UNIVERSITY OF SOUTHAMPTON

FACULTY OF ENVIRONMENTAL AND LIFE SCIENCES

HEALTH SCIENCES

IMPACT OF TRAINING ON MALAYSIAN RESPIRATORY PHYSIOTHERAPISTS' ABILITY IN DETECTING VELCRO CRACKLES FROM PRE-RECORDED LUNG SOUNDS

by

NOR AZURA AZMI

Thesis for the degree of Doctor of Philosophy

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ABSTRACT

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IMPACT OF TRAINING ON MALAYSIAN RESPIRATORY PHYSIOTHERAPISTS' ABILITY IN DETECTING VELCRO CRACKLES FROM PRE-RECORDED LUNG SOUNDS

Nor Azura Azmi

Incidence of idiopathic pulmonary disease (IPF) is increasing worldwide and currently there is no curative therapy for IPF. Velcro crackles are associated with IPF and could be detected during auscultation. There is a need to train healthcare professionals to detect Velcro crackles during auscultation to help with earlier diagnosis of IPF in clinical settings. There is a paucity regarding the impact of training on healthcare professionals' ability in detecting Velcro crackles from patients with IPF, particularly amongst Malaysian respiratory physiotherapists.

The purpose of this research is to explore the impact of training on Malaysian respiratory physiotherapists in detecting Velcro crackles from pre-recorded lung sounds of patients with IPF. To this end, the research was conducted over two studies. The first study used a test-retest design to explore the impact of training on the intra and inter-observer reliability of respiratory physiotherapists ability to identify Velcro crackles from pre-recorded lung sounds. Twelve participants were randomly assigned into two groups and assessed on two separate occasions. The findings suggested that intra-observer reliability for the trained Group A indicated substantial to perfect agreement (k=0.67-1), in contrast fair to moderate agreement found for the untrained Group B (k=0.29-0.54) during Assessment 1. However, intra-observer reliability for Group B improved, from moderate to perfect agreement (k=0.50-0.90) after the training session during Assessment 2. Inter-observer reliability score for the trained Group A reflects moderate agreement (k=0.59), whereas the untrained Group B represents slight agreement (k=0.19) during Assessment 1. Nonetheless, inter-observer reliability for Group B improved to moderate agreement (k=0.59) at Assessment 2 after receiving the training session. However, this first study has several limitations. Therefore, the second study was conducted after further improvements and development on its design to counter those limitations.

In the second study, a longitudinal mixed methods design was used to achieve the study aim, via the following objectives: 1) to evaluate the impact of training on reliability, accuracy, sensitivity and specificity of Malaysian respiratory physiotherapists in detecting Velcro crackles over time; 2) to explore participants' experiences of Velcro crackles at the baseline and after the training session; 3) to explore participants' perceptions of the training sessions; and 4) to explore participants' experiences of skill retention and skill transfer in clinical practice. This study suggested that the training has significantly improved in inter-observer reliability, accuracy and sensitivity of participants in detecting Velcro crackles from the pre-training to the post-training assessments (k improved from 0.20 to 0.56 indicates poor to moderate agreement, $p < 0.001$; accuracy increased from 58% to 87%, $p < 0.001$; sensitivity increased from 43% to 85%, $p < 0.001$ respectively). However, the reliability, accuracy and sensitivity significantly declined from the post-training to the two-month follow-up assessments (k reduced to 0.50 indicates moderate agreement, $p < 0.05$; accuracy decreased to 83%, $p < 0.05$; sensitivity decreased to 80%, $p < 0.05$). There were significant negative correlations between days of leave with accuracy and sensitivity at two-month follow-up assessment (rs = -0.85 & -0.84 respectively, