercising if the strength training content (resistant exercises with elastic band) is removed.

In contrast, the present participants were satisfied with the exercise content and structure of the Rapid-HOE programme, found it easy to perform and did not encounter any severe challenges, as the difficult elastic band exercises were not included in the Rapid-HOE programme. Based on this, the Rapid-HOE programme was judged as a practicable exercise intervention for hand OA management, which further validates its feasibility and potential use in hand OA patients when its effectiveness is established.

Having expressed satisfaction with the Rapid-HOE programme, participants suggested ways to enhance it which should be considered for future studies investigating the programme. Regarding the content, presentation, and delivery, participants' relevant recommendations included: i) adapting the exercise programme to patient specific needs and preferences; ii) making the rapid-force exercise instructions clearer; iii) including exercise videos and a statement to encourage exercise performance.

9.12.2 Proof of Concept of the Rapid-HOE programme

9.12.2.1 Proof of Concept of Rapid-HOE on Hand Pain and Function

The study results showed that Rapid-HOE programme did not show any significant changes in hand pain. These results are consistent with previous studies that reported no significant changes in pain after a 6 to 16 weeks strength and resistance training programmes in people with hand OA (Lefler *et al.*, 2004; Rogers *et al.*, 2009). However, near significant ($p=0.06$) effect was observed in the present study, with a moderate effect size ($d=0.5$), which suggests that the rapid-HOE programme produced a modest clinically important reduction in the hand pain of study participants. Similar findings have been reported in previous hand OA intervention studies (Østerås *et al.*, 2014a; Hennig *et al.*, 2015). For example, whilst previous authors reported minor reduction in pain following a 12-week high intensity exercise programme (Østerås *et al.*, 2014a), a medium clinically important reduction was recorded within the present study where participants trained for half the intervention period (i.e. 6 weeks). This therefore suggests that with a longer exercise training period and a larger sample size, the Rapid-HOE programme may show statistically significant changes in hand pain.

Hand function was evaluated with FIHOA and PSFS questionnaires, as recommended by the OMERACT Hand OA working group (Kloppenburg *et al.*, 2015). The FIHOA measured the ability of the participants to perform some hand ADLS and PSFS, the difficulty in performing participant-identified hand activities. With these two outcome measures, the feasibility and concept of rapid-HOE exercise programme on function were shown within the studied patient population.

There were significant improvements in both FIHOA scores (p=0.003) and PSFS (p=0.00) with large estimated effects (Cohen's d =0.8, -1.0) after the six weeks rapid-HOE exercise programme. The large effect sizes demonstrated the large clinically meaningful effects of the rapid-HOE programme on hand function, by not only improving the ability to perform hand functional tasks (FIHOA scores Cohen's *d* =0.8), but also reducing the difficulty in performing these activities (PSFS: Cohen's *d* = -1).

The present participants (mean age 70 years) showed greater improvement in hand function, than those previously reported who were a relatively younger population (66 years) (Østerås *et al.*, 2014a) and (61 years) (Hennig *et al.*, 2015). For instance, the mean clinical difference for FIHOA within the present study was higher (2.89 95% CI 1.09 – 4.69) compared to those reported in (Østerås *et al.*, 2014a) (-0.5 95% CI -1.6 – 0.06) and (Hennig *et al.*, 2015) (-2.2 95% CI -4.0 – 0.4) which investigated Kjeken *et al.* (2015) hand OA exercise programme. This further suggests that the rapid-HOE programme is not only successful in improving hand function in people with hand OA, but also a feasible exercise intervention for older adults with hand OA patients.

In addition, the above authors (Østerås *et al.*, 2014a; Hennig *et al.*, 2015) both investigated the evidenced-based hand OA exercise programme developed by Kjeken *et al.* (2015) with an aim to increase grip strength, ROM and joint stability of the shoulders, wrist and finger joints. Whilst these aims were largely achieved in the trials investigated, divergent reports of the exercise effectiveness were published from significant improvement on activity performance and grip strength (Hennig *et al.*, 2015) to minor effects on self-reported function and insignificant benefits on performance-based measures (Østerås *et al.*, 2014a). The Rapid-HOE exercise programme with similar aims demonstrated better effects on self-reported functional measures compared to the Kjeken et al exercises which suggests that Rapid-HOE exercise is a feasible option for hand OA management worth further investigation. Of note, this study was planned to assess hand grip strength and other performance-based measures, but COVID-19 pandemic restrictions on person-to-person contact during the active study period prevented this. Given the relatively greater improvements in self-reported measures, it will be interesting to know whether similar improvements will be reported for performance-based measures in future studies.

9.12.2.2 Proof of Concept of Rapid-HOE on Health-Related Quality of Life

The AIMS2-SF questionnaire was used to measure the HRQoL of the study participants (Guillemin *et al.*, 1997) and below, the four scales (physical scale, symptom scale, social scale affect scale) measured are discussed.

Results from the study showed a moderate improvement in the AIMS physical (d = 0.67), which suggested that the rapid-HOE programme produced clinically meaningful reduction in participants' difficulty in performing upper and lower limb activities.

This positive finding provides additional evidence to support the usefulness of the Rapid-HOE programme in improving functional tasks performance in the population studied, as previously discussed (positive FIHOA and PSFS scores). The moderate to large effect sizes of all three functional measures; FIHOA, PSFS and the AIMS physical function scale were corroborated by the interview responses. These responses highlighted participant satisfaction with the exercise programme, amongst other benefits. For example, participants in their interviews mentioned improvements in: i) hand pain, iii) handgrip strength, iii) functional ability, iv) hand joint flexibility and ROM and v) fine motor skills. These translated into their ability to perform functional tasks, such as sewing, pumping car tires, opening bottle jars, and cutting vegetables, which for some have been limited for years. These findings demonstrate that rapid-HOE programme is a feasible and promising hand OA intervention warranting further studies to establish its effectiveness.

The results of the study showed that the Rapid-HOE exercise did not improve hand OA symptoms (Symptom scale) in the study participants, which suggests its inability to cause meaningful change in hand stiffness and pain, two constructs that the Symptom scale measures. This finding contrasts results from both the quantitative NPRS scores (where near significant reduction in pain was observed) and qualitative participant interviews, where participants commented on how their hand joints were less painful and stiff, and as such could perform some hand activities better compared to before they started the Rapid-HOE programme. The sensitivity of the AIMS2-SF questionnaire has been reported and amongst the four scales, the Physical function, Symptom and Affect scales has demonstrated high sensitivity and responsiveness to changes in general health perception of arthritic patients (Guillemin *et al.*, 1997; Taal *et al.*, 2004). The present study, however, contrasts the high sensitivity report of the Symptom scale as the NPRS and the interview data suggest better improvement in hand OA pain and stiffness compared to the AIMS symptom scores (no difference). This therefore indicates the inability of the AIMS2-SF questionnaire's symptom scale to detect significant changes in the population studied.

A slight increase in the AIMS Social scale was observed contrary to expected reduction (see Figure 9-8), however this change was not significant, thus indicating that the Rapid-HOE programme had no effect on the social interactive ability of the study participants. The AIMS questionnaire social scale has been reported as being less responsive and sensitive compared to other scales (Taal *et al.*, 2004; Gignac *et al.*, 2011), and this may have limited its ability to detect change within the population studied.

However, this study was conducted during the UK national COVID lockdown (Dec2020 - Mar2021) as such, the researcher suspects that participants' limited ability to socialize and engage with family and friends during this period may have negatively affected the results.

These findings were corroborated by the participant interview data, which suggested that although participants understood the need to stay at home during the lockdown, they also shared their frustrations of feeling constrained in their ability to socialize with friends and family. Whilst such limitations are not directly related to the exercises because the Rapid-HOE did not limit their ability to socialize, it acted strongly as a relevant confounding environmental factor that influenced participants' overall health status. In contrast, the interview results suggested how participation in the Rapid-HOE programme acted as a conduit for most participants to socialize by engaging with the researcher, it is interesting that such experiences were not captured within the quantitative findings (pre-post AIMS Social scale results). The possibility of favourable results on the social health status in patients is likely in future studies conducted in less socially restrictive circumstances.

The AIMS Affect scale results demonstrated that the Rapid-HOE programme did not improve the psychological health (tension, mood, and psychological health status) of the participants. Whilst it is acknowledged that the COVID-19 restrictions may have influenced such results, contrasting findings were reported from the participant interviews. For instance, participants reported of how the Rapid-HOE programme improved their self-efficacy and changed their negative mind-set and hand OA beliefs, which they found empowering and helpful (see section 9.11.1.4.1). Hence contrary to the quantitative findings, the Rapid-HOE programme from the participants' perspectives is a feasible intervention to improve the psychological health of hand OA patients and it is argued that perhaps the AIMS questionnaire was not sensitive enough to detect the psychological benefits observed in the study participants. These qualitative results further substantiate previous evidence regarding the perception that hand exercises appear to have positive effects on mental QoL status in people with hand OA (Hoffman *et al.*, 2008; Brosseau *et al.*, 2018)

Overall, the study results indicate that the rapid-HOE programme improved only the physical functioning dimensions of HRQoL of the study participants using the AIMS2-SF questionnaire. However, the relevant benefits and positive physical and psychological effects of the programme on the study participants from the interview results suggests an overall benefit of the programme in the QoL of study participants, which need to be tested with an instrument with better sensitivity and responsiveness than the AIMS2-SF questionnaire.

Potential instruments to consider are the Short Form Health Survey 12 (SF-12) (Ware Jr *et al.*, 1996) as used in an RCT that evaluated self-management approaches in hand OA (Dziedzic *et al.*, 2015) or the Medical Outcome Study Short Form 36 Survey (SF-36) as recommended by the OMERACT hand OA group (Kloppenburg *et al.*, 2014) due to their sound psychometric properties.

The use of the AIMS questionnaire for health status evaluation in hand OA patients has been recommended by a special hand OA taskforce (Kloppenburg *et al.*, 2014) and reported in previous cross-sectional studies (Meenan *et al.*, 1992; Slatkowsky-Christensen *et al.*, 2009) and a literature review (Dziedzic *et al.*, 2005). However, at the time of writing, no evidence of its use in hand OA intervention studies was available to allow comparison with the current study results. The PhD researcher therefore adds to previous authors in the call for further research in this area (Gignac *et al.*, 2011).

One of the concepts that the feasibility study measures is limited-efficacy, which is described as the ability of an intervention to show promise of being successful with the intended population (proof of concept), and usually explores intermediate, rather than final outcomes with shorter follow-up periods (Bowen *et al.*, 2009). Based on the small to large effect sizes of the Rapid-HOE programme on hand pain, self-reported function and physical health status of study participants, the limited-efficacy of the Rapid-HOE programme has been established within the present study.

9.12.3 Adherence to the Rapid-HOE programme

Both poor to relatively high adherence to existing hand OA exercise programmes have been reported (Rogers *et al.*, 2009; Østerås *et al.*, 2014a; Dziedzic *et al.*, 2015; Hennig *et al.*, 2015). In line with previous literature, participants quantitatively recorded high adherence (93.5%) using the EARS. Evidence-based recommendations for knee and hip OA stated that adherence is the principal predictor of long term outcome of exercising (Roddy *et al.*, 2005). As such, it can be concluded that, the high adherence to the Rapid-HOE programme suggests its sustained lasting effect in people with hand OA in future longitudinal studies and eventually when used as a hand OA management option. Based on recommendations from the scoping review (Chapter 5), weekly follow-up reminders (telephone calls, emails and text messages) were employed to ensure participant exercise adherence, which participants mentioned were helpful, provided a means of exercising support and acted us exercise reminders to facilitate their exercise training. This qualitative result therefore adds to previous evidence on the benefits of weekly exercise follow-ups as relevant adherence strategies for people with hand OA.

From the qualitative interviews, participants mentioned that: i) fitting the Rapid-HOE programme exercise into their daily lives; ii) making personal effort and life adjustments to perform the exercises; and iii) developing a routine ensured their high adherence to the exercise programme.

These findings are consistent with the previous qualitative study within this PhD (Chapter 6), where similar behavioural and lifestyle modifications were reported by hand OA patients who had undergone an exercise programme as part of an RCT. It is therefore clear that such patient strategies are relevant adherence strategies and should be considered in future hand OA studies to produce optimal results.
The present study also recorded a high retention rate of 90% (proportion of patients who completed the intervention programme) which demonstrates the feasibility of the programme and indicates its ability to be evaluated in further trials (Bowen *et al.*, 2009). The PhD researcher however acknowledges that the retention rate of the study may have been influenced by the COVID-19 pandemic as participants were usually home due to the restrictions on human movements, and hence had a lot of time to focus on performing the Rapid-HOE exercises.

From the PPI discussion (Chapter 8; section 8.8.3.1), both expert and patient PPI partners highlighted the need to include patient education in the present study, as they considered the lack of education on the importance of exercises in hand OA management has led to the low reliance on exercise. Supported by findings from the scoping review (Chapter 5) and other evidence-based recommendations (Kloppenburg *et al.*, 2018), educational exercise booklets (Figure 9-3) were provided on hand OA and the exercise programme, and from the participants interviews, this was excellent as it ensured their exercise performance and adherence. Another recommendation from the PPI discussions (Chapter 8; section 8.8.3.1) was the importance of having pre-study information on exercises and their role in hand OA management via workshops or PPI activities. It was submitted that such approaches will ensure psychological wellbeing of participants, motivate and develop their trust in exercises. It is noteworthy that participant interview data corroborated this expert opinion as the majority indicated the positive impact of discussions before and during the exercise training, and the information provided in the exercise booklet on their psychological well-being. Participants discussed how such conversations; i) changed their negative exercise and hand OA beliefs; ii) encouraged them to try-out new and positive things for themselves; iii) boosted their self-confidence in the use of their hands; and iv) enhanced their positive thinking which ensured their mindfulness and mental health state.

Whilst the above findings adds to previous evidence on the importance of patient education in ensuring positive outcomes, exercise performance and adherence (Katz *et al.*, 2001; Kloppenburg *et al.*, 2018), it also highlights the positive psychological impact of pre-study conversations on patients' well-being, which is new and needs to be explored in further studies.

9.12.4 Limitations of the study

Study follow-up periods evaluate whether gains in intervention outcomes are sustained after completion of studies. Compared to previous hand OA intervention studies that reported at least three months follow-up (Dziedzic *et al.*, 2015; Hennig *et al.*, 2015), there was no follow up component in this study. As such, the PhD researcher is uncertain whether the clinical gains seen after the completion of the exercise training are sustainable. That said, this was a feasibility study which was not designed to test such aspects but to determine whether an intervention is worth recommending for a future efficacy study.

This study was initially designed to evaluate performance-based measures; hand and pinch grip strengths, and grip rate which indicates rapid-force. However, the onset of the COVID-19 pandemic (2020-2021) and limitations on person-to-person contact prevented the use of these measures. Hence, the researcher is uncertain whether the positive effects of the Rapid-HOE exercise programme recorded by the self-reported measures would be replicated if the intended performance-based measures were used. However, qualitative findings of practical benefits in functional task performance, as well as improved pain, stiffness, and hand strength, gives the PhD researcher the confidence in positive future study outcomes.

People living within the community with either medically diagnosed or self-reported hand OA, ranging from those with a history of less than a year to those who have lived with it for about 50 years (13.00±12.28 years) participated in the study. Whilst this characterised the sample as heterogenous, all participants met the ACR criteria for hand OA and as such, represented people with a well-established disease. The generalization of the study findings to males with hand OA should be cautiously done as only a few males (n=3) participated.

The study had no control group for comparison with the intervention group to see whether the positive effects found were due to the true effects of the Rapid-HOE programme or chance. However, a before and after feasibility study, such as the present one, does not have control components, as only limited effects of intervention are tested in preparation for a bigger study (Bowen *et al.*, 2009) which will contain a control group.

Without proof of concept and feasibility studies, some controlled trials would be futile and waste resources if no effects of the intervention are likely. Since biomechanical assessment of the Rapid-HOE programme was not conducted as part of the study, it remains unknown whether the exercise programme has any effect on the joint deformities, which therefore needs to be studied.

Finally, the interviews within this final study (Study-5; Chapter 9) were conducted by the PhD researcher and not by an independent interviewer due to limited study financial resources. This may have introduced the possibility of response bias (e.g. participants may have responded positively to avoid offending the researcher), however, the researcher during interviews advised participants to speak freely and reiterated that negative responses will not affect their participation.

9.13 Conclusions

1. The Rapid-HOE programme is novel, as it contains rapid-force hand exercises, which is an isotonic dynamic strength training concept known to have benefits in lower limb strength training and people with knee OA. It can be argued that the beneficial results found in the present study may be attributed to the complementary benefits of the rapid-force hand exercises within the Rapid-HOE programme

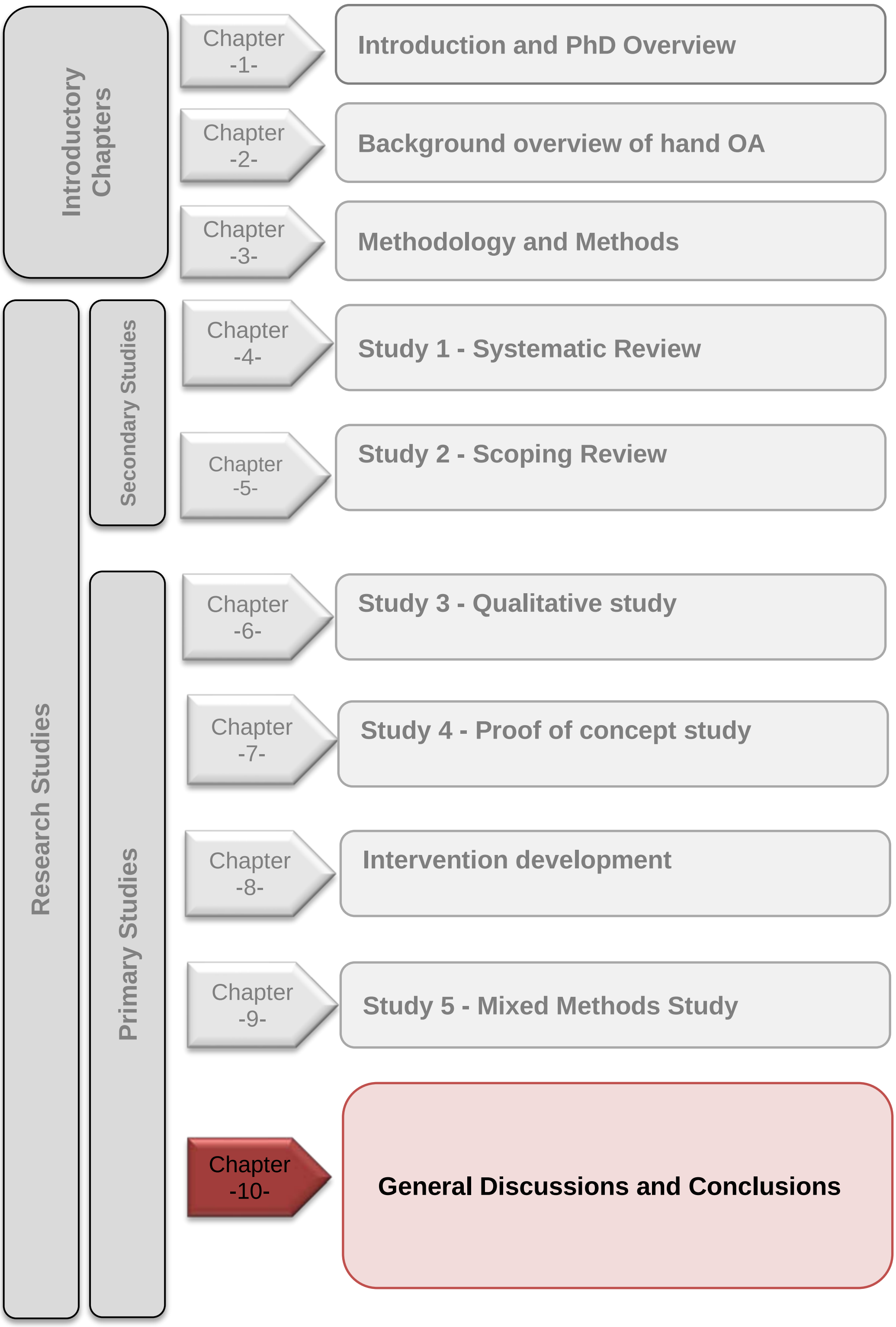
2. The rapid-HOE programme had a medium to large effect on hand pain, self-reported function, and physical health status, which established its proof of concept and feasibility in the study participants.
3. The Rapid-HOE programme is therefore a promising intervention for the management of people living with hand OA and forms preliminary data for a future RCT aimed at establishing its effectiveness.
4. Although found to be acceptable and practicable, recommendations for enhancement of the rapid-HOE programme include: i) its adaptation to patient specific needs ii) revision of exercise instructions for better clarity and the iii) inclusion of exercise videos and statements of patient encouragement, which should be considered for future use.
5. High adherence to the rapid-HOE programme was recorded, which further establishes feasibility, indicates its potential positive outcome, and provides evidence of a sustainable exercise programme, that can easily be self-managed by individual living with hand OA.

6. The Rapid-HOE programme improved only the physical functioning health status (of HRQoL) of the study participants and not the mental, symptom and social health dimensions using the AIMS2-SF questionnaire. However, the relevant positive physical and psychological effects of the programme identified from the participants' interview results suggests an overall benefit for the QoL of study participants. This therefore needs to be tested with an instrument with better sensitivity and responsiveness other than the AIMS2-SF questionnaire in future studies.

9.14 Chapter summary

The feasibility and proof of concept mixed methods study of the Rapid-HOE programme in hand OA patients has been established. Findings from this study form preliminary data for a future RCT which will aim to establish the effectiveness of the Rapid-HOE programme within this patient population

Location in thesis



Chapter 10 General Discussions and Conclusions

10.1 Discussion

10.1.1 PhD Project Summary

The conceptual framework of this PhD Research is illustrated in Figure 10-1. The overall aim was to develop an exercise programme for people with hand OA premised on calls by researchers, clinicians, and patients to identify the optimal exercise programme, which will improve hand pain, function and QoL in this patient population. To address this, the researcher first reviewed current evidence to identify the gaps and recommendations on existing hand OA exercise programmes in Phase-1 of the research project. Findings from the reviews were consolidated with that of studies 3 and 4 to inform the development and proof of concept testing of the Rapid-HOE programme in Phase-3. These exercises were found to be simple, tolerable, and beneficial in people living with hand OA. Rapid-HOE programme is therefore a promising exercise programme worth considering for future hand OA management when its effectiveness is established with further research.

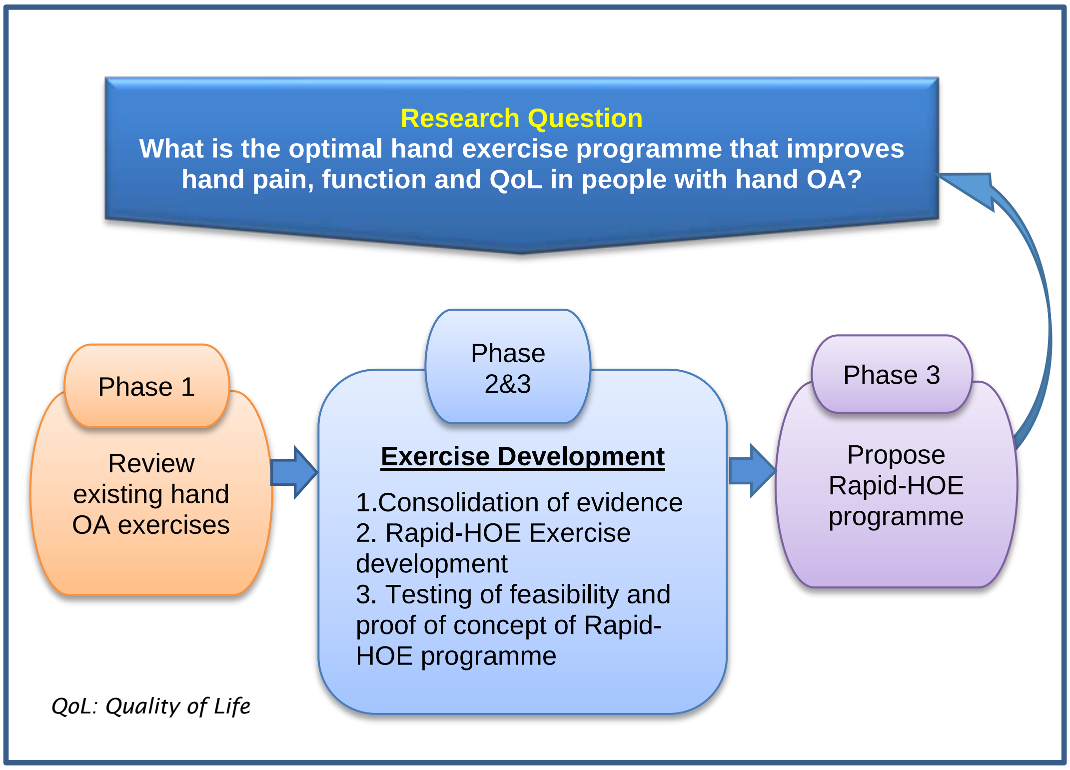


Figure 10-1: Conceptual framework of PhD Research

The concept of the Rapid-HOE programme has been demonstrated by establishing its feasibility and limited-efficacy in improving hand pain, self-reported hand function and the HRQoL (physical health component) in people living with hand OA. This exercise programme is easy to perform, well-tolerated and have both physical and psychological benefits for people living with hand OA. Isotonic exercise closely corresponds to everyday activities, and strengthening isotonic muscle contractions are therefore recommended for OA patients (Katz *et al.*, 2001). The inclusion of the rapid-force exercises, an isotonic dynamic strengthening exercises may explain the positive effect of the Rapid-HOE on hand OA outcomes. An RCT is needed to establish the effectiveness in people with hand OA to propose its use for hand OA management.

The latest EULAR recommendations for hand OA states that the words; 'optimise' and 'maximise' were used in the description of their evidence-based recommendations for hand OA to indicate that the management of hand OA should be more ambitious and not merely aim for patient-acceptable symptom state (Kloppenburg *et al.*, 2018). Within literature, there are mixed reports regarding the use of high intensity exercises for hand OA. For example, a systematic review and meta-analysis to establish the benefits of resistant training in people with hand OA reported that resistant training has only small clinically unimportant pain-relieving effect and no significant effect on hand function and grip strength (Magni *et al.*, 2017). Contrary to this report, the Rapid-HOE programme which included a resistance training exercise component showed moderate to large clinically important effects on pain and self-reported hand function. This study provides evidence to support the consideration of the use of resistive and dynamic strength training exercises for hand OA management based on the reported beneficial effects. Hence, based on the previously mentioned EULAR recommendations for hand OA (Kloppenburg *et al.*, 2018), an ambitious yet appropriate, well-tolerated and beneficial hand OA exercise programme with a high intensity exercise component has been developed. Such an intervention is therefore a plausible exercise intervention worth considering for people with hand OA.

10.1.2 Strengths and limitations

A major strength of this PhD research is the systematic and iterative evidence-based approach followed in the development of the Rapid-HOE programme, by combining evidence from: i) a systematic review of clinical guidelines recommendations on hand OA exercises; ii) a scoping review on commonly used hand exercises and exercise adherence strategies; iii) identifying patient views and expert opinion on existing hand OA programmes; and iv) exploring the emerging concept of rapid-force exercise.

Highly recommended intervention development guidelines were also reviewed. The development process followed the MRC guidance for developing and evaluating complex interventions (Craig *et al.*, 2013) in combination with the ACSM guideline, as well as evidence from hand OA patients and expert opinion (from PPI project). The above approaches ensured a rigorously robust foundation for the Rapid-HOE programme.

Another strength of this PhD is the rich tapestry of methodologically rigorous research designs conducted to produce robust evidence in an iterative manner with clear progression from the systematic review (Study-1; Chapter 4) to the scoping review (Study-2; Chapter 5), then patient perspectives (Study-3; Chapter 6), proof of concept (Study-4; Chapter 7), then intervention development (Chapter 8), before a feasibility mixed methods study (Study-5; Chapter 9). The above research studies were nested in the complex mixed methods multistrand research design and conducted under the overarching Mixed Methods Methodological paradigm, which is another strength of this PhD. Not only were the strengths of both quantitative and qualitative research designs combined, but both were integrated with structured evidence syntheses (e.g. reviews) and public stakeholder contributions (PPI) to provide in depth, informative and useful evidence to guide the Rapid-HOE programme development. This mixed methods multistrand design also increased the credibility of the findings when the relevant data sets from the research designs corroborated on the same results (e.g. agreement between systematic review, proof of concept study, PPI and mixed methods study on the positive effects on strengthening exercises in hand OA management).

One limitation within this PhD is that all quantitative assessments were conducted by the PhD researcher (due to limited study resources), and hence the possibility of observer bias is likely. However, care was taken to standardize the administration of all assessments throughout the research stages to limit such biases. Another limitation, particularly for Study 4 and Study 5 (testing emerging strength training concepts) were the lack of biomechanical assessments and hand movement analysis to ascertain the effect of the exercises on hand joints. Further limitations are considered in each experimental chapter and include participant numbers and lack of physical testing, which was not possible in the virtual study conducted during the COVID-19 pandemic (Study 5, Chapter 9).

10.1.3 Novel contributions of this PhD Thesis

1. This thesis has advanced the field of hand OA management by producing the evidenced-based Rapid-HOE programme, with the addition of the novel element of rapid-force exercises. This programme warrants further research to establish its effectiveness.
   The contribution of rapid-force contractions aims to improve rapid-force that is known to decline more rapidly with ageing than maximal force (Schettino *et al.*, 2014).
2. Establishing the feasibility of the Rapid-HOE programme within this PhD makes a step in advancing the science regarding the proof of concept of the use of rapid force exercises in the hand.
3. The use of explosive (rapid-force) strength training has been previously reported in the lower limbs but not in the hand. The present study provides a novel contribution to the body of knowledge regarding the feasibility and proof of concept of the rapid-HOE programme, first in the hands of healthy adults and then in the hands of hand OA patients.
4. Dynamic strength training is highly effective in increasing function and may be well tolerated in people with OA; however, the underpinning evidence is largely from healthy individuals, and hip and knee OA (Katz *et al.*, 2001). This PhD found evidence to support the assumption that dynamic strength training indeed improves physical function and can be tolerated in people with OA, and more specifically, for the first time, those with hand OA.
5. The OMERACT working group on hand OA stated that hand OA is a prevalent disease with high unmet needs and limited therapeutic options (Kloppenburg *et al.*, 2014). Based on the favourable findings recorded within this PhD research, the researcher submits that the Rapid-HOE programme developed is a promising therapeutic exercise option that can be considered for hand OA management and needs further studies to establish its efficacy.

10.1.4 Recommendations

10.1.4.1 Implications for clinical practice

1. Evidence-based recommendations have reported that exercise management that improves muscle strength and function, and reduces pain should be considered for all hand OA patients (Kloppenburg *et al.*, 2018). This PhD research has shown that the Rapid-HOE programme is a feasible exercise programme that meets such

recommendations and could be considered for hand OA management by patients and clinicians when its effectiveness is established.

10.1.4.2 Implications for research

1. The feasibility and proof of concept study of the Rapid-HOE programme in hand OA patients have been established. Positive findings from this study provide preliminary data for future RCTs in establishing the effectiveness of the Rapid-HOE programme within the patient population.
2. The feasibility study and proof of concept study (Study 5) did not have a follow-up phase, so it is uncertain whether the clinically improved gains seen after the completion of the exercise training were sustainable. Future trials to establish its long-term effectiveness are warranted.
3. Biomechanical assessment of the Rapid-HOE programme was not conducted as part of the study, so it is unknown whether the exercise programme has any effect on the joint deformities which therefore needs to be established through research.
4. Findings from both the systematic and scoping reviews (Chapters 4 and 5) identified the dearth of literature on hand OA from the African continent. This highlights the huge research gap within this region of the world and future research into the assessment, management and epidemiology is highly warranted. The PhD researcher is from Africa and is interested in raising the profile of exercise for OA there.

10.2 Final Conclusions

10.2.1 Study 1- Systematic review (Chapter 4)

1. Available hand OA guidelines recommend strengthening, stretching and joint mobility exercises for the management of the hand OA due to their beneficial effects on hand function, muscle strength and pain.
2. The implementation of such exercises by clinicians in practice may be challenging due to the lack of specific details regarding the type, intensity, and duration of the exercises, which therefore need to be established through research.

10.2.2 Study 2 - Scoping review (Chapter 5)

1. Six strengthening and ROM exercises were identified as commonly used exercises for hand OA management: (1) “making O sign”; (2) making a fist; (3) finger and thumb stretch; (4) grip strengthening; (5) pinch strengthening; and (6) thumb extension and abduction with elastic bands.

Based on the highlighted benefits and minimal related adverse effects, the inclusion of these exercise in hand OA programmes was proposed.

2. The best practice recommendations for exercise development and prescription were the American College of Sports Medicine (ACSM) guidelines and the Medical Research Council (MRC) guidance for developing and evaluating complex interventions, which should be followed for hand OA exercise development.
3. This scoping review adds to previous literature by highlighting the research gap regarding hand OA within the African continent, as no records were identified from that region. Future research into the assessment, management, and epidemiology of hand OA within this context is therefore highly warranted.
4. The scoping review also highlighted the gaps in exercise adherence reporting. Future authors are encouraged to document exercise adherence as this will not only facilitate the evaluation of the feasibility of the exercises by readers but also the ability of the authors themselves to assess the effects of these exercises. Positive strategies to inform this are telephone follow-up calls and exercise diaries.

10.2.3 Study 3 - Qualitative analysis study (Chapter 6)

1. Except for the elastic band exercises, which were difficult and painful to perform, participants acknowledged the OTTER exercise programme to have purposeful exercises with meaningful benefits on their hand OA symptoms.
2. Future thumb base OA exercise programmes should exclude elastic band exercises and explore alternative ways of achieving thumb abduction and extension strengthening exercises.
3. To ensure good adherence to thumb base OA exercise programmes, positive attitudes and exercise beliefs identified in patients should be considered and inculcated into hand OA exercise programmes for optimal exercise benefits in patients with thumb base OA. This can be achieved by discussing the beneficial impact of such attitudes on exercise performance during pre-training exercise briefings and periodic patient follow-ups, and additionally documenting these in exercise booklets (i.e. short statements) to encourage exercise performance.

10.2.4 Study 4 - proof of concept study (Chapter 7)

1. Rapid-force exercises increased pinch grip strength, which made it a suitable addition to hand grip strengthening exercise programme.
2. No changes were observed for hand grip strength. A longer duration exercise programme that is more comparable with previous studies that showed increased grip strength (12 weeks vs the present 6 weeks) or targeting isometric strength as well as rapid-force, may have a positive effect on hand grip strength.
3. The study showed a near significant effect of rapid-force exercises on hand grip rate ($p= 0.06$) and pinch grip rate (0.09) with small estimated effect sizes.
4. The concept of hand rapid-force exercises has been established in the hand of healthy volunteers. These exercises were found to be easy and simple, tolerable, and beneficial in improving hand and pinch rapid-force, maximal pinch strength and thenar muscle elasticity.
5. Hand rapid-force exercise is a promising dynamic hand strength exercise protocol to consider so warrants further studies with a larger sample for possible inclusion in hand strength training programmes.

10.2.5 Exercise development and PPI project (Chapter 8)

1. The Rapid-HOE programme was developed following an evidenced-based development approach.
2. The PPI partners consulted brought a wealth of knowledge to improve the content, presentation, and description of the Rapid-HOE programme and the planned feasibility study.
3. Based on relevant recommendations from the PPI discussions and the literature, the Rapid-HOE programme was revised to the version used in Chapter 9. Additionally, suggestions to improve the feasibility study were embedded into the design and conduct of the study.

10.2.6 Study 5 - Mixed methods study (Chapter 9)

1. The Rapid-HOE programme is novel, as it contains rapid-force hand exercises, which is an isotonic dynamic strength training concept known to have benefits in lower limb strength training and people with knee OA. It can be argued that the beneficial results found in the present study may be attributed to the complementary benefits of the rapid-force exercises within the Rapid-HOE programme.

2. The rapid HOE programme had a slight to large effect on hand pain, self-reported function, and physical health status (QoL), which established its proof of concept and feasibility in the study participants. Hence, it is a promising intervention for the hand OA management, and findings from this study provide preliminary data for a future RCT aimed at establishing its effectiveness.
3. Although found to be acceptable and practicable, recommendations for enhancement of the rapid-HOE programme include i) its adaptation to patient specific needs ii) revision of exercise instructions for better clarity and the iii) inclusion of exercise videos and statements of patient encouragement, which should be considered for future use.
4. High adherence to the rapid-HOE programme was recorded, which further establishes its feasibility, indicates its potential positive outcome, and provides evidence of a sustainable exercise programme that can easily be self-managed by people living with hand OA. That said, the PhD researcher acknowledges that such high adherence might also be attributed to the COVID-19 pandemic restrictions, with people having to stay at home. As such, study participants could focus on performing the Rapid-HOE exercises without much distraction and some were pleased to have something with a purpose to do.
5. Rapid-HOE programme improved only the physical functioning health status (HRQoL) of the study participants and not the mental, symptom and social health dimensions using the AIMS2-SF questionnaire. However, the relevant positive physical and psychological effects of the programme suggest an overall benefit for QoL of study participants, which needs to be tested with an instrument with better sensitivity and responsiveness other than the AIMS2-SF questionnaire.

END OF THESIS

Appendix A Systematic Review

A.1 Completed PRISMA Checklist for the Systematic review

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	29
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	N/A
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	30
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	30
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	31
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	31
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	32

Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	264 - 267
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	33
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	33
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	34
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	34
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	35
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	35

Section/topic	**#**	**Checklist item**	**Reported on page #**
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	35
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	N/A
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	36
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	38 - 40
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	41 - 43

Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	44 - 46
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	47
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	42 - 42
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	N/A
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	50- 52
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	52- 54
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	54
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	N/A

Source: Moher *et al.* (2009)

A.2 Search Strategies

A.2.1 CINAHL search strategy

#	Query
S1	(MM "Osteoarthritis/RH")
S2	(MM "Osteoarthritis, Wrist")
S3	arthritis
S4	osteoarthritis OR "osteoarthriti*"
S5	"degenerative joint disease"
S6	"OA"
S7	S1 OR S2 OR S3 OR S4 OR S5 OR S6
S8	(MM "Hand") OR "hand" OR (MH "Finger Joint")
S9	(MM "Carpal Joints") OR "carpals" OR wrist
S10	"phalangeal"
S11	(MM "Metacarpophalangeal Joint") OR "metacarpophalangeal"
S12	(MH "Fingers") OR (MH "Thumb")
S13	S8 OR S9 OR S10 OR S11 OR S12
S14	S7 AND S13
S15	(MM "Practice Guidelines")
S16	"clinical practice guideline"
S17	Clinical W1 (practice guideline*)
S18	"clinical recommendations"
S19	"Expert consensus reports"
S20	"Delphi Consensus report"
S21	"best clinical practice"
S22	"OARSI guidelines"
S23	"EULAR guidelines"
S24	"NICE guidelines"
S25	"SIGN guidelines"
S26	"consensus guidelines"
S27	"Discussion reports"
S28	"Clinical protocols"
S29	"Consensus meeting reports"
S30	"Evidence summaries"
S31	"Guideline summar*"
S32	"consensus statement"
S33	"Guideline statement"
S34	"Good Practice Points"
S35	"care pathways" or "clinical pathway" or "protocol based care" or "integrated care pathways"
S36	"standard operating procedures"
S37	S15 OR S16 OR S17 OR S18 OR S19 OR S20 OR S21 OR S22 OR S23 OR S24 OR S25 OR S26 OR S27 OR S28 OR S29 OR S30 OR S31 OR S32 OR S33 OR S34 OR S35 OR S36
S38	S14 AND S37

A.2.2 MEDLINE (Ebsco host) search strategy

#	Query
S1	(MM "Osteoarthritis")
S2	Osteoarthriti*
S3	""degenerative arthritis""
S4	S1 OR S2 OR S3
S5	(MM "Hand") OR "hand" OR (MM "Hand Joints")

#	Query
S6	(MH "Wrist") OR "wrist" OR (MH "Wrist Joint")
S7	(MH "Metacarpophalangeal Joint") OR (MH "Carpometacarpal Joints") OR "metacarpals"
S8	(MH "Finger Phalanges") OR (MH "Osteoarthropathy, Secondary Hypertrophic") OR "phalangeal"
S9	S5 OR S6 OR S7 OR S8
S10	S4 AND S9
S11	(MH "Practice Guidelines as Topic") OR (MH "Practice Guideline") OR (MH "Guideline")
S12	"clinical practice guidelines"
S13	(MH "Clinical Protocols")
S14	"clinical recommendations"
S15	""evidence-based recommendations""
S16	(MH "Consensus") OR (MH "Consensus Development Conference") OR ""Expert Consensus reports""
S17	""Delphi consensus report""
S18	"Delphi statement"
S19	""Best clinical practices""
S20	""EULAR guidelines""
S21	"NICE guidelines"
S22	"OARSI guidelines"
S23	"OARSI recommendations"
S24	"SIGN guidelines"
S25	consensus statement
S26	""Discussion papers""
S27	"Guideline summary"
S28	""Evidence-based practice summary""
S29	"Guideline statement"
S30	""Expert opinion consensus""
S31	""Good Practice Points""
S32	care pathways or clinical pathway or protocol based care or integrated care pathways
S33	S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19 OR S20 OR S21 OR S22 OR S23 OR S24 OR S25 OR S26 OR S27 OR S28 OR S29 OR S30 OR S31 OR S32
S34	S10 AND S33

A.2.3 AMED

#	Query
S1	Osteoarthritis
S2	osteoarthriti*
S3	"degenerative joint disease"
S4	"Joint arthritis"
S5	OA
S6	S1 OR S2 OR S3 OR S4 OR S5
S7	hand
S8	wrist
S9	"Carpal joints"
S10	"metatarsophalangeal joint"
S11	"Phalangeal joints"
S12	Finger OR Fingers OR Digits
S13	Thumb
S14	S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13
S15	S6 AND S14
S16	"Clinical Practice Guideline"
S17	"Practice Guidelines"
S18	"Clinical Recommendations" OR "Evidenced-based recommendations"
S19	"Expert Consensus Reports"
S20	"Expert Consensus"

#	Query
S21	"Delphi Consensus"
S22	"Best Clinical Practices"
S23	EULAR guidelines
S24	NICE Guidelines
S25	SIGN guidelines
S26	"OARSI guidelines" OR "OARSI recommendations"
S27	"Consensus guidelines"
S28	"Clinical Protocols"
S29	"Discussion Papers"
S30	"Evidence Summar*"
S31	Guideline Summar*
S32	Consensus statement
S33	"Good Practice Points"
S34	"Good Practice Points"
S35	care pathways or clinical pathway or protocol based care or integrated care pathways
S36	S16 OR S17 OR S18 OR S19 OR S20 OR S21 OR S22 OR S23 OR S24 OR S25 OR S26 OR S27 OR S28 OR S29 OR S30 OR S31 OR S32 OR S33 OR S34 OR S35
S37	S15 AND S36

A.2.4 Cochrane Library

ID Search
#1 Osteoarthritis:ti,ab
#2 Osteoarthriti*:ti,ab
#3 (Degenerative joint disease):ti,ab
#4 (non inflammatory joint disease)
#5 Osteoarthrosis:ti,ab
#6 OA:ti,ab
#7 (#1 or #2 or #3 or #4 or #5 or #6)
#8 hand
#9 (wrist joints):ti,ab or (carpal joints):ti,ab or trapeziometacarpal:ti,ab
#10 (metacarpophalangeal):ti,ab or (interpahalangeal):ti,ab or phalangeal:ti,ab
#11 (Finger* or Digit* or phalange* or thumb*):ti,ab
#12 (#8 or #9 or #10 or #11)
#13 (#7 and #12)
#14 (clinical practice guideline):ti,ab or (Practice guidelines):ti,ab or guidelines:ti,ab or (consensus guidelines):ti,ab
#15 (Clinical recommendations):ti,ab or (Clinical protocols):ti,ab
#16 (Expert consensus):ti,ab or (expert consensus report*):ti,ab or (Delphi consensus report*):ti,ab or (Discussion report*):ti,ab or (Consensus statement*) or (guideline statement*):ti,ab
#17 (Best clinical practice):ti,ab or (Good Practice Points):ti,ab
#18 (OARSI guideline*):ti,ab or (EULAR guideline*):ti,ab or (SIGN guideline*):ti,ab or (NICE guideline*):ti,ab
#19 (Guideline summar*):ti,ab or (Evidence summar*):ti,ab
#20 (Care pathway*):ti,ab or (clinical pathway*):ti,ab or (integrated care pathway*):ti,ab
#21 (#14 or #15 or #16 or #17 or #18 or #19 or #20)
#22 (#13 and #21) Publication Year from 1997 to 2017

A.2.5 Web of Science

Set	Search Terms
# 1	TS=("Osteoarthriti*") OR TS=("Arthriti*") OR TS=("Denegerative joint disease*")
# 2	TS=(Hand) OR TS=(wrist) OR TS=(Finger*) OR TS=(Digit*) OR TS=(Thumb)
# 3	TS=(carpal*) OR TS=(Metacarpal*) OR TS=(Trapeziometacarpal) OR TS=(interphalangeal) OR TS=(phalangeal)
# 4	#3 OR #2
# 5	#4 AND #1
# 6	TOPIC: ("Clinical practice guideline*") *OR* TOPIC: ("Practice guideline*") *OR* TOPIC: (Guideline*) *OR* TOPIC: ("Consensus guideline*")
# 7	TS=("Clinical recommendation*") OR TS=("Clinical protocol*") OR TS=("Expert consensus") OR TS=("expert consensus report*") OR TS=("Consensus statement*") OR TS=("Guideline statement*")
# 8	TS=("Best Clinical Practice") OR TS=("Good Practice Points") OR TS=("Guideline summar*") OR TS=("Evidence Summar*")
# 9	TS=("NICE guideline*") OR TS=("OARSI guideline*") OR TS=("SIGN guideline*") OR TS=("EULAR guideline*")
# 10	TS=("Care pathway*") OR TS=("integrated care pathway*") OR TS=("clinical pathway*")
# 11	#10 OR #9 OR #8 OR #7 OR #6
# 12	#11 AND #5
# 13	(#11 AND #5) Limiters: LANGUAGE= (English) *Timespan=1997-2017*

A.2.6 PEDro

Steps	Search Terms and Boolean Operators
1.	Hand osteoarthritis*clinical practice guidelines*
2.	osteoarthritis*clinical practice guidelines*

A.3 Data Extraction Instrument

<table>
<tr><th colspan="7">Guideline demographics</th></tr>
<tr><td colspan="2">Review ID:</td><td colspan="5">Reviewer:</td></tr>
<tr><td colspan="7">Guideline title:</td></tr>
<tr><td colspan="2">1st Author &Year of publication</td><td colspan="5"></td></tr>
<tr><td colspan="2">Country of origin/Geographical location</td><td colspan="5"></td></tr>
<tr><td colspan="2">Development organization</td><td colspan="5"></td></tr>
<tr><th colspan="7">Guideline Critical appraisal</th></tr>
<tr><td colspan="2">Overall quality of guideline</td><td colspan="5"></td></tr>
<tr><td colspan="2" rowspan="7">Overall guideline assessment</td><td colspan="5">Recommendation for use</td></tr>
<tr><td>Yes</td><td colspan="3">Yes, with modifications</td><td>No</td></tr>
<tr><td></td><td colspan="3"></td><td></td></tr>
<tr><td colspan="5">Include in review</td></tr>
<tr><td colspan="2">Yes</td><td colspan="3">No</td></tr>
<tr><td colspan="2"></td><td colspan="3"></td></tr>
<tr><td colspan="5"></td></tr>
<tr><th colspan="7">Guideline content</th></tr>
<tr><td colspan="2">Purpose of Guideline</td><td colspan="5"></td></tr>
<tr><td colspan="2" rowspan="2">Are exercises recommended</td><td colspan="3">Yes</td><td colspan="2">No</td></tr>
<tr><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td colspan="2">Exercise Recommendation</td><td colspan="5"></td></tr>
<tr><td colspan="2">Strength of recommendation</td><td colspan="5"></td></tr>
<tr><td colspan="2">Level of evidence</td><td colspan="5"></td></tr>
<tr><td rowspan="4">Content of Exercise recommended</td><td>Frequency</td><td colspan="5"></td></tr>
<tr><td>Intensity</td><td colspan="5"></td></tr>
<tr><td>Type</td><td colspan="5"></td></tr>
<tr><td>Time</td><td colspan="5"></td></tr>
<tr><td colspan="2">Adverse effects of exercises</td><td colspan="5"></td></tr>
</table>

A.4 AGREE II instrument

Domain	Item	AGREE II Rating						
		1 *Strongly Disagree*	2	3	4	5	6	7 *Strongly Agree*
Scope and purpose	1. The overall objective(s) of the guideline is (are) specifically described.							
	2. The health question(s) covered by the guideline is (are) specifically described.							
	3. The population (patients, public, etc.) to whom the guideline is meant to apply is specifically described.							
Stakeholder involvement	4. The guideline development group includes individuals from all the relevant professional groups.							
	5. The views and preferences of the target population (patients, public, etc.) have been sought.							
	6. The target users of the guideline are clearly defined.							
Rigor of development	7. Systematic methods were used to search for evidence.							
	8. The criteria for selecting the evidence are clearly described.							
	9. The strengths and limitations of the body of evidence are clearly described.							
	10. The methods for formulating the recommendations are clearly described.							
	11. The health benefits, side effects and risks have been considered in formulating the recommendations.							
	12. There is an explicit link between the recommendations and the supporting evidence.							
	13. The guideline has been externally reviewed by experts prior to its publication.							
	14. A procedure for updating the guideline is provided.							
Clarity of presentation	15. The recommendations are specific and unambiguous.							
	16. The different options for management of the condition or health issue are clearly presented.							
	17. Key recommendations are easily identifiable.							
Applicability	18. The guideline describes facilitators and barriers to its application.							
	19. The guideline provides advice and/or tools on how the recommendations can be put into practice.							
	20. The potential resource implications of applying the recommendations have been considered.							
	21. The guideline presents monitoring and/ or auditing criteria.							
Editorial independence	22. The views of the funding body have not influenced the content of the guideline.							
	23. Competing interests of guideline development group members have been recorded and addressed.							
Overall Guideline Assessment	1. Rate the overall quality of this guideline.	1 *Lowest possible quality*	2	3	4	5	6	7 *Highest possible quality*
Overall Guideline Assessment	2. I would recommend this guideline for use.	*Yes*	*Yes, with modifications*					*No*

A.5 Summary of Searches

Published Databases		Grey Literature sources		Other sources	Records Retrieved
Databases	**Records Retrieved**	**Databases & Organizational websites**	**Records Retrieved**		
AMED	0	African League of Associations for Rheumatology	0	Citation checking	3
		Agency for healthcare Research and Quality	0		
		AGREE collaboration	0		
CINAHL	18	American College of Rheumatology	1 (Process of development) https://www.rheumatology.org/Practice-Quality/Clinical-Support/Clinical-Practice-Guidelines/Osteoarthritis		
		Arthritis Research UK	0		
		Canadian Institute of Health Research	0		
Cochrane library	314	Chinese Guideline Clearing House	0	Reference tracking	6
		Epistemonikos	1		
		EULAR	2		
JBI database	0				
MEDLINE	75	Evidence for Policy and Practice Information Centre (EPPI-centre)	0		
		Guidelines International Network	4		
		Kings Fund	0		
Pedro	25	National electronic library for health	0		
		National Health and Medical Research Council (NHMRC)	0		
		National Guideline Clearing House (USA)	2		
		NICE Evidence search	1		
		OARSI	0		
Web of Science	235	SIGN	0		
		TRIP clinical search engine	0		
		World Health Organization	0		
Total	667		10		9

A.6 Reasons for Exclusion after Full Text Screening

Records	Reason for exclusion
Conaghan et al (Conaghan *et al.*, 2008)	Guideline summary of NICE guideline 59 (older version of NICE 177)
Hunter et al (Hunter *et al.*, 2015)	Recommendations of hand imaging
Kloppenberg et al (Kloppenburg *et al.*, 2014)	Evidence on imagery options for hand OA assessment
Leonelli et al (Leonelli *et al.*, 2012)	Primary research
National collaborating centre (National Collaborating Centre for Chronic Conditions (UK), 2008)	NICE guideline 59 (older version of NICE guideline 177)
NICE guideline 177 (National Guideline Clearinghouse (NGC), 2014)	Guideline from a difference source-National guideline clearing house
NICE guideline 177 from NICE website (National Institute for Health and Care Excellence, 2014)	Duplicate Document
Brosseau et al (Brouwers *et al.*, 2010a)	Literature review
Ilieva et al (Ilieva *et al.*, 2013)	Narrative review
Creamer et al (Creamer *et al.*, 1998)	Narrative review (content on hip and knee OA, nothing on hand OA)
Combe et al (Combe *et al.*, 2017)	12 Recommendation non-pharmacologic interventions with dynamic exercises for early arthritis, however evidence was based on rheumatoid arthritis rather than OA. There was also general reporting on early OA with no focus on the hand.
Katz et al (Katz *et al.*, 2001).	Evidence on recommended exercise prescription for general OA with no focus on the hand
Zhang et al (Zhang *et al.*, 2007).	An outdated version. Updated version was published in the course of the manuscript preparation (i.e. Kloppenburg et al. 2018)

A.7 Critical Appraisal of all Guidelines and Recommendations with Reviewers' Comments using the AGREE 11

A.7.1 ACR Recommandation (Hochberg *et al.*, 2012)

Domain	Item	AGREE II Rating							Reviewers' reason for rating	Location in guideline
		1 *Strongly Disagree*	2	3	4	5	6	7 *Strongly Agree*		
Scope and purpose	1. The overall objective(s) of the guideline is (are) specifically described.							√	This criterion was fully addressed. Objective was clearly stated	After authors' list
	2. The health question(s) covered by the guideline is (are) specifically described.							√	This criterion was addressed. Health question clearly stated in the manuscript	abstract
	3. The population (patients, public, etc.) to whom the guideline is meant to apply is specifically described.							√	Exceptional quality reporting of this criterion. The population i.e. patients with hand, hip and knee OA was stated	Appendix A
Stakeholder involvement	4. The guideline development group includes individuals from all the relevant professional groups.							√	Guideline development members were stated in the manuscript	
	5. The views and preferences of the target population (patients, public, etc.) have been sought.						√		Criterion was clearly reported i.e. the literature review, consulting with experts. These two were explicitly reported but no patient -public engagement was done hence the overall score was downgraded	
	6. The target users of the guideline are clearly defined.							√	Criterion was explicitly addressed i.e. Health care providers in the management of patients with symptomatic OA were reported as the target users of the guideline	Page 472
Rigor of development	7. Systematic methods were used to search for evidence.							√	Criterion was explicitly reported	
	8. The Criterion for selecting the evidence are clearly described.							√	Criterion was reported clearly with additional online supplementary material available.	Page 466-467
	9. The strengths and limitations of the body of evidence are clearly described.							√	Criterion was addressed e.g. Use of the GRADE approach in grading the evidence was documented	
	10. The methods for formulating the recommendations are clearly described.							√	This Criterion was well explained, The GRADE approach was used in formulating recommendations	
	11. The health benefits, side effects and risks have been considered in formulating the recommendations.							√	This was considered in the formulating the recommendations and was explicitly reported	Page 467
	12. There is an explicit link between the recommendations and the supporting evidence.							√	Criterion was addressed i.e. strong recommendations based on systematic reviews and metanalysis	
	13. The guideline has been externally reviewed by experts prior to its publication.							√	Exceptional quality reporting of this criterion. Draft manuscript for this recommendation was peer-reviewed by three different committees: ACR Guideline Subcommittee, ACR Quality of Care Committee, and ACR Board of Directors for their comments and votes of	Page 468

Appendix A

Domain	Item	AGREE II Rating							Reviewers' reason for rating	Location in guideline
		1 ***Strongly Disagree***	**2**	**3**	**4**	**5**	**6**	**7 *Strongly Agree***		
									approval before the submission of the manuscript for publication	
	14. A procedure for updating the guideline is provided.							√	Criterion was clearly stated and addressed i.e. Authors stated that the recommendation will be updated periodically based on changing evidence	Page. 465
Clarity of presentation	15. The recommendations are specific and unambiguous.							√	Criterion fully addressed	Pages 468, 469
	16. The different options for management of the condition or health issue are clearly presented.							√	Criterion met and fully addressed (stated in the recommendations)	
	17. Key recommendations are easily identifiable.							√	Exceptional quality reporting of this criterion e.g. Recommendations were tabulated and easily identifiable in the guideline document	Page 471
Applicability	18. The guideline describes facilitators and barriers to its application.						√		Criterion was adequately addressed. This was subtly mentioned and not easily located in the manuscript hence the highest score was downgraded	Page 466
	19. The guideline provides advice and/or tools on how the recommendations can be put into practice.					√			Adequate quality reporting of this criterion. Brief statements on how the guideline were used was mentioned but the authors failed to provide content on resources such as guideline summary, how-to manuals, etc. This therefore downgraded the overall score	
	20. The potential resource implications of applying the recommendations have been considered.	√							No information relevant to this Criterion was reported (Authors however reported their lack of consideration of the cost of care in their recommended interventions)	Page 468
	21. The guideline presents monitoring and/ or auditing Criterion.	√							No information on this Criterion was reported	
Editorial independence	22. The views of the funding body have not influenced the content of the guideline.						√		Adequate reporting of this criterion. Names of funders and sponsors of authors were explicitly stated but there was no clear statement indicating the funding bodies did not influence the content of the guideline	Page 466
	23. Competing interests of guideline development group members have been recorded and addressed.							√	Exceptional quality reporting of this criterion. Members of the group who had competing interests were recused from discussions that concerned them.	Page 467
Overall Guideline Assessment	Rate the overall quality of this guideline.	1 *Lowest possible quality*	2	3	4	**5**	6	7 *Highest possible quality*		
Overall Guideline Assessment	I would recommend this guideline for use.	Yes	Yes, with modification					No		
		√								

A.7.2 EULAR Recommendation (Kloppenburg *et al.*, 2018) Critical Appraisal

Domain	Item	AGREE II Rating							Reviewers' reason for rating	Location in guideline
		1 *Strongly Disagree*	2	3	4	5	6	7 *Strongly Agree*		
Scope and purpose	1. The overall objective(s) of the guideline is (are) specifically described.							√	Criterion fully met as required by AGREE II	Page 1
	2. The health question(s) covered by the guideline is (are) specifically described.							√	Criterion fully met; this guideline is an updated version of the 2007 EULAR guideline for hand OA	Page 1
	3. The population (patients, public, etc.) to whom the guideline is meant to apply is specifically described.							√	Exceptional quality reporting of this criterion. A population of hand OA was described	Page 1
Stakeholder involvement	4. The guideline development group includes individuals from all the relevant professional groups.							√	Exceptional quality reporting of this criterion. A detailed list of 19 experts including doctors, PTs, OTs, rheumatologist, etc. were documented including their names, institutions and affiliations were recorded	Pages 1and 7
	5. The views and preferences of the target population (patients, public, etc.) have been sought.							√	Criterion was fully met as two patient representatives with hand OA were included in the task force that developed the Recommendations	
	6. The target users of the guideline are clearly defined.							√	Criterion fully met as people with hand OA and health professionals that treat OA were documented as the target users	
Rigor of development	7. Systematic methods were used to search for evidence.							√	Criterion fully met as a systematic literature review was conducted to inform the recommendation development(Kroon *et al.*, 2018a). Further details reported in a slide deck on the EULAR website (https://www.eular.org/recommendations_management.cfm).	Pages 1 and 2
	8. The Criterion for selecting the evidence are clearly described.							√	Exceptional quality reporting of this criterion. Content explicitly explained in the published SLR (Kroon *et al.*, 2018a). Further details on this was reported in the available slide deck on the EULAR website (https://www.eular.org/recommendations_management.cfm) A description of how the evidence was graded e.g. Level of evidence, agreement and grades of recommendation were explicitly explained as recommended by AGREE II	Page 2 (Kroon *et al.*, 2018a)
	9. The strengths and limitations of the body of evidence are clearly described.							√	Exceptional quality reporting of this criterion. The strengths and limitations were not clearly defined in the Recommendation document but explicitly reported in the accompanying SLR (Kroon *et al.*, 2018a) on page 16. In the review, the risk of bias was assessed as well	Page 16 of Kroon et al, 2018

Appendix A

Domain	Item	AGREE II Rating							Reviewers' reason for rating	Location in guideline
		1 *Strongly Disagree*	2	3	4	5	6	7 *Strongly Agree*		
	10. The methods for formulating the recommendations are clearly described.							√	Criterion was fully met by the recommendation developers as the process for the SLR, survey and the voting process by all taskforce development members was reported	Page 1 & 2
	11. The health benefits, side effects and risks have been considered in formulating the recommendations.						√		Criterion was adequately considered and addressed but full score was downgraded, as item content was not easily located in the article. Additional content was found in the accompanying SLR	Page 4
	12. There is an explicit link between the recommendations and the supporting evidence.							√	Criterion fully met as an explicit link between the recommendations and supporting evidence was made and reported. An example can be found in the level of evidence and grades of recommendations used in the formulating the recommendations	Table1 & page 2
	13. The guideline has been externally reviewed by experts prior to its publication.						√		Authors documented that the article (EULAR 2018 Recommendation) was externally peered reviewed as required by the AGREE II but the details (e.g., Reviewers, their affiliations, the external peer review process, etc.) were not reported. This therefore downgraded the overall score to 6	Page 7
	14. A procedure for updating the guideline is provided.							√	A clear statement of when the update was developed was reported although the exact time was not documented. (e.g. The authors stated that an update was published when enough evidence on current treatment options or new therapies were published.)	Page 7
Clarity of presentation	15. The recommendations are specific and unambiguous.							√	Criterion was fully met and addressed. The recommendations were clearly stated, tabulated, and was easily located in the article	Page 2
	16. The different options for management of the condition or health issue are clearly presented.							√	Criterion fully met	Pages 3-6
	17. Key recommendations are easily identifiable.							√	Criterion was clearly met as 5 overarching principles which clearly answers the review questions on hand OA was stated. These were tabulated and easily seen in the manuscript	Page 2
Applicability	18. The guideline describes facilitators and barriers to its application.							√	Criterion fully met and addressed. Facilitators such as slide deck to aid with lay summaries are available on the EULAR website. Authors also stated that without the accompanying text or SLR, reading or interpreting the recommendations may be difficult	Page 7
	19. The guideline provides advice and/or tools on how the recommendations can be put into practice.							√	Criterion met and addressed optimally. Authors discussed different modes of disseminating and implementing the recommendations e.g. Slide deck on the EULAR website, national conferences, societies, etc.	Page 7

Domain	Item	AGREE II Rating							Reviewers' reason for rating	Location in guideline
		1 *Strongly Disagree*	2	3	4	5	6	7 *Strongly Agree*		
	20. The potential resource implications of applying the recommendations have been considered.							√	Criterion fully met as authors stated accompanying resources to aid the reading and interpretation of the recommendations e.g. Authors recommended the use of the text in the published Recommendation (article) together with the SLR to enhance the comprehension of the Recommendation.	Page 7
	21. The guideline presents monitoring and/ or auditing Criterion.						√		Criterion was adequately addressed but not explicitly. Total score was downgraded to "6" based on the following 1. The need for further monitoring was recognized by the authors and requested for further research enquiry 2. Authors also stated although not explicitly that monitoring of new therapies and research will be conducted to inform the update of the 2018 EULAR recommendation however, no clear date was given	
Editorial independence	22. The views of the funding body have not influenced the content of the guideline.						√		The funder (EULAR) was clearly stated but an explicit statement explaining that the funders do not have influence on the authors and the recommendation developers was not stated as recommended by the AGREE II. This therefore downgraded the overall score to 6	
	23. Competing interests of guideline development group members have been recorded and addressed.							√	Criterion was met and addressed. All authors 'competing interest were clearly stated	Page 7
Overall Guideline Assessment	Rate the overall quality of this guideline.	1 *Lowest possible quality*	2	3	4	5	6	7 *Highest possible quality*		
Overall Guideline Assessment	I would recommend this guideline for use.	Yes	Yes, with modification					No		
		√								

A.7.3 NICE Critical Appraisal

Domain	Item	AGREE II Rating							Reviewers' reason for rating	Location in guideline
		1 ***Strongly Disagree***	**2**	**3**	**4**	**5**	**6**	**7** ***Strongly Agree***		
Scope and purpose	1. The overall objective(s) of the guideline is (are) specifically described.				√				This criterion was adequately addressed, the overall score was however downgraded as this was not clearly explicit in the guideline document. The guideline objective is not clearly described although an inference of the purpose can be deduced from the title which is to provide a guideline on the care and management of OA in adults. Additional appendix document which was accessed from NICE guideline (*provided upon request from NICE*) stated the purpose is also to update the 2008 guideline on OA.	Supplementary Guideline Appendix
	2. The health question(s) covered by the guideline is (are) specifically described.							√	Criterion fully addressed i.e. the health question was clearly described	Page 23
	3. The population (patients, public, etc.) to whom the guideline is meant to apply is specifically described.							√	Full criterion met as population to whom the guideline is meant to apply to was described e.g. people with OA of the knee, hip and hand)	
Stakeholder involvement	4. The guideline development group includes individuals from all the relevant professional groups.						√		Criterion was adequately addressed. The names and roles of the guideline development group were clearly reported however, their geographical location and institutions as recommended for grading the criterion were not reported. This therefore downgraded the overall score to 6	
	5. The views and preferences of the target population (patients, public, etc.) have been sought.							√	Criterion was fully met, as there were two patient members on the guideline development group. Additionally, qualitative study on patient experiences were included in the evidence of the guideline which somewhat justifies the inclusion of patient preferences and views	
	6. The target users of the guideline are clearly defined.							√	Exceptional reporting of this criterion i.e. Health professionals were clearly described as the target users of the guideline	
Rigor of development	7. Systematic methods were used to search for evidence.							√	Exceptional quality reporting of this criterion	Page 25 and Guideline Appendices
	8. The Criterion for selecting the evidence are clearly described.							√	Exceptional quality reporting of this criterion	Guideline Appendices
	9. The strengths and limitations of the body of evidence are clearly described.							√	Full criterion and its articulations reported	
	10. The methods for formulating the recommendations are clearly described.							√	Exceptional quality reporting of this criterion i.e. The GRADE approach was used in formulating the recommendations	Page 29

Domain	Item	AGREE II Rating							Reviewers' reason for rating	Location in guideline
		1 ***Strongly Disagree***	**2**	**3**	**4**	**5**	**6**	**7** ***Strongly Agree***		
	11. The health benefits, side effects and risks have been considered in formulating the recommendations.							√	The Criterion for this AGREEII item was explicitly met and reported	
	12. There is an explicit link between the recommendations and the supporting evidence.							√	Exceptional quality reporting of this criterion. The guideline development group used evidence to inform their recommendations	Page 107
	13. The guideline has been externally reviewed by experts prior to its publication.							√	Full Criterion reported in the guideline e.g. a statement of a 6 weeks consultation was done.	Page 36
	14. A procedure for updating the guideline is provided.							√	Full criterion and its articulations exceptionally addressed and reported	Page 37
Clarity of presentation	15. The recommendations are specific and unambiguous.							√	Exceptional quality reporting of this criterion i.e. Recommendations were clearly listed, was unambiguous and specific	Page 41-45
	16. The different options for management of the condition or health issue are clearly presented.							√	Full criterion and its articulations met	
	17. Key recommendations are easily identifiable.							√	Full criterion addressed i.e. easily located in the guideline as recommended by AGREE II	
Applicability	18. The guideline describes facilitators and barriers to its application.							√	Full criterion addressed	Page 40
	19. The guideline provides advice and/or tools on how the recommendations can be put into practice.							√	Exceptional quality reporting of this criterion i.e. References to algorithms, guidance and guideline summaries were reported	Page 38
	20. The potential resource implications of applying the recommendations have been considered.							√	Exceptional quality reporting of this criterion i.e. Economic evaluations for the recommended interventions were made	Page 67
	21. The guideline presents monitoring and/ or auditing Criterion.							√	Exceptional quality reporting of this criterion e.g. Page 40 has the auditing for the guideline implementation process	Page 40
Editorial independence	22. The views of the funding body have not influenced the content of the guideline.						√		The funding body i.e. NICE (National Institute for Health and Care Excellence) was clearly stated however, no explicit statement on the lack of influence on the guideline development process was stated. This therefore downgraded the overall score by one.	Page 3
	23. Competing interests of guideline development group members have been recorded and addressed.							√	Exceptional quality reporting of this criterion i.e. Conflicts of interests declared by all guideline development group members	Page 21

Domain	Item	AGREE II Rating							Reviewers' reason for rating	Location in guideline
		1 ***Strongly Disagree***	**2**	**3**	**4**	**5**	**6**	**7** ***Strongly Agree***		
Overall Guideline Assessment	Rate the overall quality of this guideline.	1 *Lowest possible quality*	2	3	4	5	6	7 *Highest possible quality*		
Overall Guideline Assessment	I would recommend this guideline for use.	Yes	Yes, with modification					No		
		√								

A.7.4 Ottawa (2018) Critical Appraisal

Domain	Item	AGREE II Rating							Reviewers' reason for rating	Location in guideline
		1 *Strongly Disagree*	**2**	**3**	**4**	**5**	**6**	**7** *Strongly Agree*		
Scope and purpose	1. The overall objective(s) of the guideline is (are) specifically described.							√	Criterion fully met as objective was explicitly stated	Page 2 and 3
	2. The health question(s) covered by the guideline is (are) specifically described.							√	This criterion was explicitly addressed by the guideline developers e.g. The guideline looked specifically at therapeutic exercise management in hand OA	
	3. The population (patients, public, etc.) to whom the guideline is meant to apply is specifically described.							√	Criterion clearly met and addressed. A clear indication of people with hand OA i.e. Those with (fingers and base of thumb reported)	Pages 1 and 2
Stakeholder involvement	4. The guideline development group includes individuals from all the relevant professional groups.						√		This criterion was adequately met but the overall score was downgraded by one as the composition and disciplines of the guideline development group was not reported despite the fact that their institutions were reported.	
	5. The views and preferences of the target population (patients, public, etc.) have been sought.							√	Criterion was fully met and explicitly reported. Authors reported the inclusion of one patient rep in the expert panel	Page 2
	6. The target users of the guideline are clearly defined.							√	Criterion was explicitly addressed	Page 3
Rigor of development	7. Systematic methods were used to search for evidence.							√	Criterion was fully met and explicitly addressed i.e. Full details of the search was documented in the supplementary material 2 as well as the published guideline itself.	Supplementary material 2; page 4
	8. The Criterion for selecting the evidence are clearly described.							√	Exceptional reporting of this criterion i.e. A clear inclusion and exclusion Criterion were explicitly documented.	Appendix 3; supplementary material 2
	9. The strengths and limitations of the body of evidence are clearly described.							√	Exceptional reporting of this criterion	Page 17-19

Domain	Item	AGREE II Rating							Reviewers' reason for rating	Location in guideline
		1 *Strongly Disagree*	**2**	**3**	**4**	**5**	**6**	**7** *Strongly Agree*		
	10. The methods for formulating the recommendations are clearly described.							√	Criterion explicitly met and addressed i.e. The process of recommendation formulation was described both in published guideline and the supplementary material 2 Guideline developers used online Delphi questionnaire and the use of the level and strength of evidence proposed by an international expert panel	Appendix 2
	11. The health benefits, side effects and risks have been considered in formulating the recommendations.							√	Criterion explicitly met and addressed. Various exercise interventions were reviewed in relation to their effects and specific outcome measures	
	12. There is an explicit link between the recommendations and the supporting evidence.							√	Exceptional quality reporting of this criterion Recommendations were based on the underlying evidence and graded according to a previously used Ottawa grading system (A-F i.e. Hierarchical alphabetical order)	Page 2
	13. The guideline has been externally reviewed by experts prior to its publication.						√		Criterion was adequately addressed as authors stated that the recommendations were endorsed by experts. However, the overall score was downgraded to 6 as the authors were not explicit as to whether this group was external and was not part of the guideline development group.	Page 17
	14. A procedure for updating the guideline is provided.	√							No documentation on updates (time, etc.) were reported by authors.	
Clarity of presentation	15. The recommendations are specific and unambiguous.					√			Criterion was not adequately addressed hence the overall score was downgraded to 5. Recommendations although stated were not concise and appear somewhat ambiguous as one had to make inferences from the written documents despite all the composites that informs this criterion were provided Generally, the recommendations were poorly presented and not easily identified in the guideline document	Pages 6-12
	16. The different options for management of the condition or health issue are clearly presented.						√		Criterion was adequately addressed Different treatment options were provided however, the total score was downgrade since the treatment options were not clearly identifiable in the guideline document	Pages 6-12
	17. Key recommendations are easily identifiable.							√	Full criterion was met as the key recommendations were tabulated	Page 20
Applicability	18. The guideline describes facilitators and barriers to its application.						√		Criterion was not fully addressed. The total score was downgraded to 6 as the content was not clearly documented and easily identifiable in the guideline. The authors reported that sufficient research was not available to adequately support positive recommendations and therefore highlighted areas that needed further research enquiry to support their recommendation	Page 20
	19. The guideline provides advice and/or tools on how the recommendations can be put into practice.	√							Criterion was not adequately addressed. Authors provided links to online supplementary materials for the purposes of aiding the guideline users appreciate the underlying systematic review and supporting evidence and not necessarily to provide ways to implement the recommendations Tools and resources to support the implementation of the guideline recommendations were not provided	
	20. The potential resource implications of applying the recommendations have been considered.	√							Criterion was not addressed	
	21. The guideline presents monitoring and/ or auditing Criterion.	√							This criterion was not addressed. Plans for evaluating or monitoring of the guideline was not reported..	

Domain	Item	AGREE II Rating							Reviewers' reason for rating	Location in guideline
		1 *Strongly Disagree*	**2**	**3**	**4**	**5**	**6**	**7** *Strongly Agree*		
Editorial independence	22. The views of the funding body have not influenced the content of the guideline.						√		Criterion was adequately met and addressed. Guideline developers disclosed their funding body; however, the total score was downgrade to 6 as no explicit statement regarding the views of the funders was reported	Page 20
	23. Competing interests of guideline development group members have been recorded and addressed.							√	Criterion fully met and addressed as authors declared no conflict of interest	
Overall Guideline Assessment	1. Rate the overall quality of this guideline.	**1** *Lowest possible quality*	**2**	**3**	**4**	**5**	**6**	**7** *Highest possible quality*	Criterion fully met and addressed as authors declared no conflict of interest	
Overall Guideline Assessment	2. I would recommend this guideline for use.	Yes	Yes, with modification					No		
		√							Although recommended based on its overall score, the reviewers suggest the following modification of future Ottawa guidelines 1.The presentation of the guideline recommendations should be reviewed. In future guideline reporting, recommendations should be clearly and concisely written for easy identification, reporting and interpretation 2.Due to the inadequate information provided regarding its effective application and implementation of the recommendations, it would be appropriate for authors to follow a more structured approach for the reporting of guidelines such as the AGREE II Reporting checklist, which is highly recommended in literature as the most reliable instrument for the reporting guidelines(Brouwers *et al.*, 2016) This will allow for the a. Easy interpretation of the guideline document and its recommendations b. General conformity to international and highly recommended guideline development standards	

A.7.5 Ottawa (2005) Critical Appraisal

Domain	Item	AGREE II Rating							Reviewers' reason for rating	Location in guideline
		1 ***Strongly Disagree***	**2**	**3**	**4**	**5**	**6**	**7** ***Strongly Agree***		
Scope and purpose	1. The overall objective(s) of the guideline is (are) specifically described.							√	Full Criterion met	
	2. The health question(s) covered by the guideline is (are) specifically described.							√	This criterion was fully met i.e. The health question was well documented in the abstract and the body of the guideline	
	3. The population (patients, public, etc.) to whom the guideline is meant to apply is specifically described.							√	Full criterion met e.g. Patients over 18 years with OA was reported to be whom the guideline was meant to apply	Page 909

Domain	Item	AGREE II Rating 1 *Strongly Disagree*	2	3	4	5	6	7 *Strongly Agree*	Reviewers' reason for rating	Location in guideline
Stakeholder involvement	4. The guideline development group includes individuals from all the relevant professional groups.							√	The criterion and its articulations were fully addressed. All members with their names, role, institutions and geographical locations were explicitly reported	Page 908
	5. The views and preferences of the target population (patients, public, etc.) have been sought.							√	Criterion adequately reported. A patient representative was part of the guideline development group	
	6. The target users of the guideline are clearly defined.							√	Full criterion met and reported e.g. Patients, PTs, OTs, etc. were reported as the target users	Page 909
Rigor of development	7. Systematic methods were used to search for evidence.							√	Exceptional quality reporting of this criterion and its articulations	
	8. The Criterion for selecting the evidence are clearly described.							√	Exceptional quality reporting of this criterion. The panel developed and used a point-based system on the study design and expert consensus e.g. RCTs were graded as high, etc.	
	9. The strengths and limitations of the body of evidence are clearly described.							√	Exceptional quality reporting of this criterion. Panel commented on some of the strengths and limitations of the body of evidence	
	10. The methods for formulating the recommendations are clearly described.							√	Full Criterion and its articulations addressed and reported. An expert panel developed a set of Criterion for grading the recommendations	Page 909
	11. The health benefits, side effects and risks have been considered in formulating the recommendations.	√							Poor information on this criterion was reported	
	12. There is an explicit link between the recommendations and the supporting evidence.							√	Full criterion met and addressed	
	13. The guideline has been externally reviewed by experts prior to its publication.							√	Full criterion was met i.e. Guideline was reviewed by an expert panel	
	14. A procedure for updating the guideline is provided.	√							No information relevant to this AGREE criterion was reported	
Clarity of presentation	15. The recommendations are specific and unambiguous.						√		Criterion was adequately addressed. However, the overall score was downgraded by a score as the recommendations were ambiguous and not easily comprehensible	
	16. The different options for management of the condition or health issue are clearly presented.	√							Poor reporting of this criterion	
	17. Key recommendations are easily identifiable.							√	Full Criterion addressed and reported e.g. Recommendations were reported and easily located in the document as they were boldened and italics	
Applicability	18. The guideline describes facilitators and barriers to its application.						√		Facilitators such as guideline summaries as shown in appendix 4 was rewritten and reported following expert review of the guideline. However, there were no explicit comments on the barriers the guideline application.	
	19. The guideline provides advice and/or tools on how the recommendations can be put into practice.							√	Criterion fully met and reported	Page 946
	20. The potential resource implications of applying the recommendations have been considered.	√							No information on this criterion was reported	
	21. The guideline presents monitoring and/ or auditing Criterion.	√							No information on this criterion was reported	
Editorial independence	22. The views of the funding body have not influenced the content of the guideline.						√		Criterion adequately addressed as funding bodies were reported but the overall score was downgraded as an	Page 908

Domain	Item	AGREE II Rating 1 *Strongly Disagree*	2	3	4	5	6	7 *Strongly Agree*	Reviewers' reason for rating	Location in guideline
									explicit statement declaring the lack of influence on the funders in the guideline development was not stated	
	23. Competing interests of guideline development group members have been recorded and addressed.							√	Criterion was fully addressed as competing interests for the lead author (Lucie Brosseau) was reported	Page 908
Overall Guideline Assessment	Rate the overall quality of this guideline.	1 *Lowest possible quality*	2	3	4	**5**	6	7 *Highest possible quality*		
Overall Guideline Assessment	I would recommend this guideline for use.	Yes	Yes, with modification					No		
		√								

A.7.6 PANLAR (Rillo *et al.*, 2016) Critical Appraisal

Domain	Item	AGREE II Rating 1 *Strongly Disagree*	2	3	4	5	6	7 *Strongly Agree*	Reviewers' reason for rating	Location in guideline
Scope and purpose	1. The overall objective(s) of the guideline is (are) specifically described.							√	Criterion fully addressed and reported	Page 346
	2. The health question(s) covered by the guideline is (are) specifically described.							√	Criterion explicitly reported	Page 346
	3. The population (patients, public, etc.) to whom the guideline is meant to apply is specifically described.							√	Exceptional quality reporting of this criterion	Page 346
Stakeholder involvement	4. The guideline development group includes individuals from all the relevant professional groups.						√		Criterion was adequately reported but the overall score was downgraded because the Recommendation development group was devoid of Allied health professionals, a relevant professional group who play a significant role in the management of OA e.g. PTs, OTs, etc.	
	5. The views and preferences of the target population (patients, public, etc.) have been sought.							√	Criterion fully addressed and reported as the consensus development group included three patient representatives	Page 346
	6. The target users of the guideline are clearly defined.							√	Criterion fully addressed i.e. Health care providers who manage the condition were reported as the target users of the Recommendations	Page 350
Rigor of development	7. Systematic methods were used to search for evidence.							√	The full criterion and its articulations were clearly documented and reported.	Page 346
	8. The Criterion for selecting the evidence are clearly described.							√	The full criterion and its articulations were clearly documented and reported	Page 346
	9. The strengths and limitations of the body of evidence are clearly described.	√							No information on this criterion was reported	

Domain	Item	AGREE II Rating							Reviewers' reason for rating	Location in guideline
		1 *Strongly Disagree*	2	3	4	5	6	7 *Strongly Agree*		
	10. The methods for formulating the recommendations are clearly described.							√	Criterion fully addressed and reported e.g. Three Delphi rounds were conducted (Delphi Technique)	Page 346
	11. The health benefits, side effects and risks have been considered in formulating the recommendations.							√	Information on this criterion was addressed and reported	Page 350
	12. There is an explicit link between the recommendations and the supporting evidence.							√	Criterion fully met and reported. Recommendations were formulated based on the American Heart Association Evidence-based scoring system.	Some examples on page 346-347
	13. The guideline has been externally reviewed by experts prior to its publication.						√		Criterion was adequately addressed. Authors reported that the editing of the final recommendation document conducted by an editorial committee. The overall score was however downgraded because the descriptions of the external reviewers (e.g. Affiliations, number, etc.) were not described	
	14. A procedure for updating the guideline is provided.	√							No information on this criterion was reported	
Clarity of presentation	15. The recommendations are specific and unambiguous.						√		Criterion was adequately addressed. The formulated recommendations were tabulated, conspicuous and easily identifiable in the Consensus document however, the overall score was downgraded to 6 because the intent of the recommended action e.g. whether to improve the quality of life, decrease side effects, etc. as indicated scoring this criterion was not well reported.	Pages 346-347
	16. The different options for management of the condition or health issue are clearly presented.							√	Criterion was fully addressed and reported	
	17. Key recommendations are easily identifiable.							√	Criterion was fully addressed and reported	
Applicability	18. The guideline describes facilitators and barriers to its application.						√		Adequate reporting of this criterion however, the overall score was downgraded the authors reported facilitators to the application of the Recommendation with no content on the barriers	Pages 346-347
	19. The guideline provides advice and/or tools on how the recommendations can be put into practice.	√							No information on this criterion was reported	
	20. The potential resource implications of applying the recommendations have been considered.	√							No information on this criterion was reported	
	21. The guideline presents monitoring and/ or auditing Criterion.		√						Criterion was poorly reported. Brief content on monitoring was reported under pharmacological modalities (not relevant to exercise intervention)	Page 347
Editorial independence	22. The views of the funding body have not influenced the content of the guideline.						√		Adequate reporting of this criterion. The source of funding was reported however, the grading was downgraded by one score premised on the absence of an explicit statement detailing that the views of the funding body has not influenced the formulated recommendations	

Domain	Item	AGREE II Rating							Reviewers' reason for rating	Location in guideline
		1 *Strongly Disagree*	2	3	4	5	6	7 *Strongly Agree*		
	23. Competing interests of guideline development group members have been recorded and addressed.							√	Criterion fully addressed and reported	
Overall Guideline Assessment	Rate the overall quality of this guideline.	1 *Lowest possible quality*	2	3	4	5	6	7 *highest possible quality*		
Overall Guideline Assessment	I would recommend this guideline for use.	Yes	Yes, with modification					No		
			√							

A.7.7 SAMA (Brighton *et al.*, 2003) Critical Appraisal

Domain	**Item**	**AGREE II Rating**							**Reviewers' reason for rating**	**Location in guideline**
		1 *Strongly Disagree*	**2**	**3**	**4**	**5**	**6**	**7 *Strongly Agree***		
Scope and purpose	1. The overall objective(s) of the guideline is (are) specifically described.							√	Criterion fully addressed	Page 975
	2. The health question(s) covered by the guideline is (are) specifically described.	√							No information on this criterion was reported.	
	3. The population (patients, public, etc.) to whom the guideline is meant to apply is specifically described.			√					The guideline developers described the condition rather than the population the guideline is meant to apply.	
Stakeholder involvement	4. The guideline development group includes individuals from all the relevant professional groups.							√	Criterion fully addressed as guideline development group was reported	Page 990 Annexure B
	5. The views and preferences of the target population (patients, public, etc.) have been sought.	√							Information regarding this criterion was not addressed. Patient or public views were not sought.	
	6. The target users of the guideline are clearly defined.							√	Exceptional reporting of this criterion e.g. Doctors and Professional bodies mentioned as target users of guidelines	
Rigor of development	7. Systematic methods were used to search for evidence.	√							No information regarding this criterion was reported	
	8. The Criterion for selecting the evidence are clearly described.	√							No information regarding this criterion was reported	
	9. The strengths and limitations of the body of evidence are clearly described.	√							No content on strengths and limitations of the body of evidence was reported.	
	10. The methods for formulating the recommendations are clearly described.	√							Criterion not addressed e.g. No clear recommendations were made	
	11. The health benefits, side effects and risks have been considered in formulating the recommendations.	√							This is not explicitly stated in the guideline	

Domain	Item	AGREE II Rating							Reviewers' reason for rating	Location in guideline
		1 *Strongly Disagree*	**2**	**3**	**4**	**5**	**6**	**7 *Strongly Agree***		
	12. There is an explicit link between the recommendations and the supporting evidence.	√							Content on this criterion was not reported in the guideline	
	13. The guideline has been externally reviewed by experts prior to its publication.							√	Exceptional reporting of this criterion. E.g. This was done through a series of meetings with relevant professional and consumer group represented Proceedings from all meetings were documented in the methodology section	Page 990
	14. A procedure for updating the guideline is provided.	√							No information on this criterion was reported	
Clarity of presentation	15. The recommendations are specific and unambiguous.	√							Explicit recommendations have not been made or reported	
	16. The different options for management of the condition or health issue are clearly presented.							√	This criterion was fully addressed	
	17. Key recommendations are easily identifiable.	√							Poor reporting of this criterion e.g. Key recommendations are not easily identifiable in the guideline	
Applicability	18. The guideline describes facilitators and barriers to its application.		√						In adequate reporting of this criterion.	Page 987
	19. The guideline provides advice and/or tools on how the recommendations can be put into practice.				√				Advise on the guideline use was given and guideline summary also documented however, there was no report of educational tools or additional materials to support the use of the guideline. This therefore downgraded the overall score	Page 972
	20. The potential resource implications of applying the recommendations have been considered.	√							Criterion was not addressed	
	21. The guideline presents monitoring and/ or auditing Criterion.	√							No information on this criterion was reported	
Editorial independence	22. The views of the funding body have not influenced the content of the guideline.							√	Exceptional reporting of this criterion	Page 990
	23. Competing interests of guideline development group members have been recorded and addressed.						√		Process of how grant was used is explicitly reported however, no explicit statement on the declaration of conflict of interest was reported in the guideline document.	
Overall Guideline Assessment	Rate the overall quality of this guideline.	1*Lowest possible quality*	2	3	4	5	6	7 *Highest possible quality*		
Overall Guideline Assessment	I would recommend this guideline for use.	Yes	Yes, with modification					No		
			√							

A.7.8 SIR (Manara *et al.*, 2013) Critical Appraisal

Domain	Item	AGREE II Rating							Reviewers' reason for rating	Location in guideline
		1 *Strongly Disagree*	2	3	4	5	6	7 *Strongly Agree*		
Scope and purpose	1. The overall objective(s) of the guideline is (are) specifically described.							√	Full Criterion spelt out and addressed explicitly	page 168
	2. The health question(s) covered by the guideline is (are) specifically described.						√		The health question which was looked at was the management of hand OA from the 2006 EULAR Recommendation of the hand. A grade of 6 was scored because it was not clearly spelt out in the manuscript	
	3. The population (patients, public, etc.) to whom the guideline is meant to apply is specifically described.							√	Criterion was fully addressed i.e. Patient with hand OA in Italy	page167
Stakeholder involvement	4. The guideline development group includes individuals from all the relevant professional groups.							√	This criterion was explicitly addressed	page 180
	5. The views and preferences of the target population (patients, public, etc.) have been sought.	√							The Criterion was not addressed as the views and preferences of the target population was not sought. However, the authors acknowledged it in the manuscript that this was not addressed in their article	page 180
	6. The target users of the guideline are clearly defined.							√	This criterion was explicitly addressed i.e. The recommendations were made for the Italian Health Sector	Page 182
Rigor of development	7. Systematic methods were used to search for evidence.						√		This Criterion was adequately addressed but the overall score was downgraded because only one individual conducted the literature review process which may have introduced some bias in the process	Page 180
	8. The Criterion for selecting the evidence are clearly described.							√	Criterion was fully met and spelt out. Authors followed the Level of evidence and strength of recommendations used by the EULAR2006 Recommendations for hand OA	Page 170
	9. The strengths and limitations of the body of evidence are clearly described.							√	This criterion was fully addressed	Page 180
	10. The methods for formulating the recommendations are clearly described.							√	Exceptional quality reporting of this Criterion throughout the whole article. Recommendation developers followed the processes used in formulating the EULAR 2007 evidenced-based recommendations for hand OA.(Zhang *et al.*, 2007) E.g. Page 171 for the recommendation of physical exercises in hand OA management	Page 171
	11. The health benefits, side effects and risks have been considered in formulating the recommendations.	√							This criterion was not fully met. Authors reported the level of evidence that underpinned each recommendation but failed to report on the harms or benefits of each intervention	

Domain	Item	AGREE II Rating							Reviewers' reason for rating	Location in guideline
		1 *Strongly Disagree*	2	3	4	5	6	7 *Strongly Agree*		
	12. There is an explicit link between the recommendations and the supporting evidence.							√	This criterion was fully addressed. The authors reported the congruence between the literature and the recommendation which is explicitly documented in the article under each recommendation	
	13. The guideline has been externally reviewed by experts prior to its publication.	√							This criterion was not addressed	
	14. A procedure for updating the guideline is provided.	√							Criterion was not met. No statement indicating when this recommendation would be updated was stated.	
Clarity of presentation	15. The recommendations are specific and unambiguous.							√	Exceptional quality reporting of this criterion	Page 171
	16. The different options for management of the condition or health issue are clearly presented.							√	Criterion fully addressed by Recommendation developers	
	17. Key recommendations are easily identifiable.							√	Criterion fully met by authors	
Applicability	18. The guideline describes facilitators and barriers to its application.	√							No information regarding this criterion was reported	
	19. The guideline provides advice and/or tools on how the recommendations can be put into practice.	√							No information regarding this criterion was reported	
	20. The potential resource implications of applying the recommendations have been considered.	√							No information regarding this criterion was reported	
	21. The guideline presents monitoring and/ or auditing Criterion.	√							No information relevant to this criterion was reported	
Editorial independence	22. The views of the funding body have not influenced the content of the guideline.	√							No information regarding this criterion was reported	
	23. Competing interests of guideline development group members have been recorded and addressed.	√							No information on this criterion was reported	
Overall Guideline Assessment	Rate the overall quality of this guideline.	1 *Lowest possible quality*	2	3	**4**	5	6	7 *Highest possible quality*		
	I would recommend this guideline for use.	Yes	Yes, with modification					No		

Appendix A

Domain	Item	AGREE II Rating							Reviewers' reason for rating	Location in guideline
		1 *Strongly Disagree*	2	3	4	5	6	7 *Strongly Agree*		
Overall Guideline Assessment			√							

OA: Osteoarthritis; AGREE; Appraisal of Guidelines, Research and Evaluation; EULAR: European League Against Rheumatism; PT: Physiotherapist; OT: Occupational Therapist; SLR: Systematic Literature Review

Appendix B Scoping Review

B.1 Completed PRISMA-ScR for the scoping review

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	59
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	N/A
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	60-61
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	61
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	62
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	62
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	63
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	293 - 296
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	63
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	64
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	64
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	N/A
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	64

Appendix B

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	65
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	67-74
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	N/A
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	75-86
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	86-87
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	88-91
Limitations	20	Discuss the limitations of the scoping review process.	91
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	91
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	N/A

B.2 Search Strategies

B.2.1 Medline (Ebsco host) search strategy

#	Query
S1	(MM "Osteoarthritis")
S2	osteoarthriti*
S3	osteoarthrosis
S4	"degenerative joint disease"
S5	"degenerative joint disease"
S6	"degenerative arthritis"
S7	"OA"
S8	S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7
S9	(MH "Hand+") OR "hand" OR (MH "Hand Joints")
S10	(MM "Carpal Joints") OR (MH "Finger Joint") OR ""carpal joints""
S11	(MM "Wrist") OR "wrist" OR (MM "Wrist Joint")
S12	(MM "Carpometacarpal Joints") OR (MM "Finger Joint") OR ""carpometacarpal joints""
S13	""metacarpophalangeal joint"" OR (MM "Metacarpophalangeal Joint")
S14	(MH "Finger Joint") OR (MH "Finger Phalanges") OR (MH "Fingers") OR "Finger" OR "interphalangeal joint" OR "phalangeal joint"
S15	(MH "Thumb") OR "thumb" OR "base of thumb joint"
S16	""thumb joint""
S17	"trapeziometacarpal joint"
S18	"digital Osteoarthritis"
S19	S9 OR S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18
S20	S8 AND S19
S21	(MH "Exercise+") OR "Exercise" OR (MH "Exercise Therapy+") OR (MH "Warm-Up Exercise") OR (MH "Exercise Movement Techniques+")
S22	exercis*
S23	"hand exercis*"
S24	"exercise training" OR (MH "Resistance Training") OR (MH "Circuit-Based Exercise")
S25	"exercise intervention or physical activity or fitness"
S26	(MH "Muscle Stretching Exercises") OR (MH "Resistance Training") OR (MH "Cool-Down Exercise") OR ""muscle strengthening exercises""
S27	"Hand functional exercises"
S28	(MM "Rehabilitation") OR "rehabilitation" OR (MH "Physical and Rehabilitation Medicine") OR (MH "Telerehabilitation")
S29	"physiotherapy" OR "physical therapy" OR "occupational therapy"
S30	"ballistic exercises"
S31	S21 OR S22 OR S23 OR S24 OR S25 OR S26 OR S27 OR S28 OR S29 OR S30
S32	S20 AND S31 Limiters: English language, years 1997-the present, available abstracts

B.2.2 CINAHL (Ebsco) search strategy

#	Query
S1	(MH "Osteoarthritis+")
S2	osteoarthritis
S3	osteoarthriti*
S4	osteoarthrosis
S5	degenerative joint disease
S6	degenerative arthritis
S7	OA
S8	S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7
S9	(MH "Hand+") OR (MH "Hand Joints+") OR (MH "Finger Joint")

#	Query
S10	(MH "Carpal Joints") OR "carpal joint"
S11	(MM "Carpometacarpal Joints") OR "Carpometacarpal joint" or "CMC joint"
S12	(MH "Wrist Joint") OR (MH "Wrist") OR "wrist" OR (MH "Osteoarthritis, Wrist")
S13	"Phalangeal joint" OR "interphalangeal joints"
S14	"Digits" OR phalanges OR fingers OR periphery
S15	(MH "Thumb") OR "thumb"
S16	""thumb joint""
S17	"trapeziometacarpal joint"
S18	"Basal thumb joint"
S19	digital osteoarthritis
S20	S9 OR S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19
S21	S8 AND S20
S22	(MH "Therapeutic Exercise") OR (MH "Upper Extremity Exercises") OR (MH "Arm Exercises") OR (MH "Isokinetic Exercises") OR (MH "Isometric Exercises")
S23	exercise
S24	exercis*
S25	"hand exercises" OR "upper limb exercises"
S26	(MH "Open Kinetic Chain Exercises") OR "task specific exercises" OR (MH "Resistance Training") OR (MH "Sport Specific Training")
S27	(MH "Exercise") OR "stretching exercises" OR (MH "Resistance Training")
S28	"strengthening exercises" OR "Functional exercises"
S29	(MH "Physical Activity") OR "physical activity"
S30	(MH "Rehabilitation") OR "rehabilitation" OR (MH "Home Rehabilitation+")
S31	rehab*
S32	(MH "Physical Therapy") OR "physiotherapy"
S33	physiotherap*
S34	(MH "Occupational Therapy") OR "occupational therapy" OR (MH "Occupational Therapy Practice, Research-Based") OR (MH "Occupational Therapy Practice, Evidence-Based") OR (MH "Occupational Therapy Practice") OR (MH "Home Occupational Therapy")
S35	"explosive exercises"
S36	"ballistic exercises"
S37	"functional exercises" OR "functional training"
S38	S22 OR S23 OR S24 OR S25 OR S26 OR S27 OR S28 OR S29 OR S30 OR S31 OR S32 OR S33 OR S34 OR S35 OR S36 OR S37
S39	S21 AND S38
S40	S21 AND S38 Limiters: English language, years (1997-the present), available abstracts

B.2.3 Cochrane library search strategy

ID	**Search**	**Hits**
#1	osteoarthriti*	
#2	"degenerative joint disease"	
#3	"degenerative arthritis"	
#4	OA	
#5	(#1 or #2 or #3 or #4)	
#6	hand	22871
#7	(wrist joint) or (carpal joints) or (base of thumb joint) or (trapeziometacarpal joint)	
#8	(carpometacarpal joint*) or (CMC joint) or (metacarpophalangeal joint*) or (interphalangeal joint*) or (TMJ joint)	
#9	(Digital OA) or (Peripheral OA) or (upper limb OA)	
#10	(#6 or #7 or #8 or #9)	
#11	(#5 and #10)	
#12	exercis*	

#13 (exercise intervention) or (exercise training) or (physical activity)
#14 (strength training exercises) or (resistance training) or (resistive exercises) or (ballistic exercises) or (explosive exercises)
#15 (stretching exercises) or (flexibility exercises)
#16 (functional exercises) or (task-specific exercises)
#17 rehabilitation or (physical therapy) or physiotherapy or (occupational therapy)
#18 (hand exercises) or (upper limb exercises)
#19 (#12 or #13 or #14 or #15 or #16 or #17 or #18)
#20 (#11 and #19)
Limiters: Publication Year: 1998 –the present, Cochrane reviews, Trials

B.2.4 PEDro search strategy

Steps	Search Terms and Boolean Operators
1.	Hand osteoarthritis*exercises*

B.2.5 AMED search strategy

#	Query
S1	osteoarthriti*
S2	"degenerative joint disease"
S3	"degenerative arthritis"
S4	osteoarthrosis
S5	OA
S6	S1 OR S2 OR S3 OR S4 OR S5
S7	hand*
S8	"wrist joint* "OR "carpal joint*"
S9	"carpometacarpal joint" OR "metacarpophalangeal joint" OR "interphalangeal joint"
S10	thumb OR "base of thumb" OR "trapeziometacarpal joint"
S11	"Finger joint*"
S12	"Digital osteoarthritis" OR "peripheral osteoarthritis" OR "upper limb OA"
S13	S7 OR S8 OR S9 OR S10 OR S11 OR S12
S14	S6 AND S13
S15	exercis*
S16	"exercise therapy" OR "physical activity" OR "exercise intervention"
S17	"resistance training" OR "stretching exercises" OR "task-specific training"
S18	"ballistic exercises" OR "explosive exercises"
S19	physiotherapy OR "physical therapy" OR rehabilitation OR "occupational therapy"
S20	S15 OR S16 OR S17 OR S18 OR S19
S21	S14 AND S20 Limiters: 1998-the present; English Language, available abstracts

B.2.6 Web of Science search strategy

Set	Search Terms
# 1	TS=("osteoarthritis") OR TS=(osteoarthriti*) OR TS=("degenerative joint disease") OR TS=("degenerative arthritis")
# 2	TS=("hand") OR TS=(wrist*) OR TS=(Finger*) OR TS=("Digit*") OR TS=(thumb)
# 3	TS=("carpal joint") OR TS=("carpometacarpal joint") OR TS=("metacarpophalangeal joint") OR TS=("trapeziometacarpal joint") OR TS=("base of thumb") OR TS=("TMJ joint")
# 4	#3 OR #2
# 5	#4 AND #1
# 6	TS=("digital osteoarthritis") OR TS=("peripheral osteoarthritis") OR TS=("CMC osteoarthritis") OR TS=("TMJ osteoarthritis") OR TS=(upper limb osteoarthritis)
# 7	#6 OR #5
# 8	TS=("exercis*") OR TS=("exercise therapy" OR "exercise training") OR TS=("functional exercise*") OR TS=("strengthening exercises" OR "resistive training") OR TS=("physical activity" OR "physical fitness") OR TS=("ballistic exercises" OR

Set	Search Terms
	"explosive exercises") AND TS=("task-specific training") OR TS=("stretching exercises")
# 9	TS=("rehabilitation") OR TS=("physical therapy") OR TS=("physiotherapy") OR TS=("occupational therapy") OR TS=("hand exercises") OR TS=("upper limb exercises")
# 10	#9 OR #8
# 11	(#10 AND #7) Limiters: English; Timespan=1998-the present

B.2.7 Appendix I: OT Seeker search strategy

Steps	Search Terms and Boolean Operators
1.	Hand osteoarthritis*exercises*

B.2.8 Unpublished and Grey literature sources

Source	Search terms	Relevant record retrieved
NICE evidence search	"hand osteoarthritis" AND exercises	5 records +1 evidence summary
UK clinical research network	"hand osteoarthritis" AND exercises	0
Open Grey	hand osteoarthritis" AND exercises	0
British library-Zetoc	" hand osteoarthritis" AND exercises	6
WHO ICTRP	"hand osteoarthritis" AND exercises	1.http://isrctn.com/ISRCTN62513257 2. https://clinicaltrials.gov/show/NCT02701335 3. http://isrctn.com/ISRCTN79019063 4. http://clinicaltrials.gov/show/NCT01245842 5. tp://clinicaltrials.gov/show/NCT00375947
ISRCTN Registry	exercises AND "hand osteoarthritis"	1 ongoing trial (Interdisciplinary Innovative model of care for people with Hand Osteoarthritis) 4 completed trials

NB: ISRCTN - International Standard Randomized Controlled Trials Number Registry; ICTRP - International Clinical Trials Registry Platform; NICE – National Institute for Health and Care Excellence; WHO - World Health Organization; UK - United Kingdom

B.3 Data Charting form (Adapted from Peters MDJ *et al.* (2017)

<table>
<tr><th colspan="4">Scoping Review Details</th></tr>
<tr><td colspan="2">Title:</td><td colspan="2"></td></tr>
<tr><td colspan="2">Review Objective:</td><td colspan="2"></td></tr>
<tr><td colspan="2">Reviewer ID:</td><td colspan="2"></td></tr>
<tr><th colspan="4">Inclusion and Exclusion Criteria</th></tr>
<tr><td colspan="2"></td><td>Inclusion</td><td>Exclusion</td></tr>
<tr><td colspan="2">Population</td><td></td><td></td></tr>
<tr><td colspan="2">Concept</td><td></td><td></td></tr>
<tr><td colspan="2">Context</td><td></td><td></td></tr>
<tr><th colspan="4">Included Study Details and Characteristics</th></tr>
<tr><td colspan="2">Study citation details
(e.g. authors, date, title, journal, volume, issue, ages)</td><td colspan="2"></td></tr>
<tr><td colspan="2">Type of publication
(Journal article, Grey literature, etc.)</td><td colspan="2"></td></tr>
<tr><td colspan="2">Country of publication</td><td colspan="2"></td></tr>
<tr><td colspan="2">Aim</td><td colspan="2"></td></tr>
<tr><td colspan="2">Key findings</td><td colspan="2"></td></tr>
<tr><td colspan="2">Study design</td><td colspan="2"></td></tr>
<tr><td colspan="2">Participants Details
(e.g. age, gender and number)</td><td colspan="2"></td></tr>
<tr><td colspan="2">Study setting</td><td colspan="2"></td></tr>
<tr><td colspan="4">Details extracted from study</td></tr>
<tr><th colspan="4">A priori Themes
(Details in relation to the concept of the scoping review)</th></tr>
<tr><td rowspan="4">Components of exercise</td><td>Frequency</td><td colspan="2"></td></tr>
<tr><td>Type</td><td colspan="2"></td></tr>
<tr><td>Intensity</td><td colspan="2"></td></tr>
<tr><td>Time</td><td colspan="2"></td></tr>
<tr><td colspan="2" rowspan="2">Was the exercise developed following theory-based treatment development?
(evidence review, expert opinion & patient preference)</td><td>Yes</td><td>No</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2" rowspan="2">Was the exercise prescribed following best guideline recommendations?</td><td>Yes</td><td>No</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Was exercise adherence reported?</td><td>Yes</td><td>No</td></tr>
<tr><td colspan="2">Exercise adherence strategies used (e.g. Diaries, phone apps, etc.)</td><td></td><td></td></tr>
<tr><th colspan="4">Emerging Themes
(Details not captured a priori but relevant to the review)</th></tr>
<tr><td colspan="2">a.</td><td></td><td></td></tr>
<tr><td colspan="2">b.</td><td></td><td></td></tr>
</table>

B.4 Reasons for Exclusion after Full Text Screening

Records	Reasons
Ahern *et al.* (2018)	No content on exercise therapy was reported
Airth-Edblom (2013)	Article excluded as it does not fall within the concept
Ali *et al.* (2018)	Looked at education and self-management other than exercise
Ballinger *et al.* (2010)	Excluded from review as paper does not fall within the concept
Banciu (2017)	Paper did not discuss concept thus excluded
Barnett *et al.* (2018)	Aim does not fall under the construct of this review
Boustedt *et al.* (2007)	Conference abstract of Boustedt 2009, hence excluded
Brosseau *et al.* (2018)	Excluded on basis of it been a guideline, not included in the study types predetermined in the review protocol
Dziedzic (2011)	Did not cover any of these concepts, it’s a narrative review/expert opinion based on evidence review
Dziedzic *et al.* (2012)	Excluded as it’s the conference abstract of (Dziedzic *et al.*, 2015), making it duplicate evidence
Hagen *et al.* (2009)	Did not cover any of these concepts hence excluded It’s a brief narrative review
Harvard Health Letter (2013)	Newsletter hence excluded
Harvard Health Letter (2017)	Hand OA among others patient populations
Hennig *et al.* (2013)	Excluded as its duplicate evidence for (Hennig *et al.*, 2015)
Lockard (2000)	Looked at how to select exercises for patient management based on biomechanics
Lundebjerg (2001)	Reported on exercise prescription in OA, had no specific content on Hand OA
Magni *et al.* (2017)	Looking at effects of exercises which doesn’t fall under the construct of this scoping review
Marcu *et al.* (2016)	Excluded due to different concept other than what is been reviewed
Myers *et al.* (2016)	Different concept other than what is been reviewed
Østerås *et al.* (2014b)	Protocol of Østerås *et al.* (2014a). Excluded because its duplication of evidence
Villafañe *et al.* (2012)	Paper excluded as it doesn’t fall under the concept been identified i.e. looked at thumb joint mobilization (Maitland's passive accessory mobilization) when this scoping review is interested in exercise
Villafañe *et al.* (2017a)	Excluded as the aim didn’t fall under the review’s concept.

Records	Reasons
	Authors looked at evaluating YouTube video content (educational quality) and potential sources of bias in CMC exercises and not the CMC exercises themselves
Villafañe *et al.* (2017b)	Aim didn't fall under the review's concept. Authors aimed to look at neural mobilization vs. robotic assisted therapy in hand OA and not exercises
Ye *et al.* (2011)	Aim does not fall under the construct of this review

B.5 Literature Search Update (Jan 2019 – 13Jan2021)

Sources	Records retrieved
AMED	16
CINAHL	48
Medline	160
Web of Science	187
Other sources	5
Total	**416**
Duplicates removed	78
Exclusion on abstracts/ titles & full text	335
Records added	3
	Beasley *et al.* (2019) Hamasaki *et al.* (2020) Veronese *et al.* (2020)

B.6 Characteristics of identified sources of evidence

B.6.1 Study designs of included records

Studies	Numbers of records	Percentages (%)
Primary Research studies		
Randomized studies (RCTs + pilot + randomized +randomized before and after study)	13	61.9
Non-Randomized studies (non RCT+ cohort study + case study +Open label trial)	5	23.8
Protocols	2	9.5
Development paper	1	4.8
Total	**21**	100%
Secondary Research studies		
Sys rev	**6**	50%
Umbrella review	**1**	8.3%
Other reviews	**5**	41.7%
Total	**12**	100%
Grand total	**33**	

B.6.2 Origin of Included Records

Regions	Number of Publications	Percentages (%)
Individual countries		
Africa	0	0%
Asia	1	3%
Australia	1	3%
Europe	18	55%
North America	9	27%
South America	1	3%
Total	**30**	**91%**
Joint countries (numbers)		
Kroon et al. 2018 (Netherlands & Spain)	1	3%
Scott e al. 2018 (UK & Australia)	1	3%
Veronese *et al.* (2020) (Italy & UK)	1	3%
Total	**3**	**9%**
Grand total	**33**	**100%**

B.6.3 Type of Publication of included records

Publication type	Number of Publications	Percentages (%)
Journal	29	88%

Publication type	Number of Publications	Percentages (%)
Conference paper (abstract)	3	9%
Letter to editor	1	3%
Total	**33**	**100%**

B.6.4 Type of hand OA of studied by records

Hand OA type	Population	%
Hand OA	22	67%
CMC of thumb	10	30%
Both	1	3%
Total	33	

B.6.5 Study Settings of included Primary records

Study Settings	Numbers of records	Groupings	Collated numbers (%)
Primary care setting	1	Healthcare settings only	3 (14.2%)
Company clinic	1	Healthcare settings only	
Physio unit	1	Healthcare settings only	
Healthcare+ home setting	4	Home +others	6 (28.6%)
Laboratory +home setting	1	Home +others	
Hospital setting +home	1	Home +others	
Home programme	6		6 (28.6%)
Community setting	3		3 (14.2%)
Research setting	1		1 (4.8%)
Not explicit (are abstracts)	2		2 (9.5%)
Total	**21**		

B.7 Description of the summary of exercises for the management of people with hand OA

Records	Description of Exercises	Exercises Prescription		
		Frequency	Intensity	Duration of exercise
Aebischer *et al.* (2016)	Stabilization, standardized ROM, general strengthening, abduction, pinch and thumb web exercises	Not reported	Not reported	Not reported
Beasley *et al.* (2019)	AROM and resistive exercises	10 – 15 reps weekly Advise to use based sound clinical judgment	1) Exercises initiated at 40% maximal effort. 2) advise to apply clinical judgment	No specific details provided
Beasley (2012)	1) Pain-free hand home exercises 2) Active ROM exercises	No specific information reported	No specific information reported	No specific information reported
Bertozzi *et al.* (2015)	1) exercises that strengthen the stabilizing muscles of the thumb 2) exercises that provide unconscious neuromuscular control	No information provided	No information provided	No information provided
Bjurehed *et al.* (2017)	1. ROM exercises (Shoulders, elbows, wrists, finger and thumb) 2. Strengthening exercises with a soft ball (wrists & hands) (14 different exercises)	2 times/week (least 5 times each during the 25-minute session)	Program was individually progressed	25 mins/session 6-week
Boustedt *et al.* (2009)	ROM and pain free moderate strengthening of hand intrinsic 2) thumb extrinsic muscles	daily home exercises	No specific information reported	5 weeks
Brorsson *et al.* (2014)	1)Isolated finger opposition (digits II-V); rolling putty with a flat hand; squeezing putty; finger extension with putty resistance	5 mins/session (15reps/7 days)	No specific details reported	8 weeks.
Brosseau *et al.* (2017)	Structured low-intensity home knitting program	20 mins daily sessions (Increased by 5mins every 4weeks)	Progressive increase by 5mins every 4weeks	12 weeks
Davenport *et al*. (2012)	1) Specific CMC joint exercises (passive & active extension; passive extension with rubber band; pinching activities e.g. writing; practice turning or twisting activities e.g. undoing jars). 2) General exercises (touch thumb to fingertips (O sign); pinching activities; stretching thumb)	3-10 reps	Not explicitly reported	Not explicitly reported
DeMott (2017)	1. Isometric grip exercises (ball) 2) CMC joint extension/abduction with MP joint flexion,	5-second holds for 10-15 repetitions every other day	40% - 50% maximum pain-free effort of individual capacity	Not explicitly described, authors reported exercise duration were prescribed based on ACSM recommendations
Deveza *et al.* (2017)	5 exercises: 1) thumb opposition 2. paper tearing 3) line tracing on ball 4) using chopsticks to pick up objects 5) squeezing a ball	10 reps-week 1 12reps -week 2 15reps-week 3-6) for 3x weekly	Increasing the difficulty of tasks (i.e. tearing thicker paper; squeezing ball harder)	6 weeks

Records	Description of Exercises	Exercises Prescription		
		Frequency	Intensity	Duration of exercise
Dziedzic *et al.* (2015)	1. ROM exercises (wrist flexion & extension; pronation & supination; tendon gliding; radial finger walking; making an 'O' sign; thumb extension; abduction & opposition to the base of the 5th finger) 2. Strengthening exercises (Thumb extension, abduction & finger extension with elastic band and Play-Doh; wrist flexion and extension exercise with 0.5–0.75 kg weight)	3 -10 reps of each exercise performed daily or most days Exercises could be spread over several sessions during the day and performed more than once a day.	Exercises performed within participants' limit of discomfort	4 weeks
Guitard *et al.* (2018)	1. knitting program (low intensity dynamic and isometric movement of fingers, thumbs and wrists)	1)bi-weekly 20-min knitting sessions at a senior's club 2) 20-min home daily knitting sessions for the 5-remaining weekday	Knitting was prescribed not to include intensity (to respect the personal fashion and willingness of people)	Proposed 12 weeks programme
Hamasaki *et al.* (2020)	Combination of hand exercises and TM joint mobilization	Not explicitly described some information provided in results section, but no inference made in relation to the review conclusions	some information provided in results section, but no inference made in relation to the review conclusions	Not explicit
Hennig *et al.* (2015)	**5 exercise types** 1.Making "O" sign 2. Roll into fist 3. Grip strength (rubber ball) 4.Thumb abduction/extension (with rubber band) 5. Finger stretch	Week 1-10 reps, 3x weekly Week 2-3-12 reps, 3x weekly Week 4-12-15 reps, 3x weekly	Not explicit, authors reported the use of high intensity prescribed according ACSM recommendations	3 months
Kang *et al.* (2019)	**4 exercises** 1. Finger stretch; Roll into fist 2. Make O sign &Thumb abduction/extension with power web hand exerciser	10 reps (Week 1-2) 15 reps (Week 3-8)	Intensity determined through 10 repetition-maximum testing for pain relief	30 minutes/day, 5 times a week for 8 weeks.
Kjeken *et al.* (2011)	Combination daily exercises (ROM and strengthening exercises)	Minimum of 10 reps for strength exercises Minimum of 4 reps for ROM exercises	Suggestion to use ACSM recommendations	Minimum of 20minutes/day (12-15 weeks)
Kjeken *et al.* (2015)	Strengthening and ROM exercises 1. Shoulder flexion& extension (exercise band) 2. Biceps curls (with stretch band) 3. Making "O" sign & Roll in a fist 4. Thumb abduction &extension (with elastic band) 5. Grip strength (with pipe insulation tube) Warm up & cool down exercises (rubbing the hands together, arm swings &finger stretch exercise).	Week 1 -2 (10 reps) Week 3 - 12 (15 reps); 3 times weekly	Moderate to vigorous intensity (varying band tension or shortening length)	12 weeks (Session duration left to discretion of research partners)
Kroon *et al.* (2018b)	Use of exercises indicated, no specific details reported	Not reported	Content not reported	Content not reported
Lefler *et al.* (2004)	Isometric and isotonic strengthening exercises 1. rice grabs (making fist squeezing rice); 2. pinch grip lifting (sandbags); 3. wrist rolls (piece of PVC pipe)	3 times per week	1-10 reps (performed 40-60% of max voluntary Isometric contraction).	6 weeks
Nery *et al.* (2015)	Progressive resistance strength training program for intrinsic muscles of the hand	Information not reported	Information not reported	12 weeks

Appendix B

Records	Description of Exercises	Exercises Prescription		
		Frequency	Intensity	Duration of exercise
Nguyen *et al.* (2016)	Strengthening and ROM exercises	Not described	Not described	Not described
Østerås *et al.* (2014a)	Employed Kjeken *et al.* (2015) exercises Strengthening and ROM exercises (Shoulder flexion& extension; biceps curls; making "O" sign; roll in a fist; thumb abduction &extension; grip strength) Warm up & cool down exercises	Week 1 -2 (10 reps) Week 3 - 12 (15 reps); 3 times weekly	Moderate to vigorous intensity (varying band tension or shortening length)	12 weeks
Osteras *et al.* (2017)	No specific exercises recommended	No specific details recommended	No specific details recommended	No specific details recommended
Pérez-Mármol *et al.* (2017)	Fine Motor Skill intervention (using structured activity of making pictures with tissue paper balls on a figure painted at the background of the picture).	3 times/week	1)Modifying the size of paper balls from 10x10 to 4x4cm. 2) Increasing number of paper balls from 20 to 40	45 mins/session (8 weeks)
Rocchi *et al.* (2018)	Therapeutic exercises (passive & active TMC joint mobilization; stretching of the first web span)	5 days/weekly	No specific details reported	30-40mins/session (two weeks)
Rogers *et al.* (2009)	**9 exercises** 1. Joint flexibility exercises - Tabletop; small & Large fist; okay signs (making "o") &finger spread exercises 2. Strengthening grip and pinch exercises - thumb reach & (gripping; key pinch & fingertip pinch with resistance balls)	Daily exercise sessions	Use of different colour coded resistance balls Increase exercise repetitions every 4 weeks (from 10 to 12 to 20 reps)	10-15mins/session (16 weeks)
Scott (2018)	1.Strengthening exercises for Extensor pollicis brevis, Abductor pollicis brevis, Opponens pollicis (resisted 'C' position -use of rubber band or other hand) 2. Resisted tip/functional pinch with exercise balls (whilst focussing on correct positioning)	3 - 4 sessions/ day (10 - 15 repetitions)	Authors reported insufficient availability of evidence to make exercise intensity recommendations	Not reported *(review's focus was type, frequency & intensity of exercises)*
Stamm *et al.* (2002)	1. Making a fist 2. Making a small fist 3. flexing the MCP joints while keeping the PIP and DIP joints stretched 4. Touching the tip of each finger with the tip of the thumb 5. Spreading the fingers as far as possible with the hand lying flat on a table 6. Pushing each finger in the direction of the thumb with the hand lying flat on a table 7. Touching the MCP V joint with the tip of the thumb	10 times daily	No details reported	No details reported
Stoffer-Marx *et al.* (2018)	strengthening and mobility exercises (make small fist; build a housetop, make O sign; spread fingers; lateral pinch; exercise with therapy putty (building a ball with hand)	Daily exercises 10 reps (weeks 1–2) ; 12 reps (weeks 3–4); 15 reps (weeks 5–8)	No specific details reported	8 weeks
Valdes *et al.* (2012)	1.Grip and Pinch strengthening exercises (foam wedge squeeze; putty squeeze; hand gripper exercises) 2. AROM and PROM exercises (CMC web space, thumb IP, thumb MP and CMC motions) *Warm up activities* (moist heat packs, paraffin bath, or low-intensity aerobic exercise)	10-15 repetitions, 2-3 days weekly	No specific details, authors reported resistance may be upgraded as tolerated by the patient while adhering to pain free principle	Not described, authors reported that no specific duration of training has been identified for effectiveness.

Records	Description of Exercises	Exercises Prescription		
		Frequency	Intensity	Duration of exercise
Veronese *et al.* (2020)	resistance training	No specific information	No specific information	No specific information
Villafañe et al. (2013)	Used Rogers *et al.* (2009) exercises 1. Joint flexibility exercises - Tabletop; small & Large fist; okay signs (making "o") &finger spread exercises 2. Strengthening grip and pinch exercises - thumb reach & (gripping; key pinch & fingertip pinch with colour coded resistance balls)	3 sessions/week. 1.10 reps (first 4 sessions) 2. 12 reps (next 2 sessions) 3. 15 reps (next 2 sessions) 4. 20 if able (last 4 sessions)	Use of resistance balls (balls colour coded to indicate the resistance provided at 50% compression)	10-15 mins/session (4 weeks)

B.7.1 Summary of frequently included exercises for hand OA management

Exercises	Numbers of records	Contributing records
ROM or flexibility (n=24)		
Range of Motion (active and passive)	13	Aebischer *et al.* (2016); Beasley *et al.* (2019) Beasley (2012); Bjurehed *et al.* (2017); Boustedt et al. (2009); DeMott (2017); Dziedzic *et al.* (2015); Kjeken et al. (2011); Kjeken *et al.* (2015); Nguyen *et al.* (2016); Østerås *et al.* (2014a); Stamm et al. (2002); Valdes *et al.* (2012)
Making O sign (flexibility/ ROM)	11	Brorsson *et al.* (2014); Davenport *et al*. (2012) Dziedzic *et al.* (2015); Hennig *et al.* (2015); Kang *et al.* (2019); Kjeken *et al.* (2015); Østerås *et al.* (2014a); Rogers *et al.* (2009); Stamm *et al.* (2002); Stoffer-Marx *et al.* (2018); Villafañe *et al.* (2013)
Making a fist (flexibility/ rom)	9	Hennig *et al.* (2015); Kang *et al.* (2019) Kjeken *et al.* (2015); Lefler *et al.* (2004); Østerås *et al.* (2014a); Rogers *et al.* (2009); Stamm *et al.* (2002); Villafañe *et al.* (2013) Stoffer-Marx et al. (2018);

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Exercises	Numbers of records	Contributing records
Finger and thumb stretch	5	Davenport *et al.* (2012); Hennig *et al.* (2015); Kang *et al.* (2019); Kjeken *et al.* (2015); Rocchi *et al.* (2018)
Strengthening (n=20)		
Grip	12	DeMott (2017); Brorsson *et al.* (2014); Bjurehed *et al.* (2017); Deveza et al. (2017); Hennig *et al.* (2015); Kjeken *et al.* (2015); Lefler et al. (2004); Østerås *et al.* (2014a); Rogers *et al.* (2009); Stoffer-Marx *et al*. (2018); Valdes *et al.* (2012); Villafañe *et al.* (2013)
Pinch	5	Lefler *et al.* (2004); Rogers *et al.* (2009); Scott (2018); Valdes *et al.* (2012); Villafañe *et al.* (2013)
Thumb extension & abduction with elastic band	4	Davenport *et al.* (2012); Hennig *et al.* (2015) Kjeken *et al.* (2015); Scott (2018)

B.8 Results of individual sources

B.8.1 Description according evidence-based development

Evidence-based Developments	Numbers of records	Contributing records
Research + Expert + Patient	6	Dziedzic *et al.* (2015); Guitard *et al.* (2018) Kjeken *et al.* (2015); Østerås *et al.* (2014a) Scott (2018); Stoffer-Marx *et al.* (2018)
Research + Expert	5	Bjurehed *et al.* (2017); Hennig *et al.* (2015) Pérez-Mármol *et al.* (2017); Rogers *et al.* (2009); Villafañe *et al.* (2013)
Expert + Patient	1	Deveza *et al.* (2017)
Research	5	Davenport *et al.* (2012); DeMott (2017) Kang *et al.* (2019); Kjeken *et al.* (2011) Valdes *et al.* (2012)
Expert	1	Stamm *et al.* (2002)
None	15	

B.8.2 Description according best hand OA recommendations

Guideline recommendations	**Numbers of records**	**Percentages (%)**
Strength + stretch + flexibility	3	9.1%
Strength + stretch	2	6.1%
Strength + flexibility	14	42.4%
Stretch + flexibility	2	6.1%
Strength only	6	18.2%
Stretch only	0	0%
Flexibility only	2	6.1%
None	4	12.1%
Total	33	100.1

B.9 Emerging themes from the review

Records	**Emerging themes**			
	Mode of delivery	**Compliance**	**Aim of exercises**	**Adverse effects/events**
Aebischer *et al.* (2016)	Not described	Not described	Not described	Not described
Beasley *et al.* (2019)	Not described	Not described	Not described	Not described
Beasley (2012)	Home programme	Not described	Not described	Not described
Bertozzi *et al.* (2015)	Not described	Not described	Not described	Not described

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Records	Emerging themes			
	Mode of delivery	**Compliance**	**Aim of exercises**	**Adverse effects/events**
Bjurehed *et al.* (2017)	Supervised group sessions	Not described	Increase ROM, strength, & hand ADLs	Not described
Boustedt *et al.* (2009)	Supervised group & Home sessions	weekly group session attendance	1. Improve ROM; 2. strengthen hand intrinsic and thumb extrinsic muscles	Not described
Brorsson *et al.* (2014)	Not described	Not described	Not described	Not described
Brosseau *et al.* (2017)	Home programme	Adherence reported	Manage pain	Not described
Davenport *et al*. (2012)	Home programme	1) Written information on exercises 2) one to one teaching of exercises 3) regular follow-up	Increase strength and activity in APL to reduce shear and pain at the CMC joint.	Not described
DeMott (2017)	Home program	No information	1.provide joint alignment and support to thenar muscles; 2. strengthen & re-educate FDI muscles	Not described
Deveza *et al.* (2017)	1.supervised session with therapist 2. unsupervised home sessions 3. exercise booklet to deliver education and joint protection techniques 4. Visual description of exercises on website	Adherence reported	optimise ROM; improve neuromuscular control of thumb alignment & train proprioception of the CMC joint	Not described
Dziedzic *et al.* (2015)	1.Supervised group sessions 2. home exercises 3. Provision of workbooks (contains joint protection, hand exercises or two) written information (leaflet& advice)	1.Recorded participant attendances 2. Writing down the number of times exercises will be practiced	improve grip strength and dexterity.	Intervention had no reported adverse effects
Guitard *et al.* (2018)	structured and supervised context	Adherence reported	1.prevent morning stiffness 2. Maintain regular level of ADLs	N/A
Hamasaki *et al.* (2020)	Not described	Not described	Not described	Not described
Hennig *et al.* (2015)	Home-based programme	Adherence reported	1. maximise finger joints ROM 2. increase grip strength, 3. maintain joint stability 4. Prevent/ delay development of deformities.	Severe pain after 9th week of exercise
Kang *et al.* (2019)	Supervised exercises	Not described	1. maintain/ increase MCP, PIP & DIP joints flexibility. 2. increases opponens pollicis strength and grip strength. 3. strengthens the extensor and abductor pollicis muscles.	Not described
Kjeken *et al.* (2011)	Supervised exercises	Not described	1.increase grip and/or pinch strength, ROM and function 2. Maintain CMC1 stability 3. decrease swelling, pain and tenderness	Not described
Kjeken *et al.* (2015)	Not described, however reported Inclusion of warm up exercises	Adherence reported	to maintain/ increase strength and stability of 1. CMC1 joint 2. thumb web space 3. grip strength and ROM in the digits 4. Wrist, upper arm & shoulder girdle	Not reported
Kroon *et al.* (2018b)	Not described	Not described	Not described	Not described
Lefler *et al.* (2004)	Supervised exercises	Authors reported that subjects who missed more than	Improve joint stability, strength, and decrease OA pain	Not described

Records	Emerging themes			
	Mode of delivery	**Compliance**	**Aim of exercises**	**Adverse effects/events**
		two sessions were dropped		
Nery *et al.* (2015)	Not described	Not described	Not described	Not described
Nguyen *et al.* (2016)	Not described	Not described	Not described	Not described
Østerås *et al.* (2014a)	Group (supervised) and home exercises	Adherence reported	1) increase strength& stability of shoulder girdle/ upper arm muscles 2) maintain/ increase flexibility of MCP, PIP, DIP joints; thumb web space & thumb stability CMC1 OA 3) increase grip strength.	1) increased inflammation & pain in one finger (n=1) 2. increased swelling & pain of all fingers (n=2). 3. increased shoulder/ neck pain in participants with such previous problems (n=5) 4. one withdrawal
Osteras *et al.* (2017)	Supervised and home exercise	Supervised exercise sessions improve compliance	Not described	Reported hand pain, finger joint inflammation, neck/ shoulder pain and one withdrawal
Pérez-Mármol *et al.* (2017)	Supervised sessions by an OT	Adherence reported	1) improve strength, fine manual dexterity and other upper limb functions 2) Produce additional benefit in upper limb disability.	Intervention has no side effects
Rocchi *et al.* (2018)	Supervised sessions	Not described	provide a temporary mobility and pain-free thumb	Not described
Rogers *et al.* (2009)	1) Supervised and home programme 2) Provision of written and pictorial instructions for home use.	Adherence reported Compliance to sham protocol reported	1) improve joint flexibility 2) strengthen grip and pinch	High withdrawal (n=18) due to e.g. increased hand symptoms; loss of interest or lack of remembrance to do exercises, etc
Scott (2018)	1) Provide clear description of patient- centred guidance on exercise intensity 2) Potential benefit of preparatory exercises in exercise training	Not described	1) improve function and pain with physical load in patients with first CMCJ OA.	Not described
Stamm *et al.* (2002)	home program after initial instructions	Adherence reported	Not explicitly reported, but improving hand flexibility and function was inferred	Intervention free of side effects
Stoffer-Marx *et al.* (2018)	1) supervised and home programme 2) group session also indicated	Scoring traces of usage in therapy putty by assessors.	Enhance ROM and grip strength	Tendovaginitis
Valdes *et al.* (2012)	1) Precede exercise with warm-up 2) Strengthening exercises should include 48 hours recovery period between sessions.	No information	1) Maximizing pain-free functional ROM 2) increase functional strength 3) maintain joint stability 4) avoid fixed deformities of the thumb	No information
Veronese *et al.* (2020)	Not described	Not described	Not described	Not described
Villafañe et al. (2013)	supervised exercises	No information	1) improve joint flexibility 2. strengthen grip and pinch	No adverse effects reported during/ after intervention

NB: Abductor pollicis longus (APL); first dorsal interosseous (FDI); Fine Motor Skills (FMS)

Appendix C Qualitative study

C.1 Standards for Reporting Qualitative Research (SRQR) checklist (O'Brien *et al.*, 2014)

	Page/line no(s).
Title and abstract	
Title - Concise description of the nature and topic of the study Identifying the study as qualitative or indicating the approach (e.g., ethnography, grounded theory) or data collection methods (e.g., interview, focus group) is recommended	95
Abstract - Summary of key elements of the study using the abstract format of the intended publication; typically includes background, purpose, methods, results, and conclusions	N/A
Introduction	
Problem formulation - Description and significance of the problem/phenomenon studied; review of relevant theory and empirical work; problem statement	96-97
Purpose or research question - Purpose of the study and specific objectives or questions	97
Methods	
Qualitative approach and research paradigm - Qualitative approach (e.g., ethnography, grounded theory, case study, phenomenology, narrative research) and guiding theory if appropriate; identifying the research paradigm (e.g., postpositivist, constructivist/ interpretivist) is also recommended; rationale**	99
Researcher characteristics and reflexivity - Researchers' characteristics that may influence the research, including personal attributes, qualifications/experience, relationship with participants, assumptions, and/or presuppositions; potential or actual interaction between researchers' characteristics and the research questions, approach, methods, results, and/or transferability	128
Context - Setting/site and salient contextual factors; rationale**	101
Sampling strategy - How and why research participants, documents, or events were selected; criteria for deciding when no further sampling was necessary (e.g., sampling saturation); rationale**	101
Ethical issues pertaining to human subjects - Documentation of approval by an appropriate ethics review board and participant consent, or explanation for lack thereof; other confidentiality and data security issues	101
Data collection methods - Types of data collected; details of data collection procedures including (as appropriate) start and stop dates of data collection and analysis, iterative process, triangulation of sources/methods, and modification of procedures in response to evolving study findings; rationale**	102
Data collection instruments and technologies - Description of instruments (e.g., interview guides, questionnaires) and devices (e.g., audio recorders) used for data collection; if/how the instrument(s) changed over the course of the study	102
Units of study - Number and relevant characteristics of participants, documents, or events included in the study; level of participation (could be reported in results)	110
Data processing - Methods for processing data prior to and during analysis, including transcription, data entry, data management and security, verification of data integrity, data coding, and anonymization/de-identification of excerpts	102

Data analysis - Process by which inferences, themes, etc., were identified and developed, including the researchers involved in data analysis; usually references a specific paradigm or approach; rationale**	102 -103
Techniques to enhance trustworthiness - Techniques to enhance trustworthiness and credibility of data analysis (e.g., member checking, audit trail, triangulation); rationale**	103

Results/findings

Synthesis and interpretation - Main findings (e.g., interpretations, inferences, and themes); might include development of a theory or model, or integration with prior research or theory	111-124
Links to empirical data - Evidence (e.g., quotes, field notes, text excerpts, photographs) to substantiate analytic findings	126

Discussion

Integration with prior work, implications, transferability, and contribution(s) to the field - Short summary of main findings; explanation of how findings and conclusions connect to, support, elaborate on, or challenge conclusions of earlier scholarship; discussion of scope of application/generalizability; identification of unique contribution(s) to scholarship in a discipline or field	126
Limitations - Trustworthiness and limitations of findings	127

Other

Conflicts of interest - Potential sources of influence or perceived influence on study conduct and conclusions; how these were managed	N/A
Funding - Sources of funding and other support; role of funders in data collection, interpretation, and reporting	N/A

C.2 Researcher Mortar account form for the OTTER qualitative study

OCTRU

OCTRU FORM: OF-000

MORTAR Account Request

(This Form relates to OCTRU SOP: GEN-003)

First Name:	Beatrice	Last Name:	Sankah
Initials (all including middle name/s)		B.E.A.S	
Job Title:	PhD student		
Work E-mail Address:	B.E.A.Sankah@soton.ac.uk		

Team (please tick):	CSM ☐	Gastroenterology ☐	CCTR ☐	OCTO ☐	OCTRU ☒
	ORTU ☐	Rheumatology ☐	SITU ☐	Other ☐	

Previous MORTAR user:	MORTAR SILO (please circle only one): ~~1~~ 2 ~~3 4~~ *1 = OCTRU CTIMP* *2 = OCTRU NonCTIMP* *3 = Non OCTRU Trials* *4 = Non OCTRU Trials and Non OCTRU SOPs*
User Signature:	Date: 13-2-18

Role (Please specify all roles required) Note: Role 2 will require OCTRU authorisation prior to being granted system access	
1) MORTAR User (System training record, access to SOPs and OCTRU Blog)	Yes
2) MORTAR Operational Lead (Assigned to Operational Heads of Trial Units only)	No
Operational Lead Signature (or delegate such as Portfolio Lead):	Date:
All requests must be authorised prior to submission. Please submit completed form to OCTRU by post or email it to: octrutrialshub@ndorms.ox.ac.uk	

OCTRU HUB USE ONLY:		
MORTAR Account created by:	Signature:	Date:
Sent user guide ☐	Added to blog ☐	Added to email list ☐
OCTRU authorisation for additional role		
MORTAR Operational Lead Authorised: Yes / No		
Additional Comments:		
Authorised by:	Signature:	Date:
Additional privileges added into system by:	Signature:	Date:

MORTAR Account Request

OCTRU-OF-000_V5.0_30Oct2015
Effective Date 30Oct2015

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C.3 Initial list of code ideas

P1

1. Period of exercise-evening (Once daily)
2. Difficult elastic band exercise
3. ROUTINE exercises
4. Dislike of recording exercises
5. Recall challenges (remembering to record exercise sessions in diaries)-P1

P2

1. Good exercise routine
2. High compliance to exercise; Exercises are just followed because its physio; Certain Image of physiotherapy portrayed i.e. do as they say
3. Exercises got easier with time
4. Satisfactory exercise experience
5. Seasons affected exercise performance
6. Positive effect of exercise (Increased mobility; Exercises became easier as it progressed)

P3

1. Exercise described as haphazard
2. 20 minutes exercise session too long
3. Couldn’t stick to a routine due to irregular day schedule
4. Irregularity with exercise performance (personality, naturally a lazy person)
5. Client personality affected exercise performance i.e. time management
6. exercise performance affected by patient lifestyle/ time management
7. exercises helpful (didn’t felt anything needs to be change)

P4

1. Exercise performance difficult outside home
2. Lifestyle or regular life routine affects exercising
3. Visible location of exercise logbook reminds to exercise
4. Family support in exercising
5. Adequate therapy support (Periodic exercising Infront of clinicians, help check for accurate exercising, Regular phone calls from clinicians)
6. Impact of seasons on exercise performance (Anticipated challenges of exercising in cold weather)

P5

1. Difficult thumb elastic band exercises: Exercise made joint sore; Challenges with elastic band use
2. Mixed reports of exercise benefits (ambivalence views on exercise benefits)
3. difficult to perform elastic exercises
4. elastic band makes exercises even more difficult
5. regular support during exercise performance /need for regular encouragement
6. difficult exercises hindered exercise adherence/ adequate performance

P6

1. exercise helpful with symptoms/ positive changes in hand symptoms
2. Prior knowledge and experience with exercises influenced exercise performance
1. Adherence to exercise routine affected by symptoms
2. Believing in the benefits of exercises to just do it
3. Accepting the benefits of exercises on the hand to just do it when
4. Exercises are purposeful (Exercises does what’s its intended to do)
5. Exercise compliance influenced by person’s worldview/ outlook on life

P7

1. Good exercises with recognized benefits i.e moving joints
2. Painful to sit for 20 minutes and just exercise on thumb
3. Exercises split into bits which was doable
4. Splitting exercises in to blocks made exercise performance easier
5. Regular breaks helped exercise performance

P8

1. Elastic band exercises difficult to do
2. Benefit of exercise. Improved hand activities

3. Adherence to exercise performance due to return to work expectations (not to struggle with work activities)
4. Expectations of people motivated exercise performance
5. Inability to perform band exercises (difficult exercises) triggered negative emotions

P9

1. Difficult elastic band exercises
2. Difficulty of performing band exercises eased with time.
3. Time duration too long
4. Splitting exercise into 2 halves
5. Exercise performance/ adherence was influenced by personal character

P10

1. Splitting exercise time facilitated exercise performance (Made it easier to perform)
2. Exercising at a specific time helped exercise adherence
3. Having exercise items/equipment facilitates exercise performance and adherence
4. Exercise benefited participant
5. Elastic and peg exercises good due to perceived positive impact on thumb (Easy to perform as items were handy and could be carried anywhere)
6. Positive effect of exercise (Achieved it purpose and benefited participants)

C.4 Screenshot of themes and nodes generated in NVivo to address the study objectives

Name	Files	References
Patient experiences and views (RQ1 Anchor code1)	0	0
Views on exerccise programme	0	0
Difficult and painful, yet doable (Challenging)	6	9
Difficult to perform	6	15
Tolerable	4	5
Painful to perform	5	9
Satisfactory	7	8
monotonous	3	3
exercises are adequate	4	4
Purposeful	8	27
Convenient	3	3
Beneficial	5	9
Improved symptons	5	6
Awareness	2	2
Knowledge gain	1	1
Meaningful	4	6
Experinces	0	0
Painful	1	1
Non enjoyable (boredom)	1	1
Burdensome	1	1
Emotional (Provoked negative emotions)	1	1
challenging	0	0

Name	Files	References
Exercise Adherence (RQ2 Anchor code2)	10	49
Making behavioural and lifestyle modifications	7	17
Developing a routine	4	6
Accommodating exercise into daily life	7	8
Importance of reminders	3	3
Influence of personal attitudes and beliefs	9	22
Beliefs	1	2
Compliance to Physio	1	2
Attitudes	8	20
Attitudes that ensured adherence	7	14
Attitudes that limited adherence	3	6
Pain and Physical limitations	5	10
Barriers and facilitators (RQ3 Anchor code)	8	17
Barriers	4	4
Facilitators	6	13
Suggestions for exercise modification	4	13
More Encouragement	1	1
Frequent interraction with healthcare team	1	1
change band exercise	1	1
Dont watch telly whilst exercising	1	1
impact of weather	1	2
Inplications for research	1	2

C.5 Summary of Findings - Patient experiences and views on exercises

Major Theme	Sub-theme	No of records	No of References	EVIDENCE
Difficult and painful, yet doable (Challenging)	Difficult to perform exercises	6	15	“All the ones with the elastic band were difficult”. **(P1)** “Level three *[Functional exercises]* more of a problem because then there is more, [..] you’ve got the pegs and the plate and the writing to do which is more difficult if you are not at home. I’d have had a job to do it if I was working”. **(P10)** “In Manchester for a week […] so then it’s difficult isn’t it if you’ve got to remember to take paper and a pen and have a plate and have a bottle to unscrew. […] Stage of the exercises using the aids that was difficult then”. **(P10)** “I mean just having the bands, even having them in your pocket and if you are going out for the day, or if you are sitting in the car you can just do them then can’t you, but when you’ve got the plate and the writing to do, that’s difficult. You’ve got to sit at the table to do that really, haven’t you? **(P10)** A lot of exercises are difficult, because of the items you have to have to hand. **(P10)** “Some of the exercises I found very difficult”. *I did struggle with the elastic band one, when I first put the thin elastic band on, I couldn’t move my thumb at all. It’s that kind of thing that I have problems with” (P5)* **(P5)** I struggle with it *[elastic band exercises]*. […] so, the minute you put an elastic band on it, it becomes very difficult. **(P5)** “I’d do five plus five minutes, because it was quite difficult to sit there and do it for 20 minutes. **(P7)**

Major Theme	Sub-theme	No of records	No of References	EVIDENCE
				"But I did find more than 10 minutes to be quite tough going and I thought I can't do this for another 10 minutes constantly, so I'm going to have to have a break. **(P7)** "Set number one I thought at first because I struggled to lift the thumb, I don't struggle to bend it down at the joint, but I find it quite difficult to lift it. So, I struggled to do that…" **(P8)** "as I say, I couldn't do the second set of exercises, it made me angry and frustrated" **(P8)** "...the first elastic band was fine, but the thicker one I had great problems with because my hand got very tired and very sore and I had to stop. So, I did find that difficult" **(P9)** "The thicker band, yes. That was quite difficult. And doing it for 20 minutes is a long time". **(P9)** "the only comment I would make was that I thought it *[exercise programme]* started off with very easy exercises and then it had very difficult ones, for me anyway, the difficult ones being the rubber band. **(P9)**
	Painful to perform (Problems with pain)	5	10	"It took me a few weeks to do it without, easily without any pain. **(P10).** "I wouldn't say I enjoyed doing the elastic band one, because it does make the joint sore" **(P5).** "I did try with the rubber bands, the thin rubber band I could do, but after probably about four or five minutes they made my thumb ache." **(P3).** "I did find with the elastic band, if I did it two days on the trot, it was more painful" **(P5).**

Major Theme	Sub-theme	No of records	No of References	EVIDENCE
				"It *[elastic band]* hits the spot where the difficulty with my thumb joint is, that I'm putting a lot of pressure on it, and it hurts doing that without pressure on it, so the minute you put an elastic band on it, it becomes very difficult. **(P5).** "When I first put the elastic band on, I thought crikey this isn't the right size, it's so tight before I'd even moved my thumb. So, it was painful when it was on, because it made a big dent in my finger as well". **(P5).** "...when I was doing the band sometimes I'd only done it twice a week because it was just, I didn't feel I wanted to aggravate it *[thumb] really* on the days when it was bothering me. (**P6)** "the first elastic band was fine but the thicker one I had great problems with because my hand got very tired and very sore and I had to stop" **(P9)** "Well it was just the hand getting, hand and the thumb getting sore". **(P9)** "I found that it (elastic bad exercises) made the joint painful, it was painful to do, and it was painful afterwards". (P9)
	Tolerable	4	6	"No. No, it *[exercise programme]* was just, this is physio, just do it. **(P2)** "Right, these *[exercise programme]* were a little bit more haphazard. But I did try, I did try at least…" **(P3)** "Some of the exercises I found very difficult. Some I found quite helpful". **(P5)** "I can move my thumb both out and up a lot better than I could before, although I wouldn't say I enjoyed doing the elastic band one, because it does make the joint sore". **(P5)** "It was difficult to begin with, but it became easier over time". **(P9)**

Major Theme	Sub-theme	No of records	No of References	EVIDENCE
				"I wouldn't say I enjoyed doing the elastic band one, because it does make the joint sore" **(P5).**
Satisfactory	Monotonous	3	3	"As time has gone on I was alright up to 2 months, then it's starting to get a bit monotonous [..], you know what it's like when your thumb starts to feel better you say I won't do the exercise you think it's OK now. **(P10)** "I mean sometimes it's time wise it doesn't sound a long time 10 minutes but to sit there 10-15 minutes is quite a long time just to sit and do the exercises and you are doing the same sort". **(P4) -boring** "I tried to do the 20 minutes, but I found the 20 minutes was quite a long time to be just sitting doing that sort of exercise repetitively. **(P3)**
	Exercises are adequate	4	4	"Yes, I found that OK" **(P1)** "Not too bad. I mean I'll be honest there were some days when I'd forget or was too busy doing things" **(P4)** "Yes, that was OK". **(P7)** "I found it OK". **(P8)**
Purposeful	Convenient	3	3	"I thought that it *[exercise programme]* was well thought out and people could easily incorporate it in their lives to do. **(P1)** The ones with the elastic bands are quite good. You really felt you were pushing against them and the pegs […] Again, you can take them anywhere with you can't you in your pocket. **(P10)** "Even on holiday I'd sit on my sunbed […] and doing all the finger and the thumb ones and even on the plane. So, those sorts of things you can do them anywhere. **(P7)**

Appendix C

Major Theme	Sub-theme	No of records	No of References	EVIDENCE
	Meaningful	4	6	“Well I think you did it all really well. I thought it was well thought through. **(P1)** “The exercises I think because they definitely made a difference, they definitely made a difference. **(P10)** “…obviously the exercises you’ve given me have worked”. **(P10)** “The ones with the elastic bands are quite good. You really felt you were pushing against them and the pegs I think feel like they’re doing, they’re quite good. **(P10)** I think to do the exercises is very good. It does keep it moving. **(P7)** “Fine, yes, really fine. It was actually quite a good routine for me to actually stop for that time and just sit down and concentrate on the physio”. **(P2)**
	Beneficial	5	9	***Awareness*** “It made me think about what I was doing – that’s one of the main things. It made me consider how I was using my hands and how I was using my thumbs. So, I did have to consider that. So that was a good thing” **(P9)** “Fine, yes, really fine. It was actually quite a good routine for me to actually stop for that time and just sit down and concentrate on the physio”. (P2) ***Knowledge Gain*** I think because you don’t tend to think about how you turn a bottle top or a key or something like that or hold a plate, you don’t think about it you just do it. But it did make me realise that there are different ways of doing things. **(P9)** ***Improved symptoms*** “I could see what the exercises were doing, but no I mean I could feel it was getting easier and I could stretch further, so I could see it was effective in that”. **(P2)**

Major Theme	Sub-theme	No of records	No of References	EVIDENCE
				“definitely my thumb was more mobile really, as that went on”. **(P2)** “Well, personally it seems to have helped me”. **(P3)** “Well as I said, the first ones I found they certainly did help, and I have found over the three months I do have more movement now in my thumb joint than I had when I first started so they’ve obviously done something in that my thumb is more mobile. I think probably it’s a little bit stronger as well” **(P5)** Obviously more resistance and putting more of a strain on the muscles and the thumb. So perhaps I got a bit stronger though over the course of time **(P9)** I’m asked to lift it with the joint bent down and that is what I struggle to do. Now I’m lifting it at the moment, and I can lift it because the exercises have helped me to do that **(P8)**
Exercise Experiences			Less enjoyable	“I wouldn’t say I enjoyed doing the elastic band one because it does make the joint sore”. (P5)
			Was a burden	“Level three *[Functional exercises]* more of a problem because then there is more, [..] you’ve got the pegs and the plate and the writing to do which is more difficult if you are not at home. I’d have had a job to do it if I was working”. **(P10)** “I’d do five plus five minutes, because it was quite difficult to sit there and do it for 20 minutes. **(P7)** “The thicker band, yes. That was quite difficult. And doing it for 20 minutes is a long time”. **(P9**
			Negative emotional experience	“as I say, I couldn’t do the second set of exercises, it made me angry and frustrated” **(P8)**

C.6 Summary of Findings - patient reported adherence

Major theme	Sub-theme	No of records	No of References	Evidence
Behavioural and lifestyle modifications	Accommodating exercise into daily life	6	7	***Accommodating*** “when I was sat down in the evening I would do it. Occasionally I’d do it at work when I remembered, but mainly, I’d do them in evening for 230 minutes or however long and just sit there and do it then”. **(P1)** “I like to do the exercises first thing in the morning really and get them out the way and then they’re done then” **(P10)** “we’d be going somewhere in the car and my husband would be driving and I’d think oh I’ll do my exercises now. Well, because you haven’t done the warmup in the warm water but give it a rub and then do the exercises. **(P3)** “With the exercises I had to fit it in with other things, make sure I had the time to do it, spend the time warming up my thumb joint and then sit somewhere and concentrate on doing it”. **(P5)** “Even on holiday I’d sit on my sunbed and I was doing ten minutes and doing all the finger and the thumb ones and even on the plane”. **(P7)** ***Less accommodating*** In Manchester for a week [..] so then it’s difficult isn’t it if you’ve got to remember to take paper and a pen and have a plate and have a bottle to unscrew. […] It was alright while I was at home, but if you wanted to go somewhere it was difficult. **(P10)** “I’ll be honest there were some days when [..] I wasn’t in my place to do them easily and like I said we went on holiday a couple of times, so I’d forget **(P4)**
	Developing a routine	4	6	***Consistent*** “I was doing it once a day in the evening.” **(P1)**

Major theme	Sub-theme	No of records	No of References	Evidence
				“Well the first six weeks it was fine really, because I was going up to the hospital and doing it *(exercises)* up there really while my husband was busy with his treatment”. **(P10)** “I like to do the exercises first thing in the morning really and get them out the way, and then they’re done then aren’t they”. **(P10)** “It was actually quite a good routine for me to actually stop for that time and just sit down and concentrate on the physio”. **(P2)** ***Inconsistent (Lack of routine)*** “I haven’t really got a set routine in the day; it depends on what happens. Just looking at my charts, I would say three times a week definitely. Sometimes I’d do it for 20 minutes three times a week, and then do another five or ten minutes here and there”. **(P3)** “for somebody retired I’m quite a busy person, I’m involved in quite a lot of stuff, so [..] I haven’t really got a set routine in the day, it depends on what happens. **(P3)**
	Importance of reminders	3	3	“Well the first six weeks it was fine really because I was going up to the hospital and doing it *(exercises)* up there really while my husband was busy with his treatment [..]. Level three more of a problem because then there is more, my husband was home by then I think, just about home not going to the hospital, because then you’ve got the pegs and the plate and the writing to do which is more difficult if you are not at home. **(P10)** “most times you are sitting down, and you’ve just got nothing to do and you just sat and watching the TV and my husband said, I’m going to the gym and I said, ‘OK I’m just going to do my exercises, as well as sitting on the settee’”. **(P7)** “So, when we’ve been away, obviously it’s not the first thing on my mind, so I have to do them when I remember. When I’m at home I’ve got my folder already

Major theme	Sub-theme	No of records	No of References	Evidence
				out so that tends to remind me a little bit more. So, it's a little bit easier to carry them out at home. **(P4)**
Beliefs and attitudes	Beliefs	1	2	***Compliance to Physiotherapy*** No. No, it was just, this is physio just do it. **(P2)** "It was actually quite a good routine for me to actually stop for that time and just sit down and concentrate on the physio". **(P2)**
	Attitudes	8	20	**Positive attitudes – (***attitudes that aided adherence***) (7/14)** ***Committed*** "With the exercises I had to fit it in with other things, make sure I had the time to do it, spend the time warming up my thumb joint and then sit somewhere and concentrate on doing it **(P2)** ***Compliant*** "I would do whatever the trial had said. I followed it religiously" **(P1)** "I think I've followed it as required and as my body has accepted it on any given day" **(P6)** ***Positive outcome expectations*** *(motivation towards long-term goals)* "there have been days when it's just not been really very nice to do. But [..] if I thought exercising the thumb was going to help keep it going and preventing it from getting worse. Sometimes that's something that you've just got to accept" **(P6)** "So, on my hand I'm doing the exercises and I'm thinking, well this is actually helping me so when I get back to my upholstery work in September, I will find it easier to do my stitching". **(P8)** ***a keep going attitude*** "The elastic band was really hard. That I found really quite painful, but I still did them but that was, those movements were quite hard. **(P1)**

Major theme	Sub-theme	No of records	No of References	Evidence
				"these *[exercises]* were a little bit more haphazard. But I did try, I did try at least, [..] 3 - 4 times a week I tried to do the 20 minutes**. (P3)** **"**The elastic band one I breathed a sigh of relief and think that God, I don't have to do that anymore because I did not like doing it". **(P5)** "the last exercise which is supposed to be level three and I looked at and I thought I could do these anyway, so I thought I'd persevere with the elastic band one and the simpler one because I don't have any trouble, I mean writing and squeezing clothes pegs I can do anyway." **(P5)** "Whether 20 minutes is a long time to work through the pain [..], no pain no gain" **(P7)** "I couldn't do the second set of exercises, it made me angry and frustrated I suppose, but there's no harm in trying is there" **(P8)** "So, I did find that (*rubber band exercises*) difficult [..] and I spent a long time, [..] several weeks using the rubber bands because I felt that I wanted to conquer the problems I was having and I did eventually move on after several weeks." **(P9)** "I got a bit fed up with trying to do that *[rubber band exercises],* but I persisted because I'm one of those people that will persist when I'm given a challenge. **(P9)** "I haven't been so regular with the exercises as I intended to be. But I have tried". **(P3)**
				Negative Attitudes- attitudes that limited adherence **(3/6)** ***Poor time management*** "it was the time, it's my time management. I'm a bit rubbish and bit haphazard. **(P3)**

Appendix C

Major theme	Sub-theme	No of records	No of References	Evidence
				Dislike for exercises "I don't like doing exercises". **(P5)** "I'm not a great fan of doing that kind of exercise to be honest with you and as I say I did find with the elastic band one it hurt anyway. I was a bit of a wuss with it I'm afraid. **(P5)** ***Laziness*** "But I am as a person I am little bit lazy about exercise I must admit. So, I did initially say that I would do them every morning after breakfast, but my days just vary so much that sometimes I'd forget" **(P3)** ***Busy life schedule (**Lack of time'***)*** "for somebody retired I'm quite a busy person, I'm involved in quite a lot of stuff, so [..] I haven't really got a set routine in the day, it depends on what happens. **(P3)** "I mean I'll be honest there were some days when I'd forget or was too busy doing things" **(P4)**
Pain and Physical limitations	OA-related symptoms	1	1	"when I was doing the band sometimes, I'd only done it twice a week because it was just, I didn't feel I wanted to aggravate it really on the days when it was bothering me". **(P5).**
	Exercise-related pain and too high workload	6	11	***Exercises caused greater pain*** "It took me a few weeks to do it *(elastic band exercises)* without, easily without any pain". (**P10**) "I did try with the rubber bands, the thin rubber band I could do but after probably about four or five minutes they made my thumb ache and the thicker one I didn't even go there because the thinner one was making my thumb ache."(**P3**)

Major theme	Sub-theme	No of records	No of References	Evidence
				"I did find with the elastic band if I did it two days on the trot it was more painful, so I was better if I left it and then did another one another day. **(P5).** "I wouldn't say I enjoyed doing the elastic band one because it does make the joint sore". **(P5).** "When I got to the using the elastic bands, using the resistance ones the first elastic band was fine but the thicker one I had great problems with because my hand got very tired and very sore and I had to stop". **(P9)** ***Activity aggravated symptoms*** "when I was doing the band sometimes, I'd only done it twice a week because it was just, I didn't feel I wanted to aggravate it really on the days when it was bothering me". **(P5).** ***Functional limitations*** "It *(elastic band)* hits the spot where the difficulty with my thumb joint is, that I'm putting a lot of pressure on it and it hurts doing that without pressure on it so the minute you put an elastic band on it, it becomes very difficult. I have very little movement of being able to pull or pull it outwards or upwards and with an elastic band on it it's a lot harder". **(P5).** "When I first put the elastic band on, I thought crikey this isn't the right size, it's so tight before I'd even moved my thumb. So, it was painful when it was on because it made a big dent in my finger as well". **(P5).** "I can't do number two at all with the bands on my thumb for obvious reasons it's just too, it's just impossible so I've given up trying. **(P8).** "I'm asked to lift it with the joint bent down and that is what I struggle to do. Now I'm lifting it at the moment, and I can lift it because the exercises have helped me to do that, but if I put an elastic band and I've got resistance I can't do it. **(P8).**

Major theme	Sub-theme	No of records	No of References	Evidence
				“when I first put the thing elastic band on, I couldn’t move my thumb at all. It’s that kind of thing that I have problems with. I never progressed beyond that” [..] **(P5).**

C.7 Summary of Findings for - barriers and facilitators to exercise

Major theme	Sub-theme	No of records	No of References	Evidence (Data Extracts)
Barriers				
Remembering to exercise Challenges in daily life		**2**	4	“When I sat down in the evening I would do it. Occasionally I’d do it at work when I remembered, but mainly, I’d do them in the evening **(P1)** “I think the writing it down was not exactly complicated. but trying to remember that was, you know, you had to really think about, but apart from that, this is my inadequacy of thinking about it. Yes, the recording it all. I remembered to do it *(exercises),* but then 2 or 3 days later I thought, oh damn where is the bit of paper I must write down that I’ve done it”. **(P1)** “I’ll be honest there were some days when I’d forget or was too busy doing things”. **(P4)** “When we’ve been away obviously it’s not the first thing on my mind, so I have to do them when I remember. **(P4)**
Exercise programme	Exercise aids	**4**	**9**	**Handiness and ease of exercise performance** ***Aids made exercising difficult***

Major theme	Sub-theme	No of records	No of References	Evidence (Data Extracts)
				"In Manchester for a week [..] so then it's difficult isn't it if you've got to remember to take paper and a pen and have a plate and have a bottle to unscrew […]. It was alright while I was at home, but if you wanted to go somewhere it was difficult. Stage of the exercises using the aids that was difficult then". **(P10)** "when I got onto the level three exercises where you needed the aids, at first it was just doing the exercises and then I moved onto the elastic band on the hand. Level three more of a problem, because then there is more […], because then you've got the pegs and the plate and the writing to do, which is more difficult if you are not at home. I'd have had a job to do it if I was working". **(P10)** "A lot of exercises are difficult, because of the items you have to have to hand". **(P10)** "I'd like to either continue the exercises with my thumbs, but I wouldn't want to use any aids. I wouldn't want to sit at the table, I'd want exercises I can do whilst sitting down watching the television or something [..]. I don't need objects". **(P10)** ***Aids made exercising easy*** "I mean just having the bands, even having them in your pocket and if you are going out for the day or if you are sitting in the car you can just do them then can't you, but when you've got the plate and the writing to do that's difficult, You've got to sit at the table to do that really, haven't you?" **(P10)** "the band *you can* even do that in the car when you are going somewhere so that's maybe a bit easier". **(P10)** **Perception on aided exercises** ***Difficult to perform*** "Lifting the plate strangely enough was the one that caused the most problems really. I don't know why [..] the hardest one really". **(P10)** ***Easy to perform***

Major theme	Sub-theme	No of records	No of References	Evidence (Data Extracts)
				"the ones with writing and tearing bits of paper and using the pegs and things like that seemed easy". **(P9)** "Some of the things on the level three exercises I don't have a problem with anyway. I mean I can tear up paper and pick things up and write and do all sorts of things that I don't have any issues with it. I hang my washing out and put clothes pegs on, it's not something I have a problem with". **(P5)**
	Exercise content (Difficulty of the elastic band exercises) Interruption of daily routines	**4**	**6**	"I tried to do the second set of exercises *(elastic band exercises)* and I just could not do them". **(P8)** The more advanced form, which is the second set where you put a band on your thumb, I haven't been able to do those at all. I just couldn't, just no way I could do them. **(P8)** I can't do number two at all with the bands on my thumb for obvious reasons it's just too, it's just impossible so I've given up trying. **(P8)** "Well I did find the level one where I was moving my thumb and moving my fingers with my thumb, I think that did improve both the movement and the strength of the joint without making it too painful. So, if I were to do exercises I would do that one rather than the elastic band one. [..] I think mainly because I found that it made the joint painful, it was painful to do, and it was painful afterwards. **(P5)** "The elastic band was really hard. That I found really quite painful […] those movements were quite hard". **(P1)** "the only comment I would make was that I thought it started off with very easy exercises and then it had very difficult ones, for me anyway, the difficult ones being the rubber band". **(P9)**
	Prolonged exercise duration	**2**	4	"I just thought that 20 minutes at one sitting was quite a long time to be sitting doing the exercises". **(P3)**

Major theme	Sub-theme	No of records	No of References	Evidence (Data Extracts)
	(Boredom, and Tolerability)			"The thicker band [..] *(exercises)* was quite difficult. And doing it for 20 minutes is a long time". **(P9)** "20 minutes is an awfully long time. On a couple of occasions, I split the time into two lots of 10, because I couldn't do the 20". **(P9)** "There weren't any real problems with doing them, but I didn't really want to do them more than three times a week because it does take some time". **(P9)**
Hand OA symptoms	Pain	**3**	**3**	"I found that it *(elastic bad exercises)* made the joint painful, it was painful to do, and it was painful afterwards". **(P9)** "But then the second lot when I was doing the band sometimes I'd only done it twice a week because it was just, I didn't feel I wanted to aggravate it really on the days when it was bothering me". **(P6)** "Yes, it just seemed to be too much all at once, so I'd kind of rest it and then do it again. I didn't work through the pain". **(P6)**
Facilitators				
Individual attributes	Self-efficacy	**6**	**10**	**Motivation** "..there's none of it *(exercises)* that I won't have a go at every now and again [..], if I thought exercising the thumb was going to help keep it going and preventing it from getting worse. Sometimes that's something that you've just got to accept, isn't it" **(P6)** **Taking ownership of exercise programme** ***Making personal effort and adjustment.*** "I just put aside a set time and said, right it's now I've got to do it now and just got on with it". **(P9)**

Major theme	Sub-theme	No of records	No of References	Evidence (Data Extracts)
				"Yes, I think I'd do it *(exercises)* the same way, find a slot in the day that suits me to do them. I've been doing them each morning if I can before the start of the day. You can get on with your day" **(P10)** ***Dividing exercise sessions*** "I've been doing them, what I've done is 10 minutes a day instead of 20 minutes three times a day, I've been doing them" **(P10)** "Just looking at my charts, I would say three times a week definitely, sometimes I'd do it for 20 minutes three times a week and then do another five or ten minutes here and there**. (P3)** "I tried to do them, oh about three times a week and about 20 minutes a day, but sort of like sometimes it wouldn't be 20 minutes one full time. Sometimes I'd split it during the day, and it could be 10 minutes in the morning and then it could be another 10 minutes in the afternoon. Even if I didn't have that time, even if it was 5 minutes, I'd try to write it down to show how it was broken down you know **(P4)** **"**But I did find more than 10 minutes to be quite tough going and I thought I can't do this for another 10 minutes constantly so I'm going to have to have a break". **(P7)** "I'd do 5 plus 5 minutes, because it was quite difficult to sit there and do it for 20 minutes. So, I made a note, I did it for 10 minutes plus 5 minutes and then I did 15 minutes and then in the evening I did another 15 minutes". **(P7)** "...it *(exercise instructions)* says at least 20 minutes three times a week. [..] So, I just read it as, as long as I do 20 minutes. If I'm doing it on a Wednesday, I'll do 5 minutes now and I'll do 10 minutes in a minute and 5 minutes tonight. It doesn't say continuous 20 minutes to get the benefit. Do you know what I mean?" **(P7)**

Major theme	Sub-theme	No of records	No of References	Evidence (Data Extracts)
				"20 minutes is an awfully long time. On a couple of occasions, I split the time into two lots of 10 because I couldn't do the 20. That was right at the very beginning though". **(P9)** **Reasons for dividing exercise sessions** ***Time Constraints*** "Even if I didn't have that time, even if it was 5 minutes, I'd try to write it down to show how it was broken down you know" **(P4)** ***Reduce pain*** "I found it painful to sit and do it for 20 minutes on the thumb". **(P7)** "it just seemed to be too much all at once, so I'd kind of rest it and then do it again. I didn't work through the pain". **(P7)** ***Easier to manage and perform exercises*** "No, it's just easier to manage 10 minutes a day". **(P10)** **"**That again was like I'd do 5 plus 5 minutes, because it was quite difficult to sit there and do it for 20 minutes". **(P7)** ***Shortening exercise sessions*** "I mean sometimes it's time-wise, it doesn't sound a long time 10 minutes, but to sit there 10 to 15 minutes is quite a long time, just to sit and do the exercises[..] So, I'd do them, have a break from that and then go back later and do it. If I had more time, I'd do that a bit more" **(P4)** "But I did find more than 10 minutes to be quite tough going and I thought I can't do this for another 10 minutes constantly, so I'm going to have to have a break" **(P7)** "20 minutes is an awfully long time. On a couple of occasions, I split the time into two lots of 10, because I couldn't do the 20**"** **(P9)**

Appendix C

Major theme	Sub-theme	No of records	No of References	Evidence (Data Extracts)
	Personality	**3**	**4**	**Organisation** "It was good to begin with. I've got the programme in front of me and I've got notes written down. I am a very organised person". **(P9)** **Focused and concentration** "Well I can do [..] the first lot of exercises and of course it's doing it slowly, [..] to watch my hand whilst I'm doing it. It's no good trying to watch a bit of good telly and the exercises at the same time [..]. You've really got to make sure that you are really doing it and concentrate [..]. You really do need to make it work". **(P6)** **Perseverance** "...there's none of it *(exercises)* that I won't have a go at every now and again even the clothes peg thing. But I don't think that it's particularly suited me to be doing it say three times a week because there have been days when it's just not been really very nice to do. But, yes, [..] if I thought exercising the thumb was going to help keep it going and preventing it from getting worse. Sometimes that's something that you've just got to accept, isn't it" **(P6)** **"...**as I say I couldn't do the second set of exercises, it made me angry and frustrated I suppose, but there's no harm in trying is there". **(P8)**
Support	Family support	**1**	**1**	**Good spouse support** "In fairness my husband will say sometimes, have you done your exercises. So, then I feel like a naughty schoolgirl whenever I haven't". **(P4)**
	Health Professional support	**3**	**5**	**Adequate support** "The support was very good when I went to the hospital. [..] Like I said, talking it through with *(the therapist)* I said, when I'd done them [..], my thumb really aches, and she said well that's right it shows that you are using it. She would correct me, I'd show her what I was doing and would say try and do it this way, [..] so the support was good, and I've had the phone calls back up" **(P4)**

Major theme	Sub-theme	No of records	No of References	Evidence (Data Extracts)
				“I think the only thing, well it comes with a very good set of instructions, you get a follow up, so you have somebody to talk to.” **(P5)** **Lack of sufficient ongoing and follow-up support** “I think you are not sure how much pain it should or not be giving you. A little bit more support when doing the more difficult exercises I think might help.” **(P5)** “Well just maybe seeing somebody and making sure that you were doing them properly rather than just twice over the 3-month period. I appreciate they probably haven’t got the time, but exercise I think is better if you’ve got somebody to encourage you. **(P5)** “I think it *(having an extra clinic visit)* might have helped, yes. Just to give you the confidence to know that you are doing it *(exercises)* properly [..]. I was going in a few days anyway to see the physio at [..] Hospital, and I did ask her then and she said to me well just do what you can with it. And that was what I did”. **(P5)** “if we ask a question we need to be told why. [..] I said, why am I doing these [..] And they said, we don’t know, this is what we’ve been asked to do. [..]. Obviously you *(researchers*) all know what you are doing and you all know why this is happening but they *(trial research clinicians)* didn’t seem to know why and they couldn’t tell me why and I just think you need to, if you are going to do the trial you need to know why you are doing things rather than, oh I don’t know.
Exercise experience and beliefs	1.Personal experience 2.Knowledge of exercise benefits	**3**	**3**	**Positive exercise experience/ prior knowledge influence exercise behaviour** “I mean I’ve done exercise, I’ve done yoga and Pilates and all sorts of things, so I just did it *(exercises)* to the level that I felt I was making it do something without actually making it do more than it actually wanted to do” **(P5)** “Well I do like the ideas and I might be doing some good. It’s like with my chronic knees, I’ve been doing a programme of quite vicious exercises [..] and although it’s painful to do those knee exercises, I’m doing them because I know that I’m strengthening the muscles. [..] So, on my hand I’m doing the exercises and I’m

Major theme	Sub-theme	No of records	No of References	Evidence (Data Extracts)
				thinking, well this is actually helping me so when I get back to my upholstery work in September, I will find it easier to do my stitching. **(P8)** "…I'm not a fanatic at all [..] But I've done yoga for donkey's years [..]. So, getting back to doing the exercises, I've done exercises long enough to be aware of what my body is doing really. Although I'm not yoga expert at all, but I'm quite certain it's made me fairly supple at 73 nearly" **(P6)**

Appendix D Proof of concept study

D.1 Study Poster (03Oct2018Version_3)

D.2 Calibration of MIE Pinch/Grip Digital Analyser

MIE Pinch/Grip Analyser Calibration

The MIE digital grip and pinch analyser was calibrated using the Electromechanical Test machine at the Faculty of Engineering, University of Southampton with assistant from an engineer (Dr Alex Dickenson) on 22nd May 2018. Loads of varying forces were applied to the MIE analyser in increasing and decreasing values for both pinch and grip abilities. Further details discussed below.

Pinch grip

A near perfect linear correlation (correlation coefficient 0.999984) between the MIE digital analyser and the electromechanical test machine for pinch grip test was calculated as shown in Figure 1. The MIE pinch/grip analyser therefore accurately measures pinch grip ability.

Hand grip Calibration

A perfect linear correlation (correlation coefficient 0.999805) between the MIE digital analyser and the electromechanical test machine for handgrip test was calibrated as shown in Figure 1. The MIE pinch and grip analyser therefore accurately measures hand grip ability. Figure 2 shows the description of the calibration process for both tests in the laboratory.

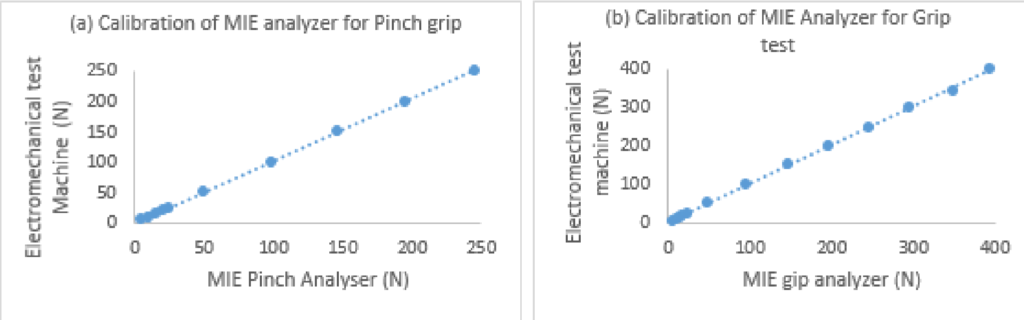


Figure 1: Correlation between of MIE digital analyser and electromechanical test machine during calibration (a) calibration for Pinch grip; (b) calibration for Hand grip

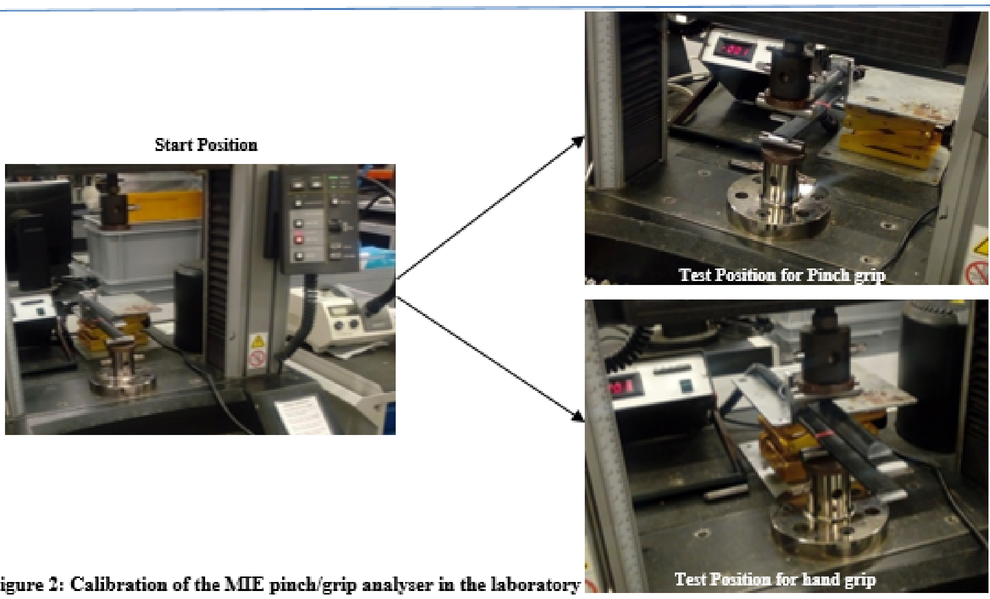


Figure 2: Calibration of the MIE pinch/grip analyser in the laboratory

D.3 Modified Borg Scale for Load Selection (Heine *et al.*, 2012)

1. Select a load (colour) that you think is within the participants' s capability
2. Ask the participant to perform 3 repetitions of grips
3. Ask the participant to rate the level of difficulty from 0 to 10 using the descriptions below as cues
4. Use the feedback to adjust the level of load for each exercise
5. Compare with the other hand. Choose the load colour using the rating from the weaker hand

   If the exercise involves exercising the different fingers, base the load on the 1st finger strength
6. Ask the participant to complete the exercise set for each hand
7. Record the load (colour) in assessment and exercise log for each exercise

   NB: For the initial session, a load that the participant rates as between 3 and 4 (moderate to somewhat strong) was selected. Subsequent progressions were made as explained in the section 7.3.7.4.

0	**Nothing at all**
1	Very easy
2	easy
3	moderate
4	Somewhat hard
5	hard
6	
7	Very hard
8	
9	
10	Very, very hard

D.4 Participant Information Sheet (16Nov2018 Version_3)

Participant Information Sheet

Study Title: Effect of explosive exercises on strength and fatigue of the hand: a proof of concept study

Researcher: Beatrice Sankah
ERGO number: 43602

You are being invited to take part in the above research study. To help you decide whether you would like to take part or not, it is important that you understand why the research is being done and what it will involve. Please read the information below carefully and ask questions if anything is not clear or you would like more information before you decide to take part in this research. You may like to discuss it with others, but it is up to you to decide whether or not to take part. If you are happy to participate you will be asked to sign a consent form.

What is the research about?
This is a student project for the academic qualification of a PhD. The researcher is a physiotherapist and PhD student within the faculty of Health Sciences, University of Southampton, funded by the Commonwealth Scholarship Commission, UK. The objective of this study is to investigate the effect of explosive exercises on handgrip strength, pinch strength and muscle fatigue in a sample of healthy adults.

Why have I been asked to participate?
You have been invited to participate in this study, as you are healthy and aged between 18 and 45 years.

What will happen to me if I take part?
You will be asked to perform two procedures: hand Measurements and the investigated hand exercise protocol for six weeks.

Procedure for Hand Measurements
On the first day of data collection, you will be asked to sign a consent form. Your weight and height will be measured. Your hand mechanical properties using a devise called the MyotonPRO will be evaluated first. This will be followed by measuring the strength you exert in your hand and fingers when you grip and pinch using a device called the MIE digital grip analyser. The rate at which your hand muscles fatigue whilst gripping will also be recorded with the same instrument. These hand measurements will last approximately 40 minutes and will be repeated again after one week and at six weeks after the exercise training. Details of the measurements are explained below.

1. Measuring your hand muscle mechanical properties
Mechanical properties of muscles include tone, stiffness, elasticity and relaxation. These will be measured in the muscles in your palm and forearm. For each muscle, the researcher will locate and mark a testing site on the skin over the muscle to be measured. The MyotonPRO device will be placed on the skin the probe on the device will apply five gentle taps to the skin. This will be repeated.

2. Measuring your explosive hand grip strength
The researcher will first demonstrate the procedure to you. She will then test it out with you making sure you are comfortable with the procedure and the standard position to assume. Before performing the assessment, the researcher will give you the following instructions.

"This test will tell me your explosive hand grip strength. When I say go, please grip the equipment as hard and fast as you possibly can until I say stop"

You will then be asked to perform the assessment as described above. Each test will last 1 second, three repeated measurements will be taken with 15 seconds of rest between each contraction.

3. Measuring your Hand Grip strength
The strength you exert in gripping with your hand will also be measured. After a demonstration and before the measurement, the following instructions will be given to you.

"This test will tell me your maximum grip strength, when I say go, please grip the equipment as hard as you can until I say stop. Before each trial, I will ask you; Are you ready? And then tell you 'Go'. As you begin to squeeze, I will say "Harder, Harder, Harder. Relax"

You will then be asked to perform the assessment as described above. Each test will last for 3 seconds, 3 repeated measurements will be taken with 15 seconds of rest between each contraction.

4. Measuring Hand Grip Endurance

Your hand muscle endurance, which is your ability to maintain your grip at a certain strength for a period of time, will also be measured. A target strength below your maximum (submaximal) will be set and you will squeeze your grip until you reach that number on the screen of the testing device and hold it at that number until you are asked to stop. After an explanation and demonstration of the test, the following instructions will be given to you:

"Please grip the device until you see the number …. on the device's screen. Keep holding your grip at this level. I will encourage you to keep your grip at this level until I ask you to stop after 1minute.

5. Measuring your Hand Pinch strength
The strength you exert in pinching will also be measured. After a demonstration, the following instructions will be given to you before the measurement:

"Please place the pad of your thumb on this side of the device and the outside of your first (index) finger on this side of the device. Curl your other fingers into your palm as am doing". "Are you ready? Pinch as hard and as quickly as you can" As you begin to pinch, I will say: "harder…harder…Relax".

You will then be asked to perform the assessment as described above. Each test will last for 3 seconds, three repeated measurements will be taken with 15 seconds of rest between each measurement.

6. Assessing and progressing your baseline hand grip resistance level
Small exercise balls with varying resistance levels will be used for your hand explosive exercises. Before the exercises, you will be given the opportunity to squeeze different coloured balls to determine your baseline resistance level using a test (Borg Scale). A second and third assessment will be done every two weeks to progress the exercise intensity by changing the colour of the ball (increasing the resistance).

Procedure for Investigated Hand Exercise Protocol.
After the hand assessments, you will be asked to perform two exercises using the hand exercise ball. The first will be 4 sets of 10 explosive hand grip contractions with your non-dominant hand (each set lasting about 1 minute; separated by 1 minute of rest). The second will be 4 sets of 10 explosive pinch grip contractions with your dominant hand (each set lasting 1 minute; separated by 1 minute of rest).

One set of exercise contraction consists of 1 explosive contraction (i.e. either hand grip or pinch, as demonstrated to you by the researcher) performed as fast and hard as possible, lasting 1 seconds and repeated 10 times with 5 seconds between each contraction.

You will be asked to perform the above two sets of exercises alternatively between each hand to allow for rest between each hand activity, avoid fatigue in the previously exercised hand and to make the exercise session more interesting. The exercise session will last approximately 10-15 minutes. Please concentrate while you are doing your exercises, to ensure you do the correct number and do them in the correct way.

You will be asked to return to the lab three times every week (if you are based on the Highfield Campus) at your most convenient time within formal working hours to repeat the exercises for six weeks. Alternatively, you can perform the exercises at home if you are not based on the Highfield campus. To ensure we stick to this schedule and as a reminder, the researcher will contact you once a week via telephone or email. You will be asked to record the number of times you perform your exercises, whether you come to the lab or do your exercises at home using an exercise diary provided by the researcher.

Are there any benefits in my taking part?
There are no direct benefits to you. However, you will be helping the researchers evaluate the feasibility of these exercises in the hand with the aim of designing a new exercise program for the management of hand osteoarthritis based on limitations of the existing ones. On completion of this study, you will have the opportunity be provided with feedback on the results.

Are there any risks involved?
There are no known risks of taking part. The risks associated with the exercises in this study include pain and fatigue after exercising if you are not used to exercising your hands. The pain will ease of its own accord and will not need any treatment. No adverse effects are anticipated but if any is noticed or reported, the exercise training will be stopped, and you will be asked to see your GP.

What data will be collected?
Data from hand grip and pinch strength, hand muscle fatigue, muscle mechanical property measurements will be collected with the MIE digital grip and pinch analyser and MyotonPro device respectively. These data will be collected at the school of Health Sciences, University of Southampton, by the primary researcher or her supervisor (Prof Stokes). In addition to this, your personal data (name, age and gender) will be collected in this study. These will be used only for the purposes of carrying out our research and will be handled according to the University's policies in line with data protection law. If any personal data is used from which you can be identified directly, it will not be disclosed to anyone else without your consent unless the University of Southampton is required by law to disclose it.

You will have an ID number which will be used throughout the study. Your data will therefore remain anonymous and your names will not be disclosed in any report or publication, hence your individual identity will be unknown. A record of all participants Name details that provides a link via a participant ID to records containing the study metrics will be kept. This record will however be locked away securely in the researcher's lead supervisor's office at the university.

Will my participation be confidential?
Your participation and the information we collect about you during the course of the research will be kept strictly confidential.

Only members of the research team and responsible members of the University of Southampton may be given access to data about you for monitoring purposes and/or to carry out an audit of the study to ensure that the research is complying with applicable regulations. Individuals from regulatory authorities (people who check that we are carrying out the study correctly) may require access to your data. All of these people have a duty to keep your information, as a research participant, strictly confidential.

To ensure participants' confidentially and anonymity in all written reports or publications, each participant will be given a study participant number which will not be linked to their biodata.
The signed consent forms and participant information sheets will be kept in a locked filing cabinet in a secure room in the Faculty of Health Sciences. Personal information will be stored electrically on the computer system of the University of Southampton, requiring a password to gain access.

Consent forms will be given to the project supervisor Professor Maria Stokes to be filed securely in a locked cabinet to comply with the Data Protection policy of the Faculty of Health Sciences and the new European Union General Data Protection Regulation (GDPR) (https://www.eugdpr.org/).
Data will be stored securely for 10 years.

Do I have to take part?
No, it is entirely up to you to decide whether or not to take part. If you decide you want to take part, you will need to sign a consent form to show you have agreed to take part.
Kindly contact the primary researcher (contact below) if you want to take part in this study

What happens if I change my mind?
You have the right to change your mind and withdraw at any time without giving a reason and without your participant rights being affected.

You have the right to withdraw at any time without your rights being affected however please note that data from you that is fully anonymous cannot be withdrawn after you have submitted them.
If you withdraw from the study, we will keep the information about you that we have already obtained for the purposes of achieving the objectives of the study only.

What will happen to the results of the research?
Your personal details will remain strictly confidential. Research findings made available in any reports or publications will not include information that can directly identify you without your specific consent.

The results of this study will be published, and you will receive a copy. Anonymised research data from this research will be made available for future research projects and will be stored for a minimum of 10 years, as per University of Southampton policy.

Where can I get more information?
If you require any further information after reading this information or have any concerns regarding this study, kindly contact the primary researcher or her supervisors on the contacts below

Name and contact details of Primary Researcher:
Beatrice E.A. Sankah
University of Southampton, Building 45, Highfield Campus, Southampton, SO17 1BJ. UK
Telephone: Tel: +44 (0)2380 22711
E-mail: B.E.A.Sankah@soton.ac.uk

Name and contact details of Supervisors:
Prof Maria Stokes
University of Southampton, Building 45, Highfield Campus, Southampton, SO17 1BJ. UK
Telephone: +44 (0)2380 596868
E-mail: m.stokes@soton.ac.uk

Prof Jo Adams
University of Southampton, Building 45, Highfield Campus, Southampton, SO17 1BJ. UK
Tel: + 44 (0)23 8059 5287
E-mail: ja@soton.ac.uk

What happens if there is a problem?
If you have a concern about any aspect of this study, you should speak to the researchers who will do their best to answer your questions.
If you remain unhappy or have a complaint about any aspect of this study, please contact the University of Southampton Research Integrity and Governance Manager (023 8059 5058, rgoinfo@soton.ac.uk).

Data Protection Privacy Notice
The University of Southampton conducts research to the highest standards of research integrity. As a publicly-funded organisation, the University has to ensure that it is in the public interest when we use personally-identifiable information about people who have agreed to take part in research. This means that when you agree to take part in a research study, we will use information about you in the ways needed, and for the purposes specified, to conduct and complete the research project. Under data protection law, 'Personal data' means any information that relates to and is capable of identifying a living individual. The University's data protection policy governing the use of personal data by the University can be found on its website (https://www.southampton.ac.uk/legalservices/what-we-do/data-protection-and-foi.page).

This Participant Information Sheet tells you what data will be collected for this project and whether this includes any personal data. Please ask the research team if you have any questions or are unclear what data is being collected about you.

Our privacy notice for research participants provides more information on how the University of Southampton collects and uses your personal data when you take part in one of our research projects and can be found at http://www.southampton.ac.uk/assets/sharepoint/intranet/ls/Public/Research%20and%20Integrity%20Privacy%20Notice/Privacy%20Notice%20for%20Research%20Participants.pdf

Any personal data we collect in this study will be used only for the purposes of carrying out our research and will be handled according to the University's policies in line with data protection law. If any personal data is used from which you can be identified directly, it will not be disclosed to anyone else without your consent unless the University of Southampton is required by law to disclose it.

Data protection law requires us to have a valid legal reason ('lawful basis') to process and use your Personal data. The lawful basis for processing personal information in this research study is for the performance of a task carried out in the public interest. Personal data collected for research will not be used for any other purpose.

For the purposes of data protection law, the University of Southampton is the 'Data Controller' for this study, which means that we are responsible for looking after your information and using it properly. The University of Southampton will keep identifiable information about you for 10years after the study has finished after which time any link between you and your information will be removed.

To safeguard your rights, we will use the minimum personal data necessary to achieve our research study objectives. Your data protection rights – such as to access, change, or transfer such information - may be limited, however, in order for the research output to be reliable and accurate. The University will not do anything with your personal data that you would not reasonably expect.

If you have any questions about how your personal data is used, or wish to exercise any of your rights, please consult the University's data protection webpage (https://www.southampton.ac.uk/legalservices/what-we-do/data-protection-and-foi.page) where you can make a request using our online form. If you need further assistance, please contact the University's Data Protection Officer (data.protection@soton.ac.uk).

Thank you.

Thank you for taking the time to read the information sheet and considering to take part in this research.

xx

D.5 Data Collection Checklist

Participant ID:			**Date:**	
Consent form filled	Yes	No	**Age:**	
Gender	M	F	**Weight**	**Height**
Hand Dominance	**R**		**L**	**A [R: L]**

Outcome Measurements

Myoton testing

	Baseline 1		**Baseline 2**		**After Week 6**	
Confirm MyotonPRO measurements completed	Yes	No	Yes	No	Yes	No

Grip Tests

Maximum hand grip strength	**R**									
	L									
Maximum pinch grip strength	**R**									
	L									

Load (Resistance) selection

		Baseline 1	**Baseline2**	**Beginning of Week 3**		**Beginning of Week 5**	
Confirm load selection with Modified Borg Scale (tick)		Yes	No	Yes	No	Yes	No
Ball colour	Grip						
	Pinch						
Record on exercise log sheet		Yes	No	Yes	No	Yes	No

Fatigue Test

		Baseline 1		**Baseline 2**		**After Week 6**	
Hand muscle fatigue (Non-dominant hand)	**Mean Grip strength**						
	% of **Mean**	75%	50%	75%	50%	75%	50%
Confirm fatigue test		Yes	No	Yes	No	Yes	No

D.6 Assessment and Intervention Duration

Process	Activity	Maximum Time Allocation (Minutes)
	Assessment	
1	Briefing and Consenting	8
2	Demonstration of test by Researcher	10
3	Trial Test with participant	5
4	MyotonPRO Measurements	5
5	Explosive hand Grip Strength	2
6	Maximum hand Grip Strength Test	2
7	Maximum Tripod Pinch Strength Test	2
8	Hand muscle fatigue	3
9	Identify Thera-Band balls for baseline resistance (modified Borg scale)	3
Session length		**40**
	Intervention	
1	Warm up	2.0
2	Hand grip exercises (1set=1minute) ×4	4
3	Pinch grip exercises (1 set=1minute) ×4	4
3	Cool down	2.0
Session Length		**12**
Total Session Length		**52**

D.7 Consent Form (03Oct2018 Version_2)

Study title: Effects of explosive exercises on Strength and Fatigue in the hand: a proof of concept study

Researcher name: Beatrice Sankah
ERGO number: 43602

Please initial the box(es) if you agree with the statement(s):

I have read and understood the information sheet (*16Nov2018 Version_3*) and have had the opportunity to ask questions about the study.	
I agree to take part in this research project and agree for my data to be used for the purpose of this study.	
I understand my participation is voluntary and I may withdraw (at any time) for any reason without my participation rights being affected.	

Name of participant (print name) ……………………………………………………………

Signature of participant…………………………………………………………………………

Date……………………………………………………………………………………………

Name of researcher (print name) ……………………………………………………………..

Signature of researcher …………………………………………………………………………

Date……………………………………………………………………………………………….

D.8 Data Collection Instructions

<table>
<tr><th>Task</th><th colspan="2">Test Positions and Instructions</th></tr>
<tr><td>1st Stage</td><td colspan="2">MyotonPRO testing</td></tr>
<tr><td>Participant Position</td><td colspan="2">• Participant were asked to lie supine
• Shoulders externally rotated; forearm supinated.
• Rolled towel placed under the wrist to flex the elbow approximately 15° (to take the stretch off the muscles & enable relaxation (Aarrestad et al., 2004).</td></tr>
<tr><td colspan="3">Testing sites</td></tr>
<tr><td>Thenar eminence</td><td>• 50% between midpoint of the distal wrist crease (thumb base) to the head of the first metacarpal.</td><td></td></tr>
<tr><td>Flexor carpi radialis muscle</td><td>• 3rd of the distance between the elbow crease and lateral side of the wrist.
• middle of muscle belly can be palpated during gentle isometric contraction while the researcher resists wrist flexion (Chuang et al., 2012).</td><td></td></tr>
<tr><td>Testing procedure</td><td colspan="2">• The above testing sites were located and marked on the skin
• MyotonPRO device were placed perpendicular to site.
• 2 consecutive sets of 5 taps were performed and recorded in the order below.
1. Dominant hand thenar
2. Dominant hand flexor carpi radialis
3. Non-dominant hand thenar
4. Non-dominant hand flexor carpi radialis</td></tr>
<tr><td colspan="3">Standard Position for strength and muscle fatigue</td></tr>
<tr><td></td><td colspan="2">• participants were seated on a chair with armrests,
• feet flat on the floor, hips as far back in the chair as possible
• hip and knees positioned at approximately 90 degrees.
• Shoulders adducted; arms unsupported; elbows flexed at 90°
• forearm in neutral position,
• wrist (0-30° dorsiflexion & 0-15° ulnar deviation)
• (MacDermid et al., 2015).</td></tr>
<tr><td>2nd Stage</td><td colspan="2">Grip strengths and hand fatigue</td></tr>
</table>

<table>
<tr><th>Task</th><th>Test Positions and Instructions</th></tr>
<tr><td>Additional position for grip tests</td><td>Researcher hold MIE by the silver coloured metal by the scale bar if equipment is too heavy for participant.
Participant Grip handles 2 cm down from the red indicator line with dominant hand.
Crook of the thumb is placed on the side with the red indicator line.
Maintain handle width (25cm) for all participants.
Press and hold the “zero” button for 5 seconds before each test.</td></tr>
<tr><td>Instructions for hand grip strength</td><td>When I say go “Go”! Please grip the device and squeeze fast, hard and forcefully as you possibly can until I say “stop” after 3seconds
Before each trial, I will ask you; Are you ready? And then tell you ‘Go’. As you begin to squeeze, I will encourage you to squeeze harder.
2 test trials were performed submaximally to familiarise the test procedure with the participant
When participant is ready, the command below were given
Are you ready? Go!
Keep squeezing, “Harder, Harder, Harder.
Relax”!
Each test will last 3 seconds, 3 tests were performed with 15 seconds rest after each test.</td></tr>
<tr><td></td><td>Pinch strength testing</td></tr>
<tr><td>Additional position for pinch test</td><td>Researcher to position the MIE handle on its side at 45°
Participant to position the distal end of the MIE handle in the web of the thumb and index finger
Participant places thumb pad on one side of the device and the lateral aspect of the index finger on the opposite side
The interphalangeal joints of the thumb, index and middle fingers are kept slightly flexed and the ring and little fingers are curled into the palm
To perform the test, the MIE device is slightly tilted towards the participant and they perform the pinch by keeping the thumb in a flexed and adducted position</td></tr>
<tr><td>Instructions for pinch strength</td><td>After the command “Go”! pinch (bend your thumb and pull it towards your first finger on the MIE device) as hard as you possibly can until I say “stop” after 3 seconds
2 test trials were performed submaximally to familiarise the test procedure with the participant
When participant is ready, the command below was given
“Are you ready? Pinch as hard as you possibly can”. As participant begin to pinch, Researcher will say: “harder…harder…Relax”.
3 measurements were taken with 15 seconds of rest after each test</td></tr>
<tr><td>3rd Stage</td><td>Assessing handgrip resistance level</td></tr>
<tr><td></td><td>Follow instructions on the modified Borg Scale</td></tr>
</table>

D.9 Researcher Exercise Log sheet for Participants

Participant ID: Date:

<table>
<tr><td></td><td colspan="18">Protocol Duration</td></tr>
<tr><td></td><td colspan="3">Week 1</td><td colspan="3">Week 2</td><td colspan="3">Week 3</td><td colspan="3">Week 4</td><td colspan="3">Week 5</td><td colspan="3">Week 6</td></tr>
<tr><td>Resistance/ Load (colour of ball)</td><td colspan="6"></td><td colspan="6"></td><td colspan="6"></td></tr>
<tr><td>Training Load (%)</td><td colspan="6"></td><td colspan="6"></td><td colspan="6"></td></tr>
<tr><td>Exercise record/Attendance</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

1. Any reports of adverse effects:

2. Comments, difficulties, reasons for not attending:

D.10 Participant Exercise Diary AND Feedback sheet

D.10.1 Exercise Diary

ERGO Number: 43602 **Participant ID:**

Hand Grip and Pinch exercises

Some few reminders: Please perform:

- Exercises by gripping ball as quickly and forcefully as possible for 1sec, count 1 and 2 by the second clock, then squeeze again. It follows this sequence: "squeeze...1...2; squeeze…1...2...; repeat 10x
- Hand grip exercises in your non-dominant hand & Pinch exercises in your dominant hand
- Exercises alternatively in each hand (*to allow rest and avoid fatigue in the previous exercised hand)*
- Exercises at similar times of the day as much as possible

WEEK 1

Ball colour [ ]	Date	Time		10 contractions x 4 sets				Comments (any discomforts, adverse reactions, missed exercises, etc.)
				Set 1	2	3	4	
			Hand Grip (Non-Dom)					
			Pinch grip (Dom)					

WEEK 2

Ball colour [ ]	Date	Time		10 contractions x 4 sets				Comments (any discomforts, adverse reactions, missed exercises, etc.)
				Set 1	2	3	4	
			Hand Grip (Non-Dom)					
			Pinch grip (Dom)					

WEEK 3

Ball colour [ ]	Date	Time		10 contractions x 4 sets				Comments (any discomforts, adverse reactions, missed exercises, etc.)
				Set 1	2	3	4	
			Hand Grip (Non-Dom)					
			Pinch grip (Dom)					

Appendix D

WEEK 4

Ball colour [ ]	Date	Time		10 contractions x 4 sets				Comments (any discomforts, adverse reactions, missed exercises, etc.)
				Set 1	2	3	4	
			Hand Grip (Non-Dom)					
			Pinch grip (Non-Dom)					

WEEK 5

Ball colour [ ]	Date	Time		10 contractions x 4 sets				Comments (any discomforts, adverse reactions, missed exercises, etc.)
				Set 1	2	3	4	
			Hand Grip (Non-Dom)					
			Pinch grip (Non-Dom)					

WEEK 6

Ball colour [ ]	Date	Time		10 contractions x 4 sets				Comments (any discomforts, adverse reactions, missed exercises, etc.)
				Set 1	2	3	4	
			Hand Grip (Non-Dom)					
			Pinch grip (Non-Dom)					

NB: Dom=Dominant Hand; Non-Dom=Non-dominant hand; sec=second

Hand positions for pinch below

Start position

Finish position

D.10.2 Participant Feedback (after 6 weeks Exercises training)

1. **Please tell us what you think about the exercises.**

a. How did you find the exercises e.g. easy, difficult, uncomfortable?

b. Was there anything that made it easier or more difficult for you to do these exercises?

c. How did you find the descriptions of the exercises? e.g. were they clear enough to follow or could we have made them clearer?

2. Are there things you think should be changed about the exercises

a. Do you think anything should be added to the exercise training?

b. Should anything be taken away from the exercises?

3. Do you have any other comments about the exercises that you would like to add or suggest?

Appendix E Intervention development

E.1 PPI Training Certificate

NIHR | National Institute for Health Research

SOAR

University of Southampton

University Hospital Southampton NHS Foundation Trust

CERTIFICATE OF ATTENDANCE

This confirms that

Beatrice E. A. Sankah

Attended the

Public and Patient Involvement Training: skills-based sessions for researchers

Session 1: What is the right way to involve people

Session 2: Working with the public – managing group discussions

Session 3: Working with the public – recruiting and keeping members

Session 4: Working with the public – getting the most out of your PPI activities

Session 5: Communicating in lay language

PJ Holloway

Pamela Holloway

Public co-trainer

Caroline Barker

Strategic Lead – Patient and Public Involvement | University Hospital Southampton NHS FT

27th August 2020

Date

E.2 PPI Partner Information Sheet

Health Sciences

UNIVERSITY OF Southampton

Stakeholders' information Sheet

Exercises to Help with Hand Osteoarthritis:
Exploring Stakeholder's Views in a Virtual Patient Public Involvement exercise

Investigator: Beatrice Sankah
Project Supervisors: Prof Maria Stokes; Prof Jo Adams

Medium: Zoom/Microsoft Teams/ WhatsApp

This information sheet provides you with a background to our project, why we would like to talk to you and how we are aiming to develop a new hand exercise programme for people living with painful hand osteoarthritis.

Why we started this project?

Hand osteoarthritis (OA) is a common painful joint condition and people living with it often have challenges carrying out their daily hand activities such as grasping objects, turning keys, etc. Research suggests that exercises can be useful in managing the symptoms of people living with hand OA. However, we do not yet know on the best way to use hand exercises to get the best possible benefit. We are therefore keen to look further into how to design the best possible exercise programme to support people to manage their hand OA. We also want to make sure that the way we design these exercises is practical and useful to people with hand OA and therapists.

What do we hope to accomplish?

We want to develop an exercise programme for people with hand OA which will help:

i. Ease their painful hands
ii. Improve their ability to perform daily hand activities and
iii. Improve general well-being

What we have done so far?

We have used previous research to inform our new exercise intervention called the Rapid-Hand Osteoarthritis Exercise (Rapid-HOE) programme as shown in Figure 1.

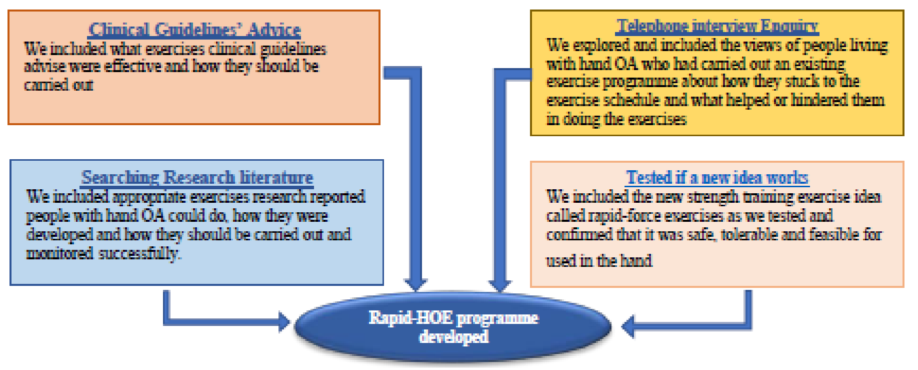


Figure 1: Rapid-HOE exercise development process

1

[09-07-2020] [v4]

Health Sciences

UNIVERSITY OF Southampton

Stakeholders' information Sheet

What have we developed?

We have developed a new set of hand exercises for people with hand OA. We hope that these are clear and straight forward to follow.

What we would like to do

Attached to this information sheet is a copy of our hand exercises and the way we think these should be used. We would like to hear your thoughts and ideas on this hand exercises before we go forward to test them and assess their benefit in people living with hand OA. We would therefore like you to look at these exercises and let us know what you think of them. We would then like to talk with you using any videoconferencing app of your choice (Zoom/Microsoft Teams/ WhatsApp video calls) for about 30 minutes. If you do not have access to any of these or you would prefer not to use videoconferencing, then we will be happy to chat over the telephone instead.

Thank you for taking out time to read this and your willingness to have this discussion

Investigator Contact:

Beatrice Sankah
University of Southampton
B.E.A.Sankah@soton.ac.uk
Tel: 07551984251

E.3 PPI Discussion Topic guide for Patient partners

Health Sciences

UNIVERSITY OF Southampton

Managing Hand Osteoarthritis Using Exercises:
Exploring Stakeholders' Views in a Virtual Patient Public Involvement exercise

Topic Guide for PPI Discussions with Patient Project partners (≤30minutes)

Facilitator: Beatrice Sankah
Observer: Maria Stokes/Jo Adams

Medium: Zoom/Microsoft Teams

Purpose of PPI:

To consult and seek the opinion of people with hand OA on a developed exercise programme; the Rapid-HOE programme and discuss ideas to co-design a future research project to test the programme feasibility.

Introductions and brief overview by facilitator

Facilitator will introduce herself, thank PPI partner for agreeing to take part in the discussion and give a brief description of the purpose of research project. The procedure for discussion will be briefly explained and permission for audio recording of discussion will be sought. If this is declined, notes will be taken instead. This topic guide will be used flexibly and follow-ups on issues of importance, probes and prompts will be included as and when appropriate.

Part 1: General views and experience of exercise

1. Please would you share with me what you know about exercises for managing hand OA before your invitation to join this discussion (i.e. invitation contains Rapid-HOE programme)?

Probes

a. Please can you tell me or describe what these exercises are?
b. Have you personally used exercises as a treatment option for your hand OA?
c. Do know someone who has?

Part 2: The Rapid-HOE programme (Views and Usability)

Facilitator to ask PPI partner to look at the Rapid-HOE programme and allow brief time to scan through (as it is expected that PPI partners would have reviewed content ahead of the discussion).

1. This is the exercise programme we developed and are hoping to test its practical use in people with hand OA. Please tell me what you think about it.

Prompts

a. Do you think it will achieve what it was intended to achieve i.e. fulfil its purpose by managing hand OA symptoms successfully?
b. Do you anticipate anything that will make the exercises easier or difficult to perform?
c. Is this an exercise programme you might consider doing when advised to use?

2. We want to make sure the Rapid-HOE programme is as good as it can be. Are there things you think should be changed about the programme?

Prompts

a. Are there things that you think could be added to the programme? Or taken away?
b. Are the exercise descriptions/illustrations clear enough? or they are confusing?
c. Do you think the time duration for exercise performance is realistic and doable?

1

PPI topic guide[09Jun20v1]

Part 3: Co-designing next phase of the project

In the next phase of our project, we want to test whether the Rapid-HOE programme is as useful as it can be and can yield positive changes in the symptoms of patients and would like to consult you on it.

Facilitator to briefly explain the project plan and the aspects to be discussed (e.g. project research design, recruitment and interview guide).

1. **Research Method**

   Please can you tell me what you think about this project plan.

   Probes

   a. Are there other factors you think we should consider?
   b. Are there things that you think could be changed about the plan?
      i. Are there things that you think could be added to the plan? Or taken out?
      ii. Are there things that you think could be taken away?

2. **Recruitment**

   We plan to recruit from the community and local OA clubs using posters, emails and word of mouth. For you as a patient, do you think these approaches will work considering the current climate (i.e. Covid-19)

   Probes

   a. Do you have any other ideas/suggestions on how we can reach people?
   b. Regarding the community, do you have suggestions on where exactly we should go or what clubs to consider?
   c. Would you like to add anything else?

3. **Usability of interview guide**

   *Facilitator to ask PPI partner to have a look at the **interview guide** and allow time to scan through (as it is expected that PPI partners would have read through ahead of discussion).*

   We want to make sure that this interview guide *(list of questions to explore)* is as good as it can be for use in the research project.

   Prompts

   a. Are the questions clear enough to you?
   b. Do you think the questions address the theme of the research?
   c. Are there questions you think could be added to this topic guide? Or taken away?

Closing: Would you like to add anything else to our discussion? Facilitator to thank PPI partner.

E.4 PPI Discussion Topic guide for clinician partners

Health Sciences

UNIVERSITY OF Southampton

Managing Hand Osteoarthritis Using Exercises:
Exploring Stakeholder Views in a Virtual Patient Public Involvement exercise

Topic Guide for PPI Discussions with Clinician Project partners (≤60minutes)

Facilitator: Beatrice Sankah
Observer: Maria Stokes/Jo Adams

Medium: Zoom/Microsoft Teams

Purpose of PPI:

To consult with clinicians (i.e. Hand therapists, physiotherapists, occupational therapists) with skills in hand OA care on the developed exercise; the Rapid-HOE programme and discuss ideas to co-design next phase of research project to test the programme feasibility.

Introductions and brief overview by facilitator

Facilitator to introduce herself, thank the PPI partner for agreeing to take part in the discussion. The procedure for discussion will be briefly explained and permission for audio recording of discussion will be sought. If this is declined, notes will be taken instead. This topic guide will be used flexibly and follow-ups on issues of importance, probes and prompts will be included as and when appropriate.

Part 1: General views and experience of exercise

1. Please could you briefly share your experience with managing hand OA prior to your invitation to join this discussion (i.e. invitation contains Rapid-HOE programme)?
   Probes
   a. Please can you briefly describe some of these exercises to me
   b. Have you personally used these exercises as a treatment option for your clients?
      i. If yes, can you please share with me some of their responses to these existing exercises
      ii. If no, can you please tell me the reason
   c. In your experience, can you please share with me the response of your clients to these exercises
      i. Are they able to tolerate these exercises?
      ii. Are they able to adhere to these exercises?

Part 2: The Rapid-HOE programme (Views and Usability)

Facilitator to ask PPI partner to look at the Rapid-HOE programme and allow brief time to scan through (as it is expected that PPI partners would have reviewed content ahead of the discussion).

1. This is the exercise programme we adapted from the literature and are planning to investigate its feasibility and prove its concept in people living with hand OA. Please tell me what you think about it.
   Prompts
   a. Do you think it will achieve it intended aim (i.e. increase and maintain ROM, and to increase strength and endurance)?
   b. Do you anticipate anything that will make the exercises easier or difficult to perform?
   c. Is this an exercise programme you might consider prescribing to clients if its effectiveness is established later?

2. We want to make sure the Rapid-HOE programme is as good as it can be. Are there things you think should be changed about the programme? i.e. presentation, illustration, format
   Prompts

a. Are there things that you think could be added to the programme? Or taken away?
b. Are the exercise descriptions clear enough? or they are confusing?
c. Do you think the time duration for exercise performance is realistic and doable?

Part 3: Co-designing next phase of the project

We want to test whether the Rapid-HOE programme is feasible to use in patients in the next phase of our project and would like to consult you on it.

Facilitator to briefly explain the project plan and the specific aspects to be discussed (e.g. project research design, recruitment and interview guide).

1. **General thoughts on plan**

   Having listened to the brief description about the project, please can you share with me your general thoughts about the plan.

2. **Research Method** (mixed methods study)

   Can you please share your thoughts on this research strategy?

   Probes

   a. In your view, do you think this method will work
   b. Are there other factors you think we should consider?
   c. Are there things that you think should be changed about the research method?
      i. Are there things that you think could be added to the plan?
      ii. Are there things that you think could be taken away?

3. **Recruitment**

   We plan to recruit from the community and local clubs using posters, emails and word of mouth. Based on your experience, do you think these approaches will work considering the current climate (i.e. Covid-19)

   Probes

   a. Do you have any other ideas/suggestions on how we can reach potential clients?
   b. Regarding the community, do you have suggestions on where exactly we should start from or what OA clubs to consider?
   c. Would you like to add anything else?

4. **Usability of interview guide**

   Facilitator to ask PPI partner to have a look at the ***interview guide*** *and allow time to scan through (as it is expected that PPI partners would have read through ahead of discussion).*

   We want to make sure that this interview guide is as good as it can be for use in the research project.

   Prompts

   a. Are the questions clear enough to you?
   b. Do you think the questions address the theme of the research?
   c. Are there questions you think could be added to the topic guide? or taken away?

Closing: Would you like to add anything else to our discussion?
Facilitator to thank PPI partner.

E.5 Flow chart of the PPI project activities

PPI partners	Scheduled Meeting dates	Booked Time	Extra time spent (m)	Total Time spent (m)	Notes/ workflow
PP1	06-07-20	10:00-11:00am	30	90	1.Session went as planned, booked for an hour, lasted 30 minutes longer 2.Partner agreed to take photos of hand in exercise positions for the exercise programme 3. Discussion summary sent to rep after meeting 5. Partner sent first set of hand exercise pictures & video of the grip rapid force exercises (06/07/20) – advised to add the pinch Rapid-force exercises as well. 6. Second set of exercise pictures received (20/07/20) (exploring dates for next PPI session) 7. second meeting scheduled (27th July) – meeting cancelled due to challenges with technology logistics
PP2	07-07-20	4:00- 5:00pm	0	60	1.Session went well, lasted as planned Partner promised to scout for people with hand OA from her Arts club and dog walking buddies 3.Also keen on doing exercises during main study 4. Discussion took place as planned (07/07/20) 5.Discussion summary sent to rep after meeting; Partner provided details of a contact with Hand OA 7. Rep feedback on hand pain and swelling after trying out exercises with a ball purchased on amazon (18-07-20). Advised to use ice and also stop exercises if still interested in taking part in final study to avoid bias
PP3	09-07-20	10:00-11:00am	1.Booked session was cancelled by rep due to personal issues 2.Rescheduled to 14th July 2020; new invitation sent to rep		

	14-07-20	10:00-11:00am	0	60	1.New date confirmed 2.Zoom invite sent and confirmed 3.Discussion took place as planned 4. Discussion summary sent to Partner (14/07/20)
RP1	14-07-20	12:00-1:00am	1. Confirmed session with Rep on 7th July20 2.Invitation sent 3. Meeting was cancelled by Partner (new dates confirmed for 15th July20; 5:30pm)		
	15-07-20	05:30-06:30pm	30	90	1.MS invite sent (14-07-20), yet to receive response 2. Rescheduled meeting took place as planned (very fruitful discussion) 3. Discussion summary sent to Partner (16/07/20)
CP1	20-07-20	10:00-11:00am			1. Partner contacted via twitter (positive response received 09-07-20) 2.PPI meeting scheduled to 20-07-20 3.PPI docs sent (11-07-20) 4. Discussion took place as planned, very helpful comments and suggestions communicated; 5. Summary sent to Partner (20/07/20)
C/RP1	13-07-20	07:00 8:00pm (14/07/20; 6-7am NZ time)	30	90	1.Positive response received (11-07-20) 2. Meeting date agreed with rep (14/07/20) 3. Discussion took place as planned (very interesting session), Partner sent some links and good papers that would be helpful for my research after the meeting 4. Discussion summary sent to Partner (16/07/20)
C/RP2	24-07-20	09:00 10:00pm (25/07/20; 8-9am New Zealand time)			1.Positive response received (11-07-20) 2.potential dates discussed with rep 3.24th July20; 9-10pm UK time confirmed 4. Discussion took place as planned 5. Discussion summary sent to Partner (25/07/20) 6. PPI rep emailed her personal notes on the discussion as well some p[papers for reference ()

PPI: Patient Public Involvement; PP: patient partner; CP: Clinician Partner; C/RP: Clinician and Researcher Partner; m: minutes; MS: Microsoft teams video conferencing tool

E.6 Snapshot of PPI summary Feedback

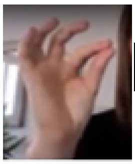
20Jul20

Exercises to help with hand OA: A virtual Patient Public Involvement Exercise
(Summary Notes for Discussion with Clinician representative1- CP1)

Location: Zoom **Date: 20July20** **Time: 10:00-11:00am UK time**
Facilitator: Beatrice Sankah

1. **General views and experience of exercise**
   a. Use a tailored approach to exercises
   b. Also had self-management group sessions which includes education
   c. Advised to leave rubber band EXERCISES OUT
   d. Advised the use of the other hand (self-assisted exercises) in place of the rubber band so patients are more in control of the level of resistance

2. **The Developed hand exercise programme**
   a. Thought exercise had a nice balance between active (flexibility) and strengthening; did not know much about rapid force exercises but thought it was great to explore it and look forward to the results
   b. Exercise-1 (making an O sign
   c. Photos are good
   d. Sometimes patients touch pad to pad instead of pinch to pinch (see **Figure 2**)
      i. So have a photo showing the wrong way of doing



wrong finger pinch position

   e. Exercise-2 (roll into a fist) (tendon and glide exercises)
      i. Thought the exercise description and illustration could be improved as it was a bit confusing with the use of DIPs and PIPs
      ii. Suggested the use of **'top two finger joints' (top and middle finger joints)** for PIPs and DIPs and **knuckles** for the MCPs
      iii. Suggested that a diagram of the hand indicating MCPs (Knuckle), PIPs (middle finger joint) and DIPs (top finger joint) joints with their names as used in the description would be a good reference point for the patients
      iv. Advised on using the description below for Exercise-2
      'start with your (fingers) straight; bend the top finger joints only into a hook position; ***roll the fingers down into a full fist****; hold for 5 seconds; straighten full fist before straightening the hook fist'*
      Or
      'start with your (fingers) straight; bend the top finger joints only into a hook position; ***bend the knuckles into a full fist****; hold for 5 seconds; straighten the knuckles fist first before straightening the top two finger joints to the start position'*
      v. Suggested the need to illustrate the above exercise positions further by using 4 or 5 pictures instead of the 2 in the current programme (can show the flow of progress with a cycle or the use of a, b, c or 1,2,3 and show these descriptors in the exercise descriptions).

20Jul20

f. **Exercise- 4b (rapid-force pinch exercise)**
    i. Expressed concern about the above exercise and thought it would impact the base of thumb based on what is available in the literature and from clinical experience
        1. Hyperextension of the MP joint of thumb will cause CMC instability
        2. From a joint protection point of view, CMC OA patients are being advised to avoid the lateral pinch position as this position translates forces into the base of thumb
    ii. Facilitator explained the exercise and described the illustration further particularly the fact that the interphalangeal joint (IP) would be flexed and not extended as the latter negatively impacts the base of thumb
        1. having a slight flexed IP joint should therefore be well described so the patients know what we are talking)
        2. Have a photo of the thumb with the wrong pinch position
    iii. Suggested the change of 'in' to 'for' for better clarity of understanding in the exercise description

Change from

Pinch ball as fast and hard as possible 'in' 1seconds, followed by 5seconds rest (repeat 6times)

To

Pinch ball as fast and hard as possible 'for' 1seconds, followed by 5seconds of rest (repeat 6times)

g. **Exercise-5 (Finger stretch/stretches)**
    i. Thought it would be helpful to include the phrase below to help patients understand which stretch exercises to do
    'you can either do this for all fingers or individual fingers'
    ii. Also suggested the inclusion of **'or'** between the two stretch picture illustrations for better clarity

h. **Exercise Prescription and adherence strategies**
    i. Thought the exercise programme was realistic, doable, achievable and not too invasive
    ii. Suggested the inclusion of the phrase below to encourage people to adhere to the programme
    'Don't worry if you don't get to do the exercises' or 'it's okay if you don't get to do the exercises, just be honest with me'

3. **Thoughts on next phase of project**
    a. Recruitment strategies and places to recruit from
        i. Explore online avenues; social media, etc
        ii. Contact other clinicians e.g. GPs, hand therapists,

4. **Three most relevant things to be considered moving forward are**
    a. Focus on the exercise description and illustration (i.e. pictures and better descriptions; use of adequate font sizes and better contrast)
    b. Look at the recruitment strategies again,
    c. Clearly describe the eligibility criteria to help with the interpretation of the results
    d. Hand photos should be part of the screening process to help identify people for the inclusion criteria

E.7 Complete summary of expert PPI results

<table>
<tr><th>PPI Questions</th><th>PPI Responses</th></tr>
<tr><td>We are interested to learn about your experiences of using hand exercises to help manage hand OA. Please can you share some with me?</td><td>Group Responses
1. All expert partners had engaged with exercises for hand OA either as researchers investigating different exercises for hand OA management or clinicians managing patients with exercises
2. All expert partners mentioned the importance of education on the benefits of exercise in improving patient symptoms (advised to include exercise education to encourage exercise performance)
3. One PPI partner (researcher) based on personal experience (previous PPI with hand OA patients), mentioned that some patients do not know much about exercises for hand OA and most times used different self-management approaches, which often are not helpful in improving their symptoms
4. Two partners (researcher & clinical academic) mentioned that anecdotally existing hand OA exercises were not pushing patients enough to exercise at sub-optimal levels as recommended by the ACR guidelines, hence the lack of positive results reported within literature
5. Clinician partner discussed their use of tailored intervention programmes (including exercises) for managing CMC1 and hand OA (OA of the fingers) differently, cited the content of the Rapid-HOE programme (excluding the rapid-force contraction exercises), as some of exercises usually used by clinicians</td></tr>
<tr><td>Please can you tell me what you think about the developed exercise programme (i.e. Rapid-HOE programme)?</td><td>1. Experts thought the programme was
• straight forward, realistic and doable exercise
• Simple and short, hence would not be easily forgotten by patients
• easy be accepted by patients as the number of exercises within the programme are not too many and the is not too much
• had a good balance between flexibility and strengthening exercise
2. Two partners (i.e. researchers) thought it was very important to have included high intensity exercises, as it brings a refreshing perspective to existing hand OA exercises
3. One clinician shared her lack of knowledge on high intensity exercises, but thought it was worth exploring rapid exercises and looks forward to the study findings
4. One (C/RP 2) raised concerns over the use of high intensity exercises in Rapid-HOE programme due to the potential harm it may cause (e.g. CMC joint instability, trigger finger, etc.)</td></tr>
</table>

PPI Questions	PPI Responses
	5. Partner also queried the use of the following: • lower limb strength training concept in upper limbs, as both have different joint loading systems and argued that the impact of high intensity exercises on the hand is detrimental, unlike the lower limbs which can take on such high impacts • the use of ACSM guideline as a guide to the developed Rapid-HOE programme prescription as evidence underpinning the guideline are extrapolated from other big joints (i.e. knee and hip) and not the hand
How do you think we could improve on this feasibility testing?	All PPI expert partners thought a feasibility study was the appropriate approach to take and no comments on improving it
Can you please share your thoughts on this research method to be used (mixed methods study)?	1. Expert Partners thought mixed methods research strategy was the right approach 2. Suggestions made include • explore levels of confidence of patients with exercises before and after the exercise training (use either a questionnaire or include question in interview guide) • use social media as part of the data collection process due to the COVID-19 situation (i.e. participant screening, study briefing and initial baseline data collection). • Use the REDcap software can be used in designed the online screening tools 3. Partners recommended the importance of clearly defining which hand OA population will be used as well identifying those populations that are responsive to achieve favourable response.
We plan to recruit from the community and local clubs using posters, emails and word of mouth. What are your thoughts on these considering the current COVID-19 climate?	1. All expert PPI partners thought these approaches will work. Suggested the following: • Social media (i.e. Facebook, twitter, etc.) • Contacting first contact professionals i.e. GPs; PTs, etc. • Contact other researchers who work within the field to contact their people from their pool of volunteer • Charities and organizations (e.g. Arthritis UK; University of the 3rd Age)
What are your thoughts on the clarity of questions in the interview guide?	1. One had no input due to lack of qualitative research expertise 2. Some thought questions were clear

PPI Questions	PPI Responses
	3. A suggestion to include a question on confidence level made (confidence in doing exercises on your own.
Please can you prioritize the top 3 things that you suggest that we amend with the exercise programme/research moving forward	Expert partners advised on the following 1. the inclusion of a pre-study participants' education on exercises by experts to enhance exercise adherence (can be achieved with a meeting or video). Topics to cover include • Importance/ benefits of exercises • hand joint anatomy and some of the things that may go wrong when exercises are done incorrectly • Reassurance that exercise works (Exercise is the new medicine) 2. Add videos for additional illustration 3. Explore online participant screening process and data collection (include hand photos in screening) 4. Clearly describe the eligibility criteria and be specific on the hand OA phenotype for study

NB: ACR: American College of Rheumatology; PPI: Patient Public Involvement; GP: General practitioner; PT: Physiotherapist; ACSM: American College of Sports

E.8 Complete summary of Patients results

PPI Questions	PPI Responses
Please can you tell me what you think about the developed exercise programme (i.e. Rapid-HOE programme)?	**1st exercise content** (Making an "O" sign) 1. one partner thought this exercise was a good one but disliked the presentation (pictures were too small; illustrations were over complicated). Suggested the following • use only two pictures instead of the four, leave out arrows and numbers • make picture bigger for better clarity and illustration • revise description for clearer understanding 2. Suggested adding a strengthening component to exercise (touch tip to tip and hold a few counts, then release) **2nd Exercise content** (Roll into a fist): 1. All patient partners agreed that PIPS, DIPS and MCPs terminologies used in descriptions were confusing • Suggested the use of top and middle finger joints instead

PPI Questions	PPI Responses
	• exercise description should include “roll into a fist” for better clarity of understanding 2. One partner suggested the illustration of the exercise hand in sideways view for better clarity of presentation **3rd exercise content** (Static hand grip exercises) 1. One partner commented on her dislike of this exercise based on the need to use an exercise ball Partner added that she has small hands which has been made even smaller with hand OA and hence struggles to hold a ball (prefers to use putty). • suggested the need for patients to be allowed to choose what to use. i.e. putty or exercise balls 2. A suggestion to merge static and rapid force grip exercises was made 3rd and 4th exercises together i.e. (3a; 3b; 3c) • Either name as ball exercises or strength exercises (do not understand why the exercise 3 and 4 should be divorced from each other) • Feel the number of repetitions of rapid force exercises was too much (suggested the gradual progression of the exercises from perhaps from 3 reps and later 6 reps **4th Exercise content** (Rapid-Force exercises) 1. Exercise description text, not consistent and should be revised 2. Exercise repetition (6reps) too much to perform as anticipated of its difficulty; Reduction from 6reps to 2 or 3 repetitions initially suggested and progression made over time. **5th exercise content** (Finger stretch/stretches) 1. All partners commented on their difficulty in understanding exercise description and illustration (one stated that the NHS exercise explanation of a similar exercise was better) 2. Another suggested the use of an OA hand in exercise illustrations instead of the non-OA hand in the initial version (PPI Partner (PR1) volunteered to support research with photos of her hand for exercise illustrations) • Suggested the need to progress exercise more quickly without rest in between (PPI partner- an active senior golfer) All patient partners agreed that the three times weekly exercise performance was good and should be a minimum requirement. Advised that exercises should be tailored to individual preferences and lifestyle if everyone does the minimum set

Appendix E

PPI Questions	PPI Responses
Are there things you think should be changed about the programme?	1. One partner thought thrice weekly performance was ideal but also advised that patients should be given the leeway to decide on more when needed 2. Other partners thought the exercise frequency (3 times weekly) was not enough and suggested the following • Regular daily exercise as felt a day of rest was not helpful • exercise at most 5 times weekly for best results (do weekdays and rest on weekends) • allow for people to decide on exercise progression, a tailored approach to what patient needs 3. Two partners thought the exercise duration (15 minutes) was ideal, one mentioned it was rather long (performs 5 minutes daily leg exercises) but still thought it was a doable programme 1. On adherence, partner suggested the need to • Educate patients on the benefits of exercises • Encourage patients to exercise and the fact that it works otherwise people will not do them • perform exercise to a work or home routine (i.e. whilst in traffic, watching the television, having a cup of tea, etc.)
Can you please share your thoughts on our project strategy to conduct the next phase of our project (i.e. mixed methods study)?	All patient partners thought it was a good idea and made sense
We plan to recruit from the community and local clubs using posters, emails and word of mouth. What are your thoughts on these considering the current COVID-19 climate?	1. Two PPI partners agreed to help with recruitment by reaching out to colleagues and friends 2. Use the internet i.e. social media 3. doctor's surgery 4. Speaking to friends of friends, gatekeepers of organizations 5. Organizations (Bridge clubs, OA patient support groups, elderly accommodation, men in sheds, University of the 3rd Age)
What are your thoughts on the clarity of questions in the interview guide?	1. Thought the questions were clear and understandable

PPI Questions	PPI Responses
Please can you prioritize the top 3 things that you suggest that we amend or look at with the exercise programme/research moving forward	1. Review the exercise description for better clarity 2. Advise participants to link exercises to something important in their life to enhance exercise performance 3. Exercise is not magical, people should be encouraged to perform exercises and although, it may be difficult, it works

NB: ACR: American College of Rheumatology; PPI: Patient Public Involvement; GP: General practitioner; PT: Physiotherapist; American College of Sports; NHS: National Health Service

E.9 Detailed PPI findings on Rapid-HOE programme (content and prescription)

E.9.1 Combined PPI findings and conclusions drawn on the Rapid-HOE programme content

Exercise Type and description	PPI comments/ suggestions	Conclusions Drawn
Making an "O" sign	1. Good photos, shows exercises clearly 2. Suggested making a "D" to "O" shape sign 3. Include photo showing the wrong way of making an O sign (i.e. pad to pad instead of tip to tip) to educate patients 4. Aim of the exercise is not flexibility but rather "improvement of thumb motor control", suggest revision 5. Use two exercise photos instead of the four (preferable the starting point photo and either photo 1 or 2), 6.Advise patients (include in exercise instructions) - to position the thumb in such a way that it creates like "a bridge's arch" with the index finger when performing this exercise 7. disliked exercise illustrations and descriptions, avoid numbers and arrows 8. Add a strengthening component to exercise (i.e. make an "O" sign, tip to tip then hold for a number of counts then release	-Photo showing the wrong & right ways of making an O sign included (see below)   Aim of exercise updated to include "improvement of thumb motor control", -two photo illustrations will be used -bigger illustrations included
Roll into a fist	1. Three hand pictures recommended instead of 2: a. Start position: hand in neutral position, b. 2nd position: hand in the "hook" fist position c. 3rd position: hand in full fist position	1. exercise programme will be updated to reflect this 2. exercise description will be revised to reflect suggestions

Exercise Type and description	**PPI comments/ suggestions**	**Conclusions Drawn**
	2. Exercise description and illustration could be improved for better clarity. Change PIPs, DIPs and MCPs to lay terms, suggested top two finger joint i.e. a. MCPs - Knuckle b. PIPs - middle finger joint c. DIPs - top finger joint (or end finger joint) 3. Exercise description could be improved, suggested: *‘start with your fingers straight; bend the top two finger joints only into a hook position; roll the fingers down into a full fist; hold for 5 seconds; straighten full fist before straightening the hook fist’* *Or* *‘start with your fingers straight; bend the top two finger joints only into a hook position; bend the knuckles into a full fist; hold for 5 seconds; straighten the knuckles first before straightening the top two finger joints back to the start position’* 4. Illustrate exercise positions with 4 or 5 pictures instead of the 2 in the current programme (can show the exercise flow with a cycle or the use of the descriptors (“a, b, c” or 1, 2, 3), and use these descriptors in the exercise descriptions). 5. Exercise might cause harm when performed repetitively (i.e. repetitive active flexion cause trigger finger). a. Suggest using passive exercises instead (effective in gaining ROM) 6. Exercise aim should be *“for finger joint flexibility”* instead of maintain/increase flexibility 7. Use sideways view for exercise illustration	3. description below will be use *‘start with your fingers straight; bend the top two finger joints only into a hook position; bend the knuckles into a full fist; hold for 5 seconds; straighten the knuckles first before straightening the top two finger joints back to the start position’* 4. exercise description and illustration will be updated to reflect this 5. pinch exercise taken out? 6. aim will be revised to include “for finger joint flexibility” 7. sideways views will be used

Appendix E

Exercise Type and description	PPI comments/ suggestions	Conclusions Drawn
Static hand grip exercises	1. Static hand grip can be beneficial for some patients but carries risk if repetitively done with poor recruitment of wrist extensors. 2. Based on clinical experience, use of putty or balls is neither functional nor beneficial to patients (cannot be provided for all who needs programme). b. Use items readily available at home (i.e. towel) instead of repetitive contractions with balls (which might not be available for all). c. Use towels in wringing motion with the affected hand doing the backward wringing to work the hand extensors 3. Use TheraBand if need be for strength training otherwise performing the functional activities such as wringing a towel is ideal 4. Patient partner disliked the use of exercises balls, suggested the use of putty 5. Suggestion to merge exercise 3 and 4 as both are addressing strength or use balls	1. This is true. Lockard (2000) reported that sustained tight gripping can aggravate osteoarthritis of the fingers and thumb. Pinch exercises excluded 2. Advice noted 5. exercises 3and 4 merged
Rapid-Force exercises 4a. Handgrip rapid-force contractions 4b. Pinch grip rapid-force contractions	**4a. Handgrip rapid-force contractions** 1.Hands not usually used for rapid force productions (rather for high sensibility and controlled function), concerned about use of these exercises	1. concept is worth exploring, exercise remains in exercise programme
	4a. Pinch grip rapid-force contractions 1.Concerned with exercises due to possible negative impact on CMC joint (based on literature and clinical experience) a. Hyperextension of the MP joint of thumb will cause CMC instability	1. Exercises taken out of the programme

Exercise Type and description	PPI comments/ suggestions	Conclusions Drawn
	b. Lateral pinch encourages thumb adduction which might cause CMC instability c. From a joint protection point of view, CMC OA patients are advised to avoid the lateral pinch position as this position translates forces into the base of thumb to cause harm d. Thought perhaps it can be after an explanation of how lateral pinch with the IP joint flexed rather extended will be used in exercise i. Good description of exercise with slight flexed IP joint should therefore be re-emphasized well described so patients know what to do ii. Have a photo of the wrong pinch position 2.Advised against the inclusion of pinch rapid force contractions as a. high intensity repetitive pinch gripping may cause CMC1 joint instability a. it may encourage extreme forceful adducted thumb positions which will be counterproductive for the CMC joint b. May contribute to the dominance of the adductor pollicis muscle which is often already overactive in CMC OA (cause CMC subluxation) c. Risks developing Carpal tunnel syndrome and/or trigger finger 3. Suggested revision of **“Exercise 4b”** description for better clarity *Change from* *“…Pinch ball as fast and hard as possible ‘in’ 1seconds….* *to*	

Exercise Type and description	PPI comments/ suggestions	Conclusions Drawn
	".Pinch ball as fast and hard as possible 'for' 1seconds…" 4. Patient partner thought exercise repetition (6reps) was too much to perform as anticipated of its difficulty; Reduction from 6reps to 2 or 3 repetitions initially suggested and progression made over time.	
Finger stretch/stretches	1. Include phrase below to help patients understand which stretch exercises to do depending on patient need to avoid ambiguity *".you can either do this for all fingers or individual fingers…"* 2. Include an *'or'* between the two stretch pictures for better clarity 3. Good exercise but can suffice as warm up a. suggest renaming as 'straightening stretches' (ironing out) 4. All patient partners had difficulty understanding the exercise, illustrations and description 5. Suggestion to use an OA hand in illustrations instead of the non-OA hand for better clarity a. PPI partner agreed to provide hand pictures and exercise positions for illustrations of the exercise programme)	1 & 4. Description updated for better clarity 2. Content revised to reflect this 3. advice noted 5. Advice noted

E.9.2 PPI findings and conclusions drawn on the Rapid-HOE programme prescription

Exercise components	**Component Details**	**PPI comments/ suggestions**	**Conclusions Drawn**
Warm up	Few seconds of rubbing the hands together and doing arm swings.	Good, suggest including exercises in warm water as well	
Frequency	1. Week 1 to 2: 6 repetitions of exercises, 3 days per week 2. Week 3 to 4: 8 repetitions of exercises, 3 days per week 2. Week 5 to 6: 10 reps of exercises, 3 days per week	1.Good content, reflects ACSM guidelines recommendations 2. Three times weekly exercise sessions are not enough, suggest 6 days with 1 'day off'	2. Three times weekly exercise sessions will be maintained based on literature support (ACSM guidelines on exercise prescription for frail elderly (Garber *et al.*, 2011) and hand OA RCT (Hennig *et al.*, 2015)
Intensity	Moderate to vigorous intensity using colour coded resistant exercise balls	No comments	No comments
Exercise duration	10-15 minutes	1. Good exercise session duration and repetition, reflects the recommendations of the ACSM guidelines.	
Exercise training period	6 weeks	1. 6 weeks training period is not enough as most programmes with such training times have not shown much significant results within the literature	Three times weekly exercise sessions was maintained based on literature support (ACSM guidelines on exercise prescription for frail elderly

Exercise components	**Component Details**	**PPI comments/ suggestions**	**Conclusions Drawn**
		A longer session such as three months of exercise training was suggested but also recognized the contextual factors that influenced research projects and particularly those conducted within PhDs. 2. 6-weeks programme might be too long, suggest higher dosage over shorter period (reflective of what happens within the clinics)	(Garber et al., 2011) and hand OA RCT (Hennig *et al.,* 2015).
Cool down	Few seconds of rubbing the hands together and doing arm & wrist swings.	No comments	No comments

E.10 Participant Information and exercise booklet

The Rapid-force
Hand Osteoarthritis Exercise Study

R-HOE Study

Exercise Booklet

Participant Information and An Exercise Programme for People Living with Hand Osteoarthritis

School of Health Sciences

University of Southampton

Ethics Number: 61579

The R-HOE Study Exercise Booklet

Contents

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The Rapid-HOE Study Exercise Booklet

What is Hand Osteoarthritis?

Hand osteoarthritis (OA) is a common painful joint condition and people living with it often have hand pain, joint stiffness and difficulty with performing some activities using their hands such as grasping objects, turning keys, etc. It usually affects people over 45 years and is more likely to occur if you are female, overweight and sometimes your occupational history (those that involve the repetitive use of your hand).

Clinically, people with hand OA may often have finger nodes (bobbly swelling at back of hand), hard tissue enlargement of the joints, soft tissue swelling and sometimes joint deformities (please see hand OA photo below - Figure 1).

Figure 1: An illustration of hand OA showing some of the clinical signs

The Rapid-HOE programme

Exercises are generally good for a person's wellbeing. The Rapid-HOE programme is a set of exercises carefully designed using information from research, expert clinicians and people living with hand OA who have helped us as patient representatives. Exercises can ease your painful hands, improve the strength and movement in your hands and your ability to carry out everyday hand activities

- It is common to experience pain or mild discomfort in your hand during and/or after performing the exercises. This discomfort should stop within 24 hours but if it does not, please record it in your adverse event form provided in your study pack and contact the investigator who will assess what needs to be done.
- Please always begin your exercises with a **warm-up exercise:** 1. Rub your hands together for a few seconds; 2. Move your arms & wrists in a circular motion, clockwise and anticlockwise for a few minutes]. These warm-up exercises will help ease your hands into the Rapid-HOE exercise programmes.

- For the best results, please follow the guide below in Table 1. It is fine if you do not get to do all your exercises in one session, just pick up from where you left off later that day.

  To ensure that you stick to the exercise programme, we advise that you make the exercises part of **your daily routine** at **work and/or home.**

Table 1: How to perform the Rapid-HOE exercise programme

Exercise components	Component Details
Frequency (how often the exercise is performed)	Week 1 to 2: 6 repetitions of each exercise, 3 days per week Week 3 to 4: 8 reps of each exercise, 3 days per week Week 5 to 6: 10 reps of each exercise, 3 days per week
Exercise Intensity (how strongly the exercise needs to be performed)	Start with moderate resistance exercise balls (investigator will help you choose). Balls will be changed every two weeks.
Exercise duration (how long a session lasts)	15-20 minutes
Exercise training period (how long the whole exercise programme lasts)	6 weeks

Please Note:
You can either spread your exercises over several exercise sessions during the day (especially if they are very tiring) or you can perform them all in the same session.

Description of hand joints

To help with understanding the Rapid-HOE programme, please see below the descriptions of the various hand joints used in the programme.

Figure 2: Photo showing hand joints descriptions used in the Rapid-HOE programme

Rapid-HOE programme content

Exercise 1: Making an "O" sign

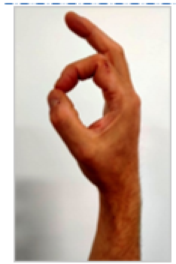
Bring the index fingertip to the thumb tip, keeping the finger joints bent. Hold for 5 seconds and then straighten the fingers. Repeat with the other fingers

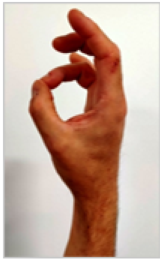
[Please repeat 6 times]

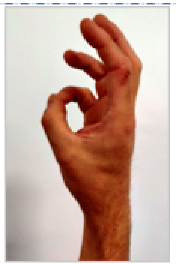
Please see the correct & wrong way of making an "O" sign

Correct position

Wrong position





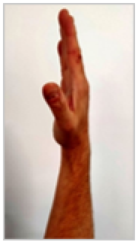


Exercise 2: Roll fingers into a fist

Start the exercise with your fingers straight (1); bend the top two finger joints only into a hook position (2); bend the knuckles into a full fist and hold for 5 seconds (3); After this, straighten the knuckles first (2) before straightening the top two finger joints (i.e. hook fist) to return back to the start position (1).

[Please repeat 6 times]

(1)



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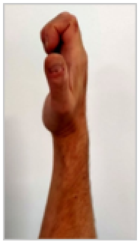

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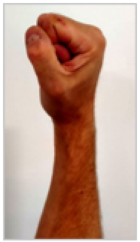

Exercise 3: Hand Grip contractions (3a & 3b)

3a. Sustained-hold handgrip contractions

Squeeze exercise ball as hard as you can and hold 5 seconds, followed by 3 seconds rest

[Please repeat 6 times]

3b. Rapid-Force handgrip contractions

Grip ball in your hand as fast and hard as possible for 1 second, followed by 3 seconds rest.

[Please repeat 6 times]

Perform 3 sets of each 6 grip contractions for the first two weeks. Progress to 6 sets during weeks 3-6 if you can.

Exercise 4: Straightening stretches (ironing out exercises)

Place OA hand on a flat surface, use other hand to apply firm pressure to stretch the top two finger joints and knuckles at the same time (1)

[Press and hold for 30 seconds; please repeat two times]
You can either do this for the individual fingers (1) or all fingers together in a group (2).

(1)

(2)

Additional Information

Attached to this booklet is a hand Osteoarthritis leaflet for your information (An online version can be found here: (https://jigsaw-e.com/wp-content/uploads/2019/10/OA-Hand-Leaflet-v.0.10-02.02.18-LC-FINAL.pdf)

Acknowledgments

We thank all our Patient and Public Involvement partners for their input, advice and support with the modification of an earlier version of the developed Rapid-HOE programme.

For further enquiries, please contact the primary investigator:

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Thank you for taking part in this research project.

Appendix F Mixed Methods Feasibility Study

F.1 Poster

F.2 Study's social media flier

F.3 Study invitation letter

Health Sciences

UNIVERSITY OF Southampton

Ethics No: 61579

October 30, 2020

Dear Sir/ Madam

We would like to invite you to take part in a research project being conducted by investigators from University of Southampton. The study aims to see if an exercise programme developed for people living with hand osteoarthritis can ease their painful hands, improve their ability to perform daily hand activities and their general well-being.

To achieve this, we need the help of older people living in the community with hand osteoarthritis to test this exercise programme. We will send you the study information sheet that explains in more details what the study involves. Please take time to read the information sheet. We are happy to answer any questions if anything you read is not clear or if you would like further information. Please find the contact details of the investigators at the end of this letter.

If you are interested in taking part in this study, please contact the investigators by email or telephone. We will ask you a few questions about your health to check if this project is suitable for you. Then we will schedule an appointment with you at a convenient time and date to brief you about the study and possible start of your involvement in the project.

Thank you for your consideration.

Yours Sincerely
Beatrice Sankah
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The address for both is:
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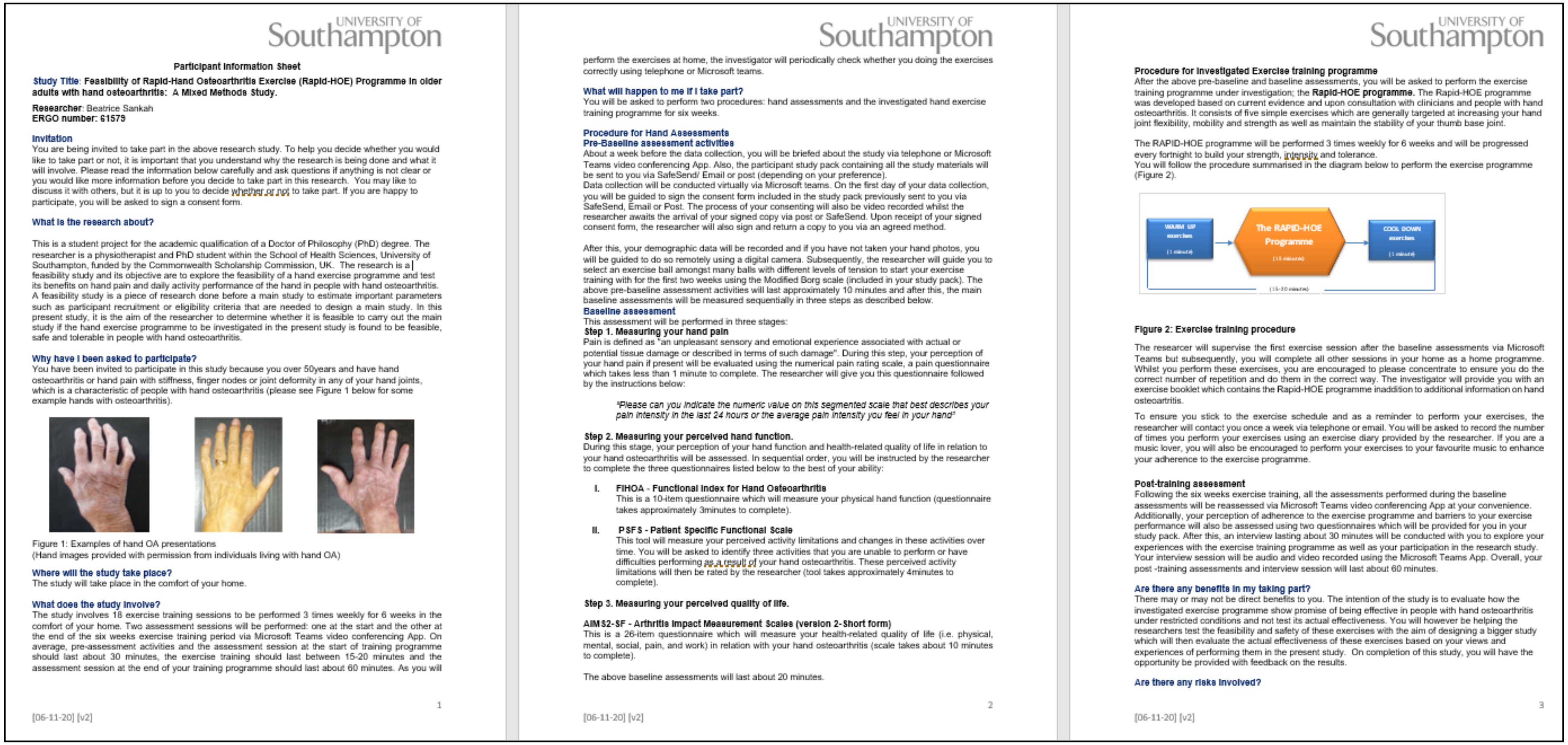
F.4 Participant Information Sheet (Version_2)



UNIVERSITY OF Southampton

Participant Information Sheet

Study Title: Feasibility of Rapid-Hand Osteoarthritis Exercise (Rapid-HOE) Programme in older adults with hand osteoarthritis: A Mixed Methods Study.

Researcher: Beatrice Sankah
ERGO number: 61579

Invitation
You are being invited to take part in the above research study. To help you decide whether you would like to take part or not, it is important that you understand why the research is being done and what it will involve. Please read the information below carefully and ask questions if anything is not clear or you would like more information before you decide to take part in this research. You may like to discuss it with others, but it is up to you to decide whether or not to take part. If you are happy to participate, you will be asked to sign a consent form.

What is the research about?

This is a student project for the academic qualification of a Doctor of Philosophy (PhD) degree. The researcher is a physiotherapist and PhD student within the School of Health Sciences, University of Southampton, funded by the Commonwealth Scholarship Commission, UK. The research is a feasibility study and its objective are to explore the feasibility of a hand exercise programme and test its benefits on hand pain and daily activity performance of the hand in people with hand osteoarthritis. A feasibility study is a piece of research done before a main study to estimate important parameters such as participant recruitment or eligibility criteria that are needed to design a main study. In this present study, it is the aim of the researcher to determine whether it is feasible to carry out the main study if the hand exercise programme to be investigated in the present study is found to be feasible, safe and tolerable in people with hand osteoarthritis.

Why have I been asked to participate?
You have been invited to participate in this study because you over 50years and have hand osteoarthritis or hand pain with stiffness, finger nodes or joint deformity in any of your hand joints, which is a characteristic of people with hand osteoarthritis (please see Figure 1 below for some example hands with osteoarthritis).

Figure 1: Examples of hand OA presentations
(Hand images provided with permission from individuals living with hand OA)

Where will the study take place?
The study will take place in the comfort of your home.

What does the study involve?
The study involves 18 exercise training sessions to be performed 3 times weekly for 6 weeks in the comfort of your home. Two assessment sessions will be performed: one at the start and the other at the end of the six weeks exercise training period via Microsoft Teams video conferencing App. On average, pre-assessment activities and the assessment session at the start of training programme should last about 30 minutes, the exercise training should last between 15-20 minutes and the assessment session at the end of your training programme should last about 60 minutes. As you will

1

[06-11-20] [v2]

UNIVERSITY OF Southampton

perform the exercises at home, the investigator will periodically check whether you doing the exercises correctly using telephone or Microsoft teams.

What will happen to me if I take part?
You will be asked to perform two procedures: hand assessments and the investigated hand exercise training programme for six weeks.

Procedure for Hand Assessments
Pre-Baseline assessment activities
About a week before the data collection, you will be briefed about the study via telephone or Microsoft Teams video conferencing App. Also, the participant study pack containing all the study materials will be sent to you via SafeSend/ Email or post (depending on your preference).
Data collection will be conducted virtually via Microsoft teams. On the first day of your data collection, you will be guided to sign the consent form included in the study pack previously sent to you via SafeSend, Email or Post. The process of your consenting will also be video recorded whilst the researcher awaits the arrival of your signed copy via post or SafeSend. Upon receipt of your signed consent form, the researcher will also sign and return a copy to you via an agreed method.

After this, your demographic data will be recorded and if you have not taken your hand photos, you will be guided to do so remotely using a digital camera. Subsequently, the researcher will guide you to select an exercise ball amongst many balls with different levels of tension to start your exercise training with for the first two weeks using the Modified Borg scale (included in your study pack). The above pre-baseline assessment activities will last approximately 10 minutes and after this, the main baseline assessments will be measured sequentially in three steps as described below.
Baseline assessment
This assessment will be performed in three stages:
Step 1. Measuring your hand pain
Pain is defined as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such damage". During this step, your perception of your hand pain if present will be evaluated using the numerical pain rating scale, a pain questionnaire which takes less than 1 minute to complete. The researcher will give you this questionnaire followed by the instructions below:

> *"Please can you indicate the numeric value on this segmented scale that best describes your pain intensity in the last 24 hours or the average pain intensity you feel in your hand"*

Step 2. Measuring your perceived hand function.
During this stage, your perception of your hand function and health-related quality of life in relation to your hand osteoarthritis will be assessed. In sequential order, you will be instructed by the researcher to complete the three questionnaires listed below to the best of your ability:

I. **FIHOA - Functional Index for Hand Osteoarthritis**
This is a 10-item questionnaire which will measure your physical hand function (questionnaire takes approximately 3minutes to complete).

II. **PSFS - Patient Specific Functional Scale**
This tool will measure your perceived activity limitations and changes in these activities over time. You will be asked to identify three activities that you are unable to perform or have difficulties performing as a result of your hand osteoarthritis. These perceived activity limitations will then be rated by the researcher (tool takes approximately 4minutes to complete).

Step 3. Measuring your perceived quality of life.

AIMS2-SF - Arthritis Impact Measurement Scales (version 2-Short form)
This is a 26-item questionnaire which will measure your health-related quality of life (i.e. physical, mental, social, pain, and work) in relation with your hand osteoarthritis (scale takes about 10 minutes to complete).

The above baseline assessments will last about 20 minutes.

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[06-11-20] [v2]

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Procedure for Investigated Exercise training programme
After the above pre-baseline and baseline assessments, you will be asked to perform the exercise training programme under investigation; the **Rapid-HOE programme.** The Rapid-HOE programme was developed based on current evidence and upon consultation with clinicians and people with hand osteoarthritis. It consists of five simple exercises which are generally targeted at increasing your hand joint flexibility, mobility and strength as well as maintain the stability of your thumb base joint.

The RAPID-HOE programme will be performed 3 times weekly for 6 weeks and will be progressed every fortnight to build your strength, intensity and tolerance.
You will follow the procedure summarised in the diagram below to perform the exercise programme (Figure 2).

Figure 2: Exercise training procedure

The researcer will supervise the first exercise session after the baseline assessments via Microsoft Teams but subsequently, you will complete all other sessions in your home as a home programme. Whilst you perform these exercises, you are encouraged to please concentrate to ensure you do the correct number of repetition and do them in the correct way. The investigator will provide you with an exercise booklet which contains the Rapid-HOE programme inaddition to additional information on hand osteoartritis.

To ensure you stick to the exercise schedule and as a reminder to perform your exercises, the researcher will contact you once a week via telephone or email. You will be asked to record the number of times you perform your exercises using an exercise diary provided by the researcher. If you are a music lover, you will also be encouraged to perform your exercises to your favourite music to enhance your adherence to the exercise programme.

Post-training assessment
Following the six weeks exercise training, all the assessments performed during the baseline assessments will be reassessed via Microsoft Teams video conferencing App at your convenience. Additionally, your perception of adherence to the exercise programme and barriers to your exercise performance will also be assessed using two questionnaires which will be provided for you in your study pack. After this, an interview lasting about 30 minutes will be conducted with you to explore your experiences with the exercise training programme as well as your participation in the research study. Your interview session will be audio and video recorded using the Microsoft Teams App. Overall, your post -training assessments and interview session will last about 60 minutes.

Are there any benefits in my taking part?
There may or may not be direct benefits to you. The intention of the study is to evaluate how the investigated exercise programme show promise of being effective in people with hand osteoarthritis under restricted conditions and not test its actual effectiveness. You will however be helping the researchers test the feasibility and safety of these exercises with the aim of designing a bigger study which will then evaluate the actual effectiveness of these exercises based on your views and experiences of performing them in the present study. On completion of this study, you will have the opportunity be provided with feedback on the results.

Are there any risks involved?

3

[06-11-20] [v2]

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There are no known risks of taking part. The risks associated with the exercises in this study include pain and fatigue after exercising if you are not used to exercising your hands. The pain will ease off on its own accord usually within 24 hours and will not need any treatment. No adverse effects are anticipated but if you notice any, then you will be encouraged to record it in your Adverse Events form provided in your study pack and inform the researcher immediately who will assess what needs to be done. In severe situations, you will be asked to stop your exercise training and subsequently advised to see your GP.

What data will be collected?
Data from the questionnaires you fill will be collected, this will be done remotely with Microsoft Teams video conferencing App by the primary researcher or her supervisor (Prof Stokes)

Videos and audio recordings of your consent and 30-minutes interview session will be collected using Microsoft Teams App. These will be kept separately and that for your consent will be destroyed immediately after receiving your signed written content via email, SafeSend or post based on your preference. The recording of your interview will be securely transcribed as soon as possible and then securely destroyed following the study's completion (31/03/2021).

Your postal address will be collected in this study to allow for the exercise balls to be used for your exercise training and the study pack containing all the study materials to be posted to you if it's an option you would prefer. The researcher will obtain your address securely using email (researcher's university email account) or SafeSend, a secure way of exchanging confidential information recommended by University of Southampton. Your postal address will be securely stored away from the other research data in line with the University's data protection policies.

Your hand photos will be stored in a password protected computer as soon as possible following receipt from you via SafeSend or email. In adhering to the latest data protection regulations, hand photos will not be backed up to any cloud-based storage and once data collection is complete, your hand images will be deleted.

In addition, your personal data (name, age and gender) will be collected in this study. These will be used only for the purposes of carrying out our research and will be handled according to the University's policies in line with data protection law. If any personal data is used from which you can be identified directly, it will not be disclosed to anyone else without your consent unless the University of Southampton is required by law to disclose it.

You will have an ID number which will be used throughout the study (all questionnaires and interview recordings). Your data will therefore remain anonymous and your names will not be disclosed in any report or publication, hence your individual identity will be unknown. Where any of your personal information is collected during the interview session, these will be replaced with artificial identifiers as soon as practicable for storage. A record of all participants' Name details that provides a link via a participant ID to records containing the study metrics will be kept. This record will however be locked away securely in the researcher's lead supervisor's office at the university.

Will my participation be confidential?
Your participation and the information we collect about you during the research will be kept strictly confidential. Only the research team and responsible members of the University of Southampton may be given access to data about you for monitoring purposes and/or to carry out an audit of the study to ensure that the research is complying with applicable regulations. Individuals from regulatory authorities (people who check that we are carrying out the study correctly) may require access to your data. All of these people have a duty to keep your information, as a research participant, strictly confidential.

To ensure your confidentially and anonymity in all written reports or publications, you will be given a study participant number which will not be linked to their biodata. The signed consent forms and participant information sheets will be kept in a locked filing cabinet in a secure room in the School of Health Sciences. Your personal information will be stored electrically on the computer system at the University of Southampton, requiring a password to gain access. All these will be done to comply with the Data Protection policy of the School of Health Sciences and the new European Union General

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[06-11-20] [v2]

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Data Protection Regulation (GDPR) (https://www.eugdpr.org/). Data will be stored securely for 10 years.

Do I have to take part?
No, it is entirely up to you to decide whether or not to take part. If you decide you want to take part, you will need to sign a consent form to show you have agreed to take part.
Kindly contact the primary researcher (contact below) if you want to take part in this study

What happens if I change my mind?
You have the right to withdraw at any time without your rights being affected. If you withdraw from the study, we will keep the information about you that we have already obtained for the purposes of achieving the objectives of the study only.

What will happen to the results of the research?
Your personal details will remain strictly confidential. Research findings made available in any reports or publications will not include information that can directly identify you without your specific consent. The results of this study will be published, and you will receive a copy. Anonymised research data from this research will be made available for secondary analysis in future research projects and will be stored for a minimum of 10 years, as per University of Southampton policy.

Where can I get more information?
If you require any further information after reading this information or have any concerns regarding this study, kindly contact the primary researcher or her supervisors on the contacts below

Name and contact details of Primary Researcher:
Beatrice E.A. Sankah
University of Southampton
Building 67, Highfield Campus, Southampton, SO17 1BJ. UK
Telephone: Tel: +44 (0)2380 22711
E-mail: B.E.A.Sankah@soton.ac.uk

Name and contact details of Supervisors:
Prof Maria Stokes
University of Southampton
Building 67, Highfield Campus, Southampton, SO17 1BJ. UK
E-mail: m.stokes@soton.ac.uk

Dr James Gavin
University of Southampton
Building 67, Highfield Campus, Southampton, SO17 1BJ. UK
E-mail: J.P.Gavin@soton.ac.uk

What happens if there is a problem?
If you have a concern about any aspect of this study, you should speak to the researchers who will do their best to answer your questions.
If you remain unhappy or have a complaint about any aspect of this study, please contact the University of Southampton Research Integrity and Governance Manager (023 8059 5058, rgoinfo@soton.ac.uk).

Data Protection Privacy Notice
The University of Southampton conducts research to the highest standards of research integrity. As a publicly-funded organisation, the University has to ensure that it is in the public interest when we use personally-identifiable information about people who have agreed to take part in research. This means that when you agree to take part in a research study, we will use information about you in the ways needed, and for the purposes specified, to conduct and complete the research project. Under data protection law, 'Personal data' means any information that relates to and is capable of identifying a living individual. The University's data protection policy governing the use of personal data by the University can be found on its website (https://www.southampton.ac.uk/legalservices/what-we-do/data-protection-and-foi.page).

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This Participant Information Sheet tells you what data will be collected for this project and whether this includes any personal data. Please ask the research team if you have any questions or are unclear what data is being collected about you.

Our privacy notice for research participants provides more information on how the University of Southampton collects and uses your personal data when you take part in one of our research projects and can be found at
http://www.southampton.ac.uk/assets/sharepoint/intranet/ls/Public/Research%20and%20Integrity%20Privacy%20Notice/Privacy%20Notice%20for%20Research%20Participants.pdf

Any personal data we collect in this study will be used only for the purposes of carrying out our research and will be handled according to the University's policies in line with data protection law. If any personal data is used from which you can be identified directly, it will not be disclosed to anyone else without your consent unless the University of Southampton is required by law to disclose it. Data protection law requires us to have a valid legal reason ('lawful basis') to process and use your Personal data. The lawful basis for processing personal information in this research study is for the performance of a task carried out in the public interest. Personal data collected for research will not be used for any other purpose.

For the purposes of data protection law, the University of Southampton is the 'Data Controller' for this study, which means that we are responsible for looking after your information and using it properly. The University of Southampton will keep identifiable information about you for 10years after the study has finished after which time any link between you and your information will be removed.
To safeguard your rights, we will use the minimum personal data necessary to achieve our research study objectives. Your data protection rights – such as to access, change, or transfer such information - may be limited, however, in order for the research output to be reliable and accurate. The University will not do anything with your personal data that you would not reasonably expect.
If you have any questions about how your personal data is used, or wish to exercise any of your rights, please consult the University's data protection webpage (https://www.southampton.ac.uk/legalservices/what-we-do/data-protection-and-foi.page) where you can make a request using our online form. If you need further assistance, please contact the University's Data Protection Officer (data.protection@soton.ac.uk). **Thank you.**
Thank you for taking the time to read the information sheet and considering to take part in this research.

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[06-11-20] [v2]

F.5 Qualitative interview topic guide

Health Sciences

The Rapid-force
Hand Osteoarthritis Exercise – R-HOE Study

UNIVERSITY OF Southampton

Participant ID: **ERGO Number: 61579**

Topic guide for Hand OA Feasibility Study: Virtual interviews (≤30minutes)
(to take place after the post training data assessment)

PURPOSE:
Use to guide qualitative Virtual interviews for all study volunteers

INSTRUCTIONS:

Preamble:

Researcher to thank the participant for consenting to have face-to-face interview and to explain the purpose of the qualitative interview. Researcher to ask if the participant has any questions, answer these questions if any and re-affirm consent. If the participant does not wish to be audio-recorded, researcher will seek their permission to write notes instead. If the participant does not wish to have their views noted, then the participant will be thanked for their consideration and the interview will not proceed. This topic guide contains areas that will be addressed in all interviews, but the interviewer will use it flexibly and follow up on issues of importance to the participant and add probes and prompts into the verbal questions as and when appropriate to do.

Part 1: Experience with exercises

a. **Please tell me what you think about the exercise programme.**
   Prompts
   1. Please would you describe your experience in doing the hand exercise programme?
   2. Was there anything that made it easier or difficult to perform these exercises?
   3. Was there anything you liked in your exercise programme?
   4. Was there anything you disliked about your exercise programme?

b. **The researcher wants to make sure that the exercise programme is as good as it can be. Are there things you think should be changed about the exercise programme?**

   Prompts
   1. Are there things that you think could be added to the programme?
   2. Are there things that you think could be taken away from the programme?
   3. Would you do anything differently if you were to do the exercises again or not? If yes, what would these be?
   4. Do you have any other suggestions on ways to improve the exercises?

Part 2: Other comments

a. Are there other things that you would like to talk about in relation to your hand?

Part 3: Closing

Researcher to thank participant and remind them of name and contact details.

F.6 Adverse events form

Health Sciences

The Rapid-force
Hand Osteoarthritis Exercise – R-HOE Study

UNIVERSITY OF Southampton

ERGO Number: 61579

Participant ID:

Adverse event form

Date: ………….

Time: ………………

Description of Event

……

……

……

……

Location of Event: ……………………………………………

Start of event:

Date: ……………………………… **Time:** ……………………

Measures taken to manage the adverse event

……

……

……

Person who reported the event

Name: ………………………………………………………………………

Signature: ……………………………………………………………………

[06-11-20] [v1]

F.7 Exercise diary

Ethics Number: **Participant ID:**

Please mark with an (x) or (✓) anytime you perform the exercises

Exercises		Weekly sessions	Weekly Record					
			Wk. 1	Wk. 2	Wk. 3	Wk. 4	Wk. 5	Wk. 6
Exercise 1: Making an "O" sign		1st						
		2nd						
		3rd						
Exercise 2: Roll into a fist		1st						
		2nd						
		3rd						
Exercise 3: Hand Grip contractions	3a. Static contractions	1st						
		2nd						
		3rd						
	3b. Rapid-Force contractions	1st						
		2nd						
		3rd						
Exercise 4: Straightening stretches		1st						
		2nd						
		3rd						

NB: Wk. - week

F.8 Exercise Adherence Rating Scale

Health Sciences

The Rapid-force
Hand Osteoarthritis Exercise – R-HOE

UNIVERSITY OF Southampton

Participant ID:

Exercise Adherence Rating Scale (EARS)

For each of the following 6 statements, please tick the box which best describes how you do your recommended exercises/activities. When thinking about your answer, please consider any exercises/activities that you have been asked to do as part of your treatment.

1. I do my exercises as often as recommended

Completely agree				*Completely disagree*
0	*1*	*2*	*3*	*4*
☐	☐	☐	☐	☐

2. I forget to do my exercises

Completely agree				*Completely disagree*
0	*1*	*2*	*3*	*4*
☐	☐	☐	☐	☐

3. I do less exercise than recommended by my healthcare professional

Completely agree				*Completely disagree*
0	*1*	*2*	*3*	*4*
☐	☐	☐	☐	☐

4. **I fit my exercises into my regular routine**

Completely agree				*Completely disagree*
0	*1*	*2*	*3*	*4*
☐	☐	☐	☐	☐

5. **I don't get around to doing my exercises**

Completely agree				*Completely disagree*
0	*1*	*2*	*3*	*4*
☐	☐	☐	☐	☐

6. **I do most, or all, of my exercises**

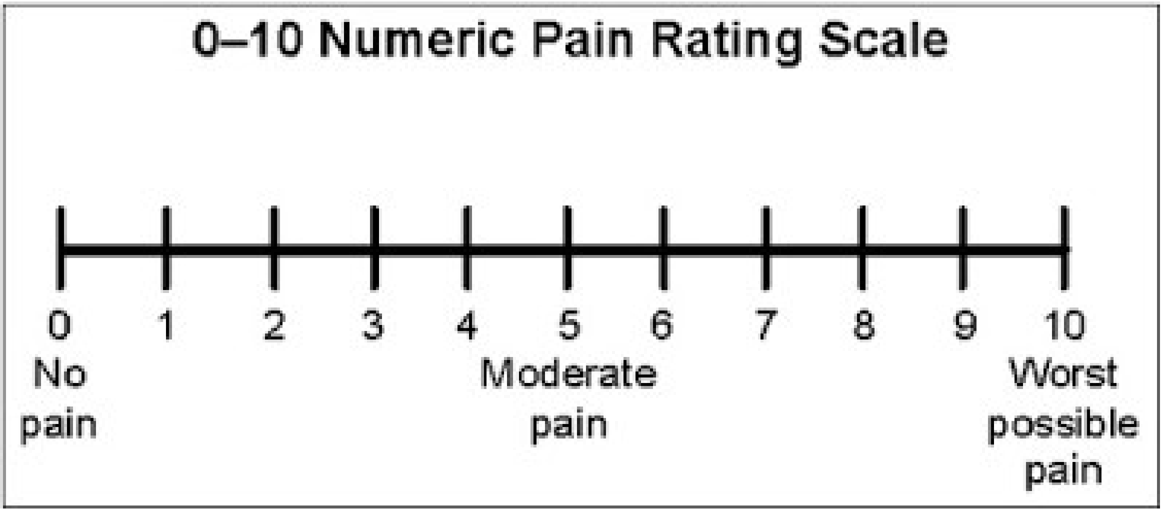
Completely agree				*Completely disagree*
0	*1*	*2*	*3*	*4*
☐	☐	☐	☐	☐

Source: Newman-Beinart, N.A. et al. (2017) 'The development and initial psychometric evaluation of a measure assessing adherence to prescribed exercise: the Exercise Adherence Rating Scale (EARS)', Physiotherapy, 103(2), pp. 180-185.

F.9 Numerical Pain Rating Scale

Instructions

Please can you indicate the numeric value on this segmented scale that best describes your pain intensity in the last 24 hours or the average pain intensity you feel in your hand [instructions adapted from Hawker *et al.* (2011)].



Scoring and interpretations

Score	Meaning
0	No pain
0-1	Mild pain
4-5	moderate
7-9	severe
10	Worse pain imaginable

F.10 Functional Index for Osteoarthritis (FIHOA)

FIHOA

FUNCTIONAL INDEX FOR HAND ARTHROPATHIES (FIHOA)

Scoring system
0: possible without difficulty
1: possible with slight difficulty
2: possible with important difficulty
3: impossible

1.	Are you able to turn a key in a lock?	☐0 ☐1 ☐2 ☐3
2.	Are you able to cut meat with a knife?	☐0 ☐1 ☐2 ☐3
3.	Are you able to cut cloth or paper with a pair of scissors?	☐0 ☐1 ☐2 ☐3
4.	Are you able to lift a full bottle with the hand?	☐0 ☐1 ☐2 ☐3
5.	Are you able to clench your fist?	☐0 ☐1 ☐2 ☐3
6.	Are you able to tie a knot?	☐0 ☐1 ☐2 ☐3
7.	*For women* - Are you able to sew? *For men* - Are you able to use a screwdriver?	☐0 ☐1 ☐2 ☐3
8.	Are you able to fasten buttons?	☐0 ☐1 ☐2 ☐3
9.	Are you able to write for a long period of time (10 mn)?	☐0 ☐1 ☐2 ☐3
10.	Would you accept a handshake without reluctance?	☐0 ☐1 ☐2 ☐3

Result	
Weight (in Kilograms)	
Height (in Centimeters)	
BMI	
Gender	
Age	

F.11 Patient Specific Functional Scale

Patient-Specific Functional Scale

This questionnaire can be used to quantify activity limitation and measure functional outcome for patients with an orthopaedic condition.

Clinician to read and fill in. Complete at the end of the history and prior to physical examination.

Initial assessment

I am going to ask you to identify up to three important activities that you are unable to do or are having difficulty with as a result of your ______________ problem. Today, are there any activities that you are unable to do or having difficulty with because of your ________________ problem? (Clinician: show scale to patient and have the patient rate each activity).

Follow-up assessments

When I assessed you on (state previous assessment date), you told me that you had difficulty with (read all activities from list). Today, do you still have difficulty with (read and have patient score each item in the list)?

Patient-specific activity scoring scheme (Point to one number):

0 1 2 3 4 5 6 7 8 9 10

Unable to perform activity

Able to perform activity at the same level as before injury or problem

(Date and score)

Activity	**Initial**					
1.						
2.						
3.						
4.						
5.						
Additional						
Additional						

F.12 AIMS2-SF Questionnaire

AIMS-2 SF
ARTHRITIS IMPACT MEASUREMENT
SCALES 2 Short Form

INSTRUCTIONS : Please answer the following questions about your health.
Most questions ask about your health during the past 4 weeks.
There are no right or wrong answers to the questions and most can be answered with a simple check (✓).
Please answer every question.

DURING THE PAST 4 WEEKS ...	**All days**	**Most days**	**Some days**	**Fews days**	**No days**
1. How often were you physically able to drive a car or use public transportation?	❑	❑	❑	❑	❑
2. How often were you in a bed or chair for most or all of the days ?	❑	❑	❑	❑	❑
3. Did you have trouble doing vigorous activities such as running, lifting heavy objects, or participating in strenuous sports ?	❑	❑	❑	❑	❑
4. Did you have trouble either walking several blocks or climbing a few flights of stairs ?	❑	❑	❑	❑	❑
5. Were you unable to walk unless assisted by another person of by a cane, crutches, or walker ?	❑	❑	❑	❑	❑
6. Could you easily write with a pen or pencil ?	❑	❑	❑	❑	❑
7. Could you easily button a shirt or blouse ?	❑	❑	❑	❑	❑
8. Could you easily turn a key in a lock ?	❑	❑	❑	❑	❑
9. Could you easily comb or brush your hair ?	❑	❑	❑	❑	❑
10. Could you easily reach shelves that were above your head ?	❑	❑	❑	❑	❑
11. Did you need help to get dressed ?	❑	❑	❑	❑	❑
12. Did you need help to get in or out of bed ?	❑	❑	❑	❑	❑

AIMS2 SF 1.3 - Quality of Life Group in Rheumatology, France 1995. Arthritis & Rheumatism 1997; 40: 1267-74
Adaptation from AIMS2 - R. Meenan - Boston, Ms

DURING THE PAST 4 WEEKS	All days	Most days	Some days	Few days	No days
13. How often did you have severe pain from you arthritis ?	❑	❑	❑	❑	❑
14. How often did your morning stiffness last more than one hour from the time you woke up ?	❑	❑	❑	❑	❑
15. How often did your pain make it difficult for you to sleep ?	❑	❑	❑	❑	❑
	Always	**Very often**	**Some times**	**Almost never**	**Never**
16. How often have you felt tense of high strung ?	❑	❑	❑	❑	❑
17. How often have you been bothered by nervousness or your nerves ?	❑	❑	❑	❑	❑
18. How often have you been in low or very low spirits ?	❑	❑	❑	❑	❑
19. How often have you enjoyed the things you do ?	❑	❑	❑	❑	❑
20. How often did you feel a burden to others ?	❑	❑	❑	❑	❑
	All days	**Most days**	**Some days**	**Few days**	**No days**
21. How often did you get together with friends or relatives ?	❑	❑	❑	❑	❑
22. How often were your on the telephone with close friends or relatives ?	❑	❑	❑	❑	❑
23. How often did you go to a meeting of a church, club, team or other group ?	❑	❑	❑	❑	❑
24. Did you feel that your family or friends were sensitive to your personal needs ?	❑	❑	❑	❑	❑
If you are unemployed, disabled or retired, END of questionnaire.	**All days**	**Most days**	**Some days**	**Few days**	**No days**
25. How often were you unable to do any paid work, house work or school work ?	❑	❑	❑	❑	❑
26. On the days that you did work, how often did you have to work a shorter day ?	❑	❑	❑	❑	❑

AIMS2 SF 1.3 - Quality of Life Group in Rheumatology, France 1995. Arthritis & Rheumatism 1997; 40: 1267-74
Adaptation from AIMS2 - R. Meenan - Boston, Ms

F.13 Assessment and Intervention Duration

NB: s = seconds; m = minutes

<table>
<tr><th></th><th>Process</th><th colspan="2">Activity</th><th>Maximum Time Allocation (Minutes)</th></tr>
<tr><td rowspan="14">Pre-training Session</td><td colspan="4">Pre-assessment activities</td></tr>
<tr><td>1.</td><td colspan="2">Briefing and Consenting</td><td>4</td></tr>
<tr><td>2.</td><td colspan="2">Demographic data collection</td><td>2</td></tr>
<tr><td>3.</td><td colspan="2">Exercise load selection (Borg Scale)</td><td>2</td></tr>
<tr><td>Activity length</td><td colspan="2"></td><td>8</td></tr>
<tr><td colspan="4">Baseline Assessment</td></tr>
<tr><td>1.</td><td colspan="2">Hand Pain</td><td>2</td></tr>
<tr><td>2.</td><td colspan="2">Patient Specific Functional Scale (PSFS)</td><td>4</td></tr>
<tr><td>3.</td><td colspan="2">Functional Index for Hand Osteoarthritis (FIHOA)</td><td>3</td></tr>
<tr><td>4.</td><td colspan="2">AIMS2-SF</td><td>10</td></tr>
<tr><td>Assessment length</td><td colspan="2"></td><td>19</td></tr>
<tr><td>Session length</td><td colspan="2"></td><td>27</td></tr>
<tr><td rowspan="10">Exercise training</td><td colspan="4">The Rapid-HOE programme</td></tr>
<tr><td>1.</td><td colspan="2">Warm up</td><td>1</td></tr>
<tr><td>2.</td><td colspan="2">Make an “O” sign (1set/cycle=10s) ×6</td><td>2</td></tr>
<tr><td>3.</td><td colspan="2">Roll into a fist (1set=15s) ×6</td><td>3</td></tr>
<tr><td rowspan="2">4.</td><td rowspan="2">Hand Grip contractions</td><td>Static handgrip contractions (15s) ×6</td><td>2</td></tr>
<tr><td>Rapid-Force Handgrip contractions (1set=40s) × 3</td><td>3</td></tr>
<tr><td>5.</td><td colspan="2">Straightening stretches (2m)</td><td>3</td></tr>
<tr><td>6.</td><td colspan="2">Cool down</td><td>1</td></tr>
<tr><td>Session Length</td><td colspan="2"></td><td>15</td></tr>
<tr><td rowspan="5">Post training Session</td><td colspan="4">Post training Assessment</td></tr>
<tr><td>1.</td><td colspan="2">All baseline measurements</td><td>19</td></tr>
<tr><td>2.</td><td colspan="2">Exercise Adherence Rating Scale (EARS)</td><td>2</td></tr>
<tr><td>3.</td><td colspan="2">Virtual interview</td><td>30</td></tr>
<tr><td>Session Length</td><td colspan="2"></td><td>51</td></tr>
</table>

F.14 Consent Form (Version_2)

UNIVERSITY OF Southampton

CONSENT FORM

Study title: Feasibility of Rapid-Hand Osteoarthritis Exercise (Rapid-HOE) Programme in older adults with hand osteoarthritis: A Mixed Methods Study.

Researcher name: Beatrice Sankah

Please initial the box(es) if you agree with the statement(s):

I have read and understood the information sheet [06-11-20/v2] and have had the opportunity to ask questions about the study.	
I agree to take part in this research project and agree for my data to be used for the purpose of this study.	
I understand my participation is voluntary and I may withdraw at any time for any reason without my participant rights being affected.	
I understand that taking part in the study involves audio and video recording which will be transcribed and then destroyed for the purposes set out in the participant information sheet.	
I agree to take part in the interview for the purposes set out in the participant information sheet and understand that these will be recorded using audio, video and written notes.	
I understand that I may be quoted directly in reports of the research but that I will not be directly identified (e.g. that my name will not be used).	
I understand that my personal information collected about me such as my name or where I live will not be shared beyond the study team	
I give permission for the data that I provide to be stored by University of Southampton for 10 years as described in the participant information sheet so it can be used for secondary analysis in future research projects	

Name of participant (print name)……………………………………………………………………………

Signature of participant……………………………………………………………………………………

Date………………………………………………………………………………………………………

Name of researcher (print name)……………………………………………………………………………

Signature of researcher ……………………………………………………………………………………

Date………………………………………………………………………………………………………

[06-11-20] [V2] [Ethics 61579]

F.15 Data Collection Checklist

<table>
<tr><td colspan="4">Participant ID:</td><td colspan="3">Date:</td></tr>
<tr><td colspan="2">Consent form filled (Circle):</td><td>Yes</td><td>No</td><td colspan="3">Age:</td></tr>
<tr><td>Gender (Circle):</td><td>M</td><td colspan="2">F</td><td colspan="3"></td></tr>
<tr><td colspan="3">Weight:</td><td colspan="4">Height:</td></tr>
<tr><td colspan="3">Disease duration (years):</td><td colspan="4">Symptom duration (years):</td></tr>
<tr><td>Hand Dominance (Circle)</td><td colspan="3">R</td><td colspan="3">L</td></tr>
<tr><td rowspan="2">No. of painful joints (0–15)</td><td colspan="6">Right hand:</td></tr>
<tr><td colspan="6">Left hand:</td></tr>
<tr><td rowspan="2">load selection (Modified Borg Scale)</td><td colspan="2">Baseline</td><td colspan="2">Beginning of Week 3</td><td colspan="2">Beginning of Week 5</td></tr>
<tr><td>Yes</td><td>No</td><td>Yes</td><td>No</td><td>Yes</td><td>No</td></tr>
</table>

<table>
<tr><td colspan="2" rowspan="2">Outcomes</td><td colspan="2">Outcome Measurements</td></tr>
<tr><td>Baseline 1</td><td>After Week 6</td></tr>
<tr><td colspan="2">Hand Pain (NPRS)</td><td></td><td></td></tr>
<tr><td rowspan="2">Hand Function</td><td>PSFS questionnaire</td><td></td><td></td></tr>
<tr><td>FIHOA questionnaire</td><td></td><td></td></tr>
<tr><td colspan="2">HRQoL (AIMS2-SF)</td><td></td><td></td></tr>
<tr><td colspan="3">Exercise Adherence (EARS questionnaire)</td><td></td></tr>
<tr><td colspan="3">Interview Session</td><td></td></tr>
</table>

F.16 Data Collection Instructions

<table>
<tr><th colspan="2">Task</th><th colspan="2">Test Positions and Instructions</th></tr>
<tr><td colspan="2">1st Stage</td><td colspan="2">Pre-assessment activities</td></tr>
<tr><td colspan="4">Modified Borg Scale</td></tr>
<tr><td colspan="2">Instructions</td><td colspan="2">1. Participants will be instructed to squeeze different coloured balls to determine their baseline resistance level as indicated on the Borg scale.
2. Guided by the researcher, a moderate resistant exercise ball will be selected to perform the grip exercises for the first two weeks.
3. Balls (i.e. colours) will be changed to higher resistance ball at the beginning of week 3 and 5 to progress the exercise intensity</td></tr>
<tr><td colspan="2">2nd Stage</td><td colspan="2">Pre & Post-training assessment</td></tr>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">Hand Pain (NPRS)</td></tr>
<tr><td colspan="2">Instructions on scale (see xx)</td></tr>
<tr><td colspan="4">Patient reported outcomes</td></tr>
<tr><td rowspan="2">Hand Function</td><td>PSFS questionnaire</td><td colspan="2">Instructions on scale (See Appendix F.11)</td></tr>
<tr><td>FIHOA questionnaire</td><td colspan="2">Please answer the questions to the best of your ability, I am happy to answer any questions you may have ((See Appendix F.10)</td></tr>
<tr><td colspan="2">HRQoL (AIMS2-SF) questionnaire</td><td colspan="2">Instructions on questionnaire (See Appendix F.12)</td></tr>
<tr><td colspan="2">Exercise Adherence Rating Scale (EARS)</td><td colspan="2">Instructions on questionnaire (See Appendix F.8)</td></tr>
</table>

F.17 Returned and completed participant exercise diary

Health Sciences

The Rapid-force Hand Osteoarthritis Exercise – R-HOE Study

UNIVERSITY OF Southampton

Ethics Number: 61579

Participant ID: 131

Please mark with an (x) or (✓) anytime you perform the exercises

Exercises		Weekly sessions	Weekly Record					
			Fri	Fri	Fri	Fri	Sun	Sat.
			Wk. 1	Wk. 2	Wk. 3	Wk. 4	Wk. 5	Wk. 6
Exercise 1: Making an "O" sign		Fri 1st	✓	✓	✓	✓	✓	✓
		2nd	✓	✓	✓	✓	✓	✓
		3rd	✓	✓	✓	✓	✓	✓
Exercise 2: Roll into a fist		1st	✓	✓	✓	✓	✓	✓
		2nd	✓	✓	✓	✓	✓	✓
		3rd	✓	✓	✓	✓	✓	✓
Exercise 3: Hand Grip contractions	3a. Static contractions	1st	✓ 2 sets	✓	✓ x4	✓ x6	✓	✓
		2nd	✓ x3	✓	✓	✓ x6	✓	✓
		3rd	✓ x3	✓	✓	✓ x6	✓	✓
	3b. Rapid-Force contractions	1st	✓ 2 sets	✓	✓ x4	✓ x6	✓	✓
		2nd	✓ x3	✓	✓	✓ x6	✓	✓
		3rd	✓ x3	✓	✓	✓ 6	✓	✓
Exercise 4: Straightening stretches		1st	✓	✓	✓	✓	✓	✓
		2nd	✓	✓	✓	✓	✓	✓
		3rd	✓	✓	✓	✓	✓	✓

NB: Wk. - week

[06-11-20] [v2]

F.18 Screenshot of themes and nodes generated in NVivo

Name	Files	References
Acceptability of rapid-HOE	0	0
Satisfaction with exercises	8	22
perceived appropriateness	5	8
intent to continue use	3	4
Practicability of rapid-HOE exercise	0	0
positive effects on participants	7	11
Negative effects on target participants	3	5
Ability of participants to carry out programme	3	3
Suggestions on modification of exercise	1	1
No change	5	8
Modification for exercise presentation	0	0
Modification for exercise delivery	0	0
Modification for exercise content	0	0
Views on rapid-HOE	8	25
Exercise presention	8	25
Good instructions and researcher support	8	15
confusing counting of exercise frequency	1	1
appropriate and well structured	6	9
Exercise content	0	0
Positive feedback	0	0
Negative feedback	0	0
adherence	8	22

F.19 Complete results- views on Rapid-HOE exercise content and presentation

Major Theme	Sub-theme	No of records	No of References	EVIDENCE
Exercise content	Good and tolerable exercises	7	10	**Good exercises** "…I actually thought four exercises wasn't gonna be enough, but my hands ached at the end of it. I was surprised actually, and the ache lasted overnight on the first couple of sessions and then that settled down. [..] so I was pleased with that. [..] I'm impressed actually because I didn't think I was gonna notice too much difference, but my hands are definitely much stronger, and my wrists haven't been aching anywhere near as much as they used to" **(P-115)** "it *(exercises)* was surprisingly good and I'm sorry that sounds disrespectful but I didn't really think that I will get a benefit but I have, I really have and I've been continuing to use the little balls as well. I think they were good exercises" **(P-115)** "…I think it *(exercises)* was really good because it gave you something positive to try and help yourself. And I definitely do think that doing exercises has helped. I've got a lot more. I can grip things; I can pick things up better than I did before" **(P-116)** "…I mean you couldn't really feel that you were doing anything specific with it *(exercises)* but it worked. Because when you are doing it and holding the ball, you could feel the pressure of the ball melting in your hand. You couldn't feel a lot in your hand but obviously it was doing good**. (P-119)** " …I thought that *(making a fist)* was very good. That I've never done[..] before. And I thought quite often, you know, I'm waiting for the kettle to boil or something, I'll do that? **(P-120)**

				Exercises are tolerable "I think the exercise program is good, in the fact that, it enables you to loosen your fingers during the exercises, whereas they were stiff before. [..] I found after the fourth week it became a lot easier. I think the program is a good program" **(P-122)** "I knew that it *(exercise)* was essential to do it in order to benefit from the exercises. At first, I found it difficult because it was painful, and[..] awkward to do. As the weeks went by, I realized that it became easier…". **(P-122)** ".. *(making O sign exercise)* because it's the thumb, a times was painful to get to the small finger but that was all. I mean, I could work through that." **(P-118) -**male (tolerable) " I think for the first two weeks are a lot easier than the last two, because all the sets and the number of times we did things went up. But actually, that was good. So, although I didn't like it, I don't think you can cut it out." **(P-129)** **"…**doing this (making a fist), I felt I wasn't getting better, it felt a bit weird trying to do this bit, but now I can do it without difficulty" **(P-119)**
	Exercises are beneficial	9	25	"I found the exercise easy to do, [..]I found that my thumbs and my wrist have been pain-free without using splints []. I mean that's a definitely a positive for me because normally I'm wearing the splints most day because of the pain but I found, it's been really good" **(P-119)** **"**I'm impressed actually, because I didn't think I was gonna notice too much difference, but my hands are definitely much stronger, and my wrists haven't been aching anywhere near as much as they used to" **(P-115)**

				“I think they were good exercises. You know, we don't perform life at 1 speed, everything is at different speeds and I think you covered that nicely with weekly exercises because that made the muscles work in a variety of different ways. You know from a physio point, that's really functional**” (P-115)** **“…**I actually enjoyed it *(exercises).* To be honest, that's a really weird thing for me. I like the result that my hand is much less swollen now**” (P-115)** “I think[..]it was really good because it gave you something positive to try and help yourself. And I definitely do think that doing exercises has helped. I've got a lot more. I can grip things; I can pick things up better than I did before” **(P-116)** “… I could see that it was beneficial, that each time I did it, I've got a little bit more range of movement. **(P-116)** “…I think it's been really good[..]and I've been really pleased you know. To think that by doing this, I might be helping other people in the future. I would do it again. [..]I've been really happy to do it”. **(P-116)** **“…**I could feel the strength with the balls moving on. And doing this (making a fist), I felt I wasn't getting better, it felt a bit weird trying to do this bit, but now I can do it without difficulty” **(P-119)** **“**… I've obviously benefited from it *(exercises).* So no, All praise for it*(exercises).* I should definitely do it but not as a counting. [..]When I'm waiting for the kettle to boil, I shall do some exercises, that I feel helped me”. **(P-120)**

				“My hand has become for the first time flexible. Whereas I used to find it was stiff and painful. Now I find that, [..]the palm of my hand doesn't hurt. [..]and my fingers moved a lot more freely. When I'm preparing meals or doing things in the kitchen, it's a lot easier than it was” **(P-122)** **““…**I felt they *(exercises)* were very good, you know, by the end, my hands feel more mobilised” **(P-125)** **“**My observation from the very start was that my fingertips started to feel a bit numb. But I was interested, and I wondered if the blood supply was sort of, you know, basically being enhanced because of unblocking hands that I was holding. And so[..]I noticed from the start to now, this sort of development of different sensations in my hands” **(P-125)** “…by the end, I feel I can[..]clench my fists really quite hard. And it feels good. It feels strong []. The way the exercises progress has trained my mind to understand the way my hands can work []. It’s a nice way of educating us into the potential of our hands because joint pain in the hands makes you stop using them a bit. And so, it's a good way of retraining your brain to go, ***No! I am dexterous and I can do things!*** Here are the things that helped me”. **(P-125)** “I found them *(exercises)* useful, some more novel than others. I found[..]the one where you curl your fingers down and then make a fist. I found that very useful and really improved in that one from the beginning to the end”. **(P-127)** “And the last one where you press your finger onto the table for 30 seconds, I found that one very useful as well”. **(P-127)-dislike for other** “I know before I was having trouble with actually holding a sewing needle, because it was hard, but I can do that a little bit better” **(P-129)**

				"I have really lost a lot of movement in my left hand. Actually, I've got it back, but I still can't put those fingers all the way back *(discussing exercise-2).* Whereas I can on my right hand, but they are an awful lot better than they were" **(P-129)** "mine *(osteoarthritis)* is often worse over the wintertime. [..]I've had greater benefit now because normally in the wintertime, I'm really suffering,[..]visiting casualty, going to the hand clinic because my left hand was particularly bad. I don't know whether it was because of your exercises but my hands have been a lot better recently" **(P-129)** "It's *(exercises)* made a big difference to my life. [..]You know those round cabbages? I used to have terrible trouble holding them while I did the first cut. If it was starting, it was fine. If I did the first cut, it was just awful. And I had one the other day and I literally just picked it up, cut it and I probably having done that in two years" **(P-129)** "You know, it had made some little differences, but it's also made some big differences. And that to me, that was brilliant. You know like just pumping up my car tyres, I was having trouble getting the pump fitted into the wheel but now, that's easier. I wouldn't say ever so easy but it's easier". **(P-129)** "…. Blowing up my bike tyres, trying to get all those fiddly things together. Again, it's not perfect but it's a lot easier than it was. It wasn't a squeeze and turn but it was a turn, and I use to be swearing and now I can just get that done" **(P-129)** **Potential benefits for chronic OA** I would say that the exercise of the hands is probably going to be very helpful. But I do not feel that possibly for me, it was a little bit too late.[..]I mean, I feel that had I had something like this, maybe five or 10 years ago, it could well have been very beneficial. But I feel that they've *(hand*

				OA) progressed to such a state that it's not much. Although I will continue to exercise my hands, because I think it's important. I will continue to do that. **(P-112)** "But I think if you had somebody with no complete stiffness, it would be more helpful than somebody who[..]have already got the deformity so it's too late to do anything with that now. I just wish, I'd had it when my hands weren't in such a bad state" **(P-120)** "But it *(ironing out exercises)* was painful when I first did it. I thought, Oh, wow. Because, when you've got a stiff joint, and you force it, there's no movement in there at all. Whereas if it had been earlier, because when this was all happening, I didn't realise that it was stiffening up,[..]So if I'd had this programme right at the beginning, then that would have made more sense" " **(P-120)** **(profound statement)** "…I as a physio I knew what was happening to my hands but couldn't prevent it is the same. [..]I've had two replacement hips, and that just got stiffer and stiffer. And I exercise them every single day to try and prevent it and the arthritis still won and it was the same with the hands. I was very aware that they were getting stiff. And I did do putting them flat on the table. And I did do making fist and the Arthritis still won. So, I just think people shouldn't be too downhearted when the Arthritis does win because it does. It's a nasty thing. It wins!." **(P-120)**
Less desirable views	Ironing out exercise are not helpful	1	1	"oh! the other thing, I didn't like the pressing down." **(P-120)**
	Exercises were boring	2	3	"My first thought was it was very boring []. You know sitting there and doing: 1, 2, 3, 4...[] I was just thinking if you had a class full of people, you could, you know, jolly it up a bit and even sing along" **(P-120)**

				"… it was just about the right length of time. [..]what I found as I progressed, and I had to move to doing 10 and eights and six repeats, it took a little bit longer. That was okay, but I think you don't want to go any further than that. That's not because of the pain or anything like that. But because it gets boring. **(P-112)** "…only the repetition of the squeezing, having to count, I found that boring". **P-120)**
	Exercise repetitions too much	1	1	" …I think if I did nothing else at all, I might not have had the pain, but[..]I'm not just sitting doing nothing all day, my hands are being used constantly and so to add 120 squeezes on the top of that, it's just too much. It's probably too much even if I were doing nothing anyway. But otherwise, I thought it was fine. (**P-120)**
OA	**Easy and convenient**	7	10	**Easy (Simple)** "The exercises were straightforward, and I even sat there and watched TV doing it" **(P-115)** "it's *(exercises)* quite easy to do, and I could feel the strength with the balls moving on. And doing this (making a fist), I felt I wasn't getting better but it felt a bit weird trying to do this bit, but now I can do it without difficulty". **(P-119)** "..I like the fact that it's very easy to do,[..]and that's very convenient. It's not as though you have to get dressed up, [..]wear your leggings and make that". **(P-127)** "I found the exercise easy to do, [..]I found that my thumbs and my wrist have been pain-free without using splints []. I mean that's a definitely a positive for me because normally I'm wearing the splints most day because of the pain but I found, it's been really good" **(P-119)** .."it's very well structured. And I found it easy", **(P-112)**

				“*That (rapid-force exercises*) was quite easy to do? No problem. No, its fine” **(P-118)** **convenient** “…so, when you are a bit tight on time, you could just fit them in into different parts of your life []. When I was waiting for the kettle to boil, I did a few squeezes []. I slotted them through the day, but I still got the all done” **(P-115)** “they *(exercises)* were simple and straight forward and easy to perform and as I said you could do them anywhere” **(P-115)** “You can do it *(exercises)* at any time. It's really convenient. It’s really, really easy to fit in.” **(P-127)** ” I think for the first two weeks are a lot easier for the last two, because all the sets and the number of times we did things went up. But actually, that was good. So, although I didn't like it, I don't think you can cut it out.” **(P-129)**
Exercise presentation	**Appropriate and well structured**	6	14	**Appropriate content** “The exercises were suitable with the increasing events of frequency, to enable me to strengthen and to get through that initial time when my hands were hurting, because I was doing unfamiliar exercise.” **(P-125)** “And then, [..]they were holistic, the whole hands with the ball. I thought that was a really nice way of mobilising.” **(P-125)** “… it was just about the right length of time. [..]what I found as I progressed, and I had to move to doing 10 and eights and six repeats, it took a little bit longer. That was okay, but I think you don't want to go any

				further than that. That's not because of the pain or anything like that. But because it gets boring. **(P-112)** “I think you covered the fine aspect and you covered the power and you covered the speed as well” **(P-115)** “But the actual programme itself, I thought was excellent” **(P-112)** “I think the first two weeks are a lot easier than the last two, because all the sets and the number of times we did things went up. But actually, that was good.” **(P-129)** **“**the program is adequate, provided you continue to do the exercises as it states. [..]I found after the fourth week it became a lot easier. I think the program is a good program” **(P-122)** “I don’t think so *(change anything about programme) b*ut certainly, you know, three times a week seem to be ideal.” **(P-118)** **Structured programme** “It (exercises) was very well structured. And it was just about the right length of time. [..]It's very well structured. And I, I found it easy” **(P-112)** “I think you covered the fine aspect and you covered the power and you covered the speed as well” **(P-115)** **“**I think they were good exercises. You know, we don't perform life at 1 speed, everything is at different speeds and I think you covered that nicely with weekly exercises because that made the muscles work in a variety of different ways. You know from a physio point, that's really functional**” (P-115)**

				Paraphrased -Participants mentioned that the structured nature of the exercise enabled his exercise adherence **(P-118)** **Thoroughly developed exercises** “I saw it was well thought through and yes my hands are definitely become stronger as a result of it so I'm very happy with that” **(P-115)** “I think you covered the fine aspect and you covered the power and you covered the speed as well” **(P-115)**
	Good instructions and researcher support	6	11	**Good instructions** “I just think it was very well presented; it was easy to follow. The instructions were easy to follow. And I think that, you know, it's just about right. You don't want to go any further.” **(P-112)** “I didn't find it (exercise instructions) a problem, although I had to revert back to[..]have a look to see how many[..]repetitions I was supposed to be doing. I suppose, if anything, you could have made that a little bit clearer, but I personally didn't find it a problem” **(P-116)** “I thought the book was helpful. And I did refer to that, especially in the beginning, when I was still sort of it wasn't coming” **(P-120)** “And it's (exercise instructions) written out OK” **(P-122)** “..I think the explanations, the paper based explanations, the personal conversation really helps and I felt very encouraged. Then the actual exercises and how I was encountering them, and what they were. I felt were very good, you know, by the end, my hands feel more mobilised.” **(P-125)** “…the actual setup of the booklet and the patient information leaflets. And going through it all with you. And I always read the instructions for

				each exercise before I did it, even though I'd only done it two days before. I thought the booklet and the information stuff was excellent". **(P-129)** "…I think it was very well presented; it was very clear what I had to do. The information in the little booklet was very clear" **(P-112)**
				Good researcher support "The follow up messages do help because. Again, it focuses your mind back on it (exercises) and if you've forgotten to do it for a few days, hit just gives you that jolt, that I better catch up and start doing it again[]. I thought it all went very well. **(P-118)** "I wonder whether a visual check of a week would be a good idea. Okay. I know from past experience, that you teach somebody an exercise and you think you've done it properly; you think they understand it? And when they come back the following week, they're doing something completely different. Yeah. Which isn't what you said at all". **(P-120)** "The encouragement that you give was good" **(P-129)** "So, I think the first thing is that the setup [], your support and explanations were very useful. I found that[..]you'd anticipated the potential difficulties very well. And you'd manage those by the regular check ins and following up that rehearsal that we did together[..]you were very good at gently prodding me." **(P-125)** "I think it was good to feel that any problems, I could come to you. And the fact that I had email did help with that" **(P-129)**

F.20 Complete results - acceptability and practicability of Rapid-HOE programme

Major Theme	Sub-theme	Evidence
Acceptability	Satisfaction (suitable for hand OA)	“In fact, some days I did it more than the three times a week, just because [..] I could see that it was beneficial that each time I did it, I've got a little bit more range of movement” **(P-115)** “In fact, I liked it. I found I could even sit and do them when I was watching a television program”. **(P-115)** “I've been very delighted to participate” **(P-125)** “I’m impressed actually because I didn't think I was gonna notice too much difference, but my hands are definitely much stronger, and my wrists haven't been aching anywhere near as much as they used to” **(P-115)** “…I saw it *(exercises)* was well thought through and yes my hands are definitely become stronger as a result of it so I'm very happy with that” **(P-115)** “…I actually thought four exercises wasn't gonna be enough, but my hands ached at the end of it. I was surprised actually, and the ache lasted overnight on the first couple of sessions and then that settled down”. ” **(P-115)** “it's much easier to be negative about something than the other way around. But no, I've obviously benefited from it. So no, all praise for it” **(P-120)** “And the last week of doing the exercises, I progressed myself onto the blue ball and I didn't have any problems with that at all” **(P-115)**
	perceived appropriateness	“…I feel that if I had something like this, maybe five or 10 years ago, it could well have been very beneficial” **(P-112) - appropriate for early to moderate hand OA** “..it was very well structured. And it was just about the right length of time” **(P-112)**

		“I just think it was very well presented, it was easy to follow[..]and I think that, you know, it's just about right. You don't want to go any further” **(P-112)** “you know, three times a week seem to be ideal” **(P-118)** “I did not really have a like or dislike it was. It was a necessary thing to do, right, in order to improve my hands.” **(P-122)** “because it really doesn't take that long to do the whole set of exercises” **(P-112)**
	intent to continue use	“…I will continue to exercise my hands because I think it's important. I will continue to do that”. **(P-112)** “Yes, I would do it again. Now you know, I've been really happy to do it.” **(P-115)** “I should definitely do it but not as a counting []. When I'm waiting for the kettle to boil, I shall do some exercises[..]or if I'm waiting at the bus stop or getting on the bus, or train...” **(P-120)** “As long as you're not going to ask me for those eggs back, I should carry on doing the exercises, because it certainly has improved my pain” **(P-115)**
Practicability	Positive effects on target participants	**4. Pain reduction** “I think the exercise program is good, in the fact that, it enables you to loosen your fingers during the exercises, whereas they were stiff before. And you found that as you carried on during the exercises, your ability was better, instead of hurting so much, it didn't hurt so much.” **(P-122)** “…my hands are definitely much stronger, and my wrists haven't been aching anywhere near as much as they used to” **(P-115)** “I think the exercise program is good, [..]it enables you to loosen your fingers during the exercises, whereas they were stiff before. And you found that as you carried on during

		the exercises, your ability was better, instead of hurting so much, it didn't hurt so much" **(P-122)** "As long as you're not going to ask me for those eggs back, I should carry on doing the exercises, because it certainly has improved my pain" " **(P-115)** **5. handgrip strength improvement** "…my hands are definitely much stronger, and my wrists haven't been aching anywhere near as much as they used to" **(P-115)** **"…**I could feel the strength with the balls moving on." **(P-119)** "…by the end, I feel I can[..]clench my fists really quite hard. And it feels good. It feels strong…**(P-125)** **Improved functional task performance** "…I definitely do think that doing exercises has helped. I've got a lot more. I can grip things, I can pick things up better than I did before" **(P-116)** ""…. blowing up my bike tyres, trying to get all those fiddly things together. [..]it's not perfect but it's a lot easier than it was." **(P-129)"** "My hand has become for the first time, flexible whereas I used to find it was stiff and painful. Now I find that, [..]the palm of my hand doesn't hurt.[..]and my fingers moved a lot more freely. When I'm preparing meals or doing things in the kitchen, it's a lot easier than it was" **(P-122)** **6. Improved hand joint flexibility and ROM** "And doing this (making a fist), I felt I wasn't getting better, [..]but now I can do it without difficulty" **(P-119)**

		"… I thought that *(making a fist)* was very good that I've never done that before.[..]the fingers wont all the way down because I've got stiffness but certainly slightly and that doesn't hurt" **(P-119)** "I think the exercise program is good,[..]it enables you to loosen your fingers during the exercises, whereas they were stiff before." **(P-122)** "….I felt very encouraged, then the actual exercises and how I was encountering them, and what they were, I felt were very good, you know, by the end, my hands feel more mobilised". **(P-125)** "My hand has become for the first time, flexible whereas I used to find it was stiff and painful. Now I find that,[..]the palm of my hand doesn't hurt.[..]and my fingers moved a lot more freely. When I'm preparing meals or doing things in the kitchen, it's a lot easier than it was" **(P-122)** **7. Improved fine motor skills** "I know before I was having trouble with actually holding a sewing needle, because it was hard, but I can do that a little bit better" **(P-129)** **8. Improved positive self-image (self-efficacy)/ changed beliefs on OA** "….I felt very encouraged, then the actual exercises and how I was encountering them, and what they were, I felt were very good, you know, by the end, my hands feel more mobilised". **(P-125)** "…The way the exercises progress has trained my mind to understand the way my hands can work []. It's a nice way of educating us into the potential of our hands because joint pain in the hands makes you stop using them a bit. And so, it's a good way of retraining your brain to go, ***No! I am dexterous and I can do things!*** Here are the things that helped me". **(P-125)** "I think it was really good because it gave you something positive to try and help yourself. And I definitely do think that doing exercises has helped." **(P-116)**

		"… when you make time for yourself, it repays you, and because of my life at the moment, that is a bit of a blur[..] So actually, [..] it's been the only times I spend time just for myself. And that's been a habit that I've had to read try to make a constant" **(P-125)**
	Negative effects on target participants	**1. Muscle spasm** "…mainly the last two weeks with using the ball, sometimes my hand would go into a spasm and I would just have to give it a rest then and go back to it later. But apart from that no I didn't have any problems at all". **(P-116)** **2. Challenges with MCP and IP extension** "once I've done the exercises *(isometric handgrip exercises),* I found that I had difficulty actually opening my hand". **(P-122).** **NB**: However, this patient reported of having a claw hand ("I'm still slightly concerned that my left hand still resembles sort of a claw. Whereas my right hand will stay flat. But I don't know if there's any way of improving that") **3. Sore fingers** "…exercises 3a and b where I found to begin with my finger got really sore because, I squeezed [ ] but that wasn't a problem" **(P-129).**
	ability of participants to carry out rapid-HOE programme	"*That (rapid-force exercises*) was quite easy to do? No problem. No, its fine" **(P-118)** "I think[..]I do it the same way because it worked, and I managed to achieve doing all the exercises as a result of it" **(P-115)**

F.21 Complete results – Participant reported adherence to Rapid-HOE programme

Adherence	Accommodating exercise into daily life	"Well, the foundation of this, of course, is that you can sort of do it while you're watching television or something like that, which is tended to be when I did it." **(P-118)** "…at the beginning of each exercise day, [..] I made sure I sort of went through my day [..] I'll do them just before I have my cup of tea or something. **(P-120)** "I think being able to do at different times during the day helped." **(P-122)**
	Making personal effort and adjustment	"…I think that if you're doing them say, between 11 and 12, every day. Like my brother knew, that's when I was going to be doing them *(exercises)* and not to disturb me. [..] You could tell friends or family, don't ring me or contact me between 11 and 12 because that's what I've done to set time aside for my exercises. "… when you make time for yourself, it repays you, and because of my life at the moment, that is a bit of a blur[..] So actually, [..] it's been the only times I spend time just for myself" **(P-125)** "…at the beginning of each exercise day, [..] I made sure I sort of went through my day [..] I'll do them just before I have my cup of tea or something. **(P-120)**
	Developing a routine	"… I just, [..] picked a time of the day that suited me, usually early in the evening and I just worked right through the whole of the exercises [..] without stopping" **(P-116)** "….my advice would be to, because it really doesn't take that long to do the whole set of exercises to just pick a time, [] just say, right, I've got a window here, I'm gonna sit and do my exercises **(P-116)** "And will probably doing it in the evening. I haven't got to worry about all the other things that I normally do in the day." **(P-116)**

		"…obviously everybody's had a lot more time because COVID that were in lockdown. [..] I think to pick a time of the day when everything else that you had on your list to do is done and out the way. Because there's no pressure on you, then to sit and do them. **(P-116)** "So, had to do various other exercises during my lifetime and I know that they do help, so [..], I managed to find time to do it". **(P-129)** "I tried to set myself a specific time of day to do it. Okay. So that I didn't suddenly think past six in the evening. Oh, I've got my sizes**" (P-129)**
	Motivation	"it's been interesting and of course, the fact that we were aiming to get to today, that that was the discipline that make sure you do it every time" **(P-118)** "… to know that there was going to be an end of session assessments, that kept me going". **(P-120)** "… to know that there was going to be an end of session assessments, that kept me going". If it was just do this for six weeks, and then nothing happens. [..] it would be so much easier to give up. **(P-120)**
	weekly follow up	"I found it helpful that you did an email every week, just to remind me and I could feel it was easy to communicate with you to say, if I was having any problems or not [..] that kept me going". **(P-120)**
	Support (Researcher support/ family)	"I think it was good to feel that any problems, I could come to you, and the fact that I had email did help with that" **(P-129)**
	Previous exercise knowledge and experience	"So, had to do various other exercises during my lifetime and I know that they do help, so [..] I guess I have found it easier than a lot of people would have. **(P-129)**

F.22 Complete results - Suggestions for modification of Rapid-HOE programme

No change	No change (6)	“I think[..]I do it the same way because it worked, and I managed to achieve doing all the exercises as a result of it” **(P-115)** “I don’t think so *(change anything about programme) b*ut certainly, you know, three times a week seem to be ideal.” **(P-118)** “Would I do anything differently? No, I don't think so. When I started, I tried to make a definite time to do it. **(P-120)** “…the program is adequate, provided you continue to do the exercises as it states? it shouldn't need to change it” **(P-122)** “…I think I’ll do the same thing again because the first couple of weeks, I did all the exercises together. No, I think the way you're doing it is fine” **(P-122)** “I don't think so. I don't think so” **(P-125)**
Modification for exercise content	Maintain exercise duration	“… it was just about the right length of time. [..]what I found as I progressed, and I had to move to doing 10 and eights and six repeats, it took a little bit longer. That was okay, but I think you don't want to go any further than that. That's not because of the pain or anything like that. But because it gets boring. **(P-112)**
	Increase exercise duration and frequency	**Adapt exercises to meet patient needs** “doing it three times a week,[..]do that, then you can do it more often if you want to “You can adapt it.[..]I suppose some people, the most severe would still stay at three times, but you could actually improve it and maybe add another day, four days a week” **(P-125)** **Increase duration from 6 to 8 weeks** “…maybe 8 weeks rather than 6 weeks because I think a lot of people may find the first couple of weeks difficult or they can't get into the routine. So then maybe

		weeks 3, 4, 5 and 6 they begin to do the routine and then by week 7 and 8, they are into it, and that may encourage them[..]to continue it afterwards" **(P-127)** "…I think in a way, I might have been better if I done the exercises every day but in reality, I don't think my hands could have tolerated. I did think that when I did them on the Friday and then again, on the Monday, I'd almost lost something". **(P-129)** "….I think that might be good to have a minimum.[..]I think would be once a day. I think you don't want people doing it more than once today. They could run into problems". **(P-129)**
Modification for exercise presentation	Additions for exercise instructions	**4. Describe exercise frequency clearer** "I didn't find it (exercise instructions) a problem, although I had to revert back to[..]have a look to see how many[..]repetitions I was supposed to be doing. I suppose, if anything, you could have made that a little bit clearer **(P-116)** **5. Include a statement that both hands can be exercised together** "…and perhaps, if you're happy with that, a mention could be made that you can do both hands together, especially for the squeezing" **(P-120)**. **6. Include statement on caution of hyperextension of fingers** "Pressing the hand flat *(ironing out exercises),* I think that needs to come with a warning" **(P-120)**. Participant advised that fingers could hyperextend when excessively moved, which can be detrimental to the hand"
	Include exercise videos	3. "if you had the video with somebody actually taking the class, making jokes and doing some encouragement that I could put on there. And I could do it with you. And that would, you know, liven it up a bit". **(P-120)**.

		4. "Only the repetition of the squeezing, having to count, I found that boring. Whereas if you somebody had been leading it (in a video), then I could have just[..]concentrated on the squeezing and not on the counting. Person on the screen would say right, would do five more or something like that. That would have been more enjoyable than just doing". **(P-120)**. Participant advised on three video sessions a. First - to interact, pre and teach programme b. 2nd - to check on quality of exercise performance, repetition, and adherence to programme content c. 3rd – post training assessment. 5. "people don't read booklets, everything's done on YouTube these days [..]I wonder whether[..]you could expand your capacity by having a video to help people and maybe conversations" **(P-125)**.
	Additions for exercise booklet	**Include descriptor for CMC joint in hand diagram** "I thought the book was helpful and I did refer to that, especially in the beginning, []. But there was one slight disappointment. There's was a picture of a hand with what you were calling all joints[..]but there was nothing for the base of thumb and I'm sure, I'm not the only one who gets pain down there" " **(P-120)**. **Include statements to encourage and boost patient confidence** "…put something in *(exercise booklet)* that encourages people. So, it *(exercise booklet*) just describes the features of osteoarthritis, it doesn't necessarily talk about in the programme, about what[..]may happen with people as they develop it *(osteoarthritis).* I wonder whether that's where you say, you know, we've observed that for many people, pain can result in people stopping doing things, the exercise programme is sort of trying to open out what might have closed down and words to that effect " Participant quoted this example ("some people will live with it, and they

		won't let it constrain them, other people quite quickly respond to pain or to disfigurement, and stop doing things"). " **(P-125)**. Include participant expectation and goal setting" **(P-125)**.
Modification for exercise delivery	Once weekly visual check	"I wonder whether a visual check after a week would be a good idea because I know from past experience, that you teach somebody an exercise and you think you've done it properly; you think they understand it? And when they come back the following week, they're doing something completely different which isn't what you said at all and may be causing harm" **(P-120)**.
	Group exercise sessions	"My first thought was it was very boring [..]. If you had a class full of people, you could, you know, jolly it up a bit and even sing along"

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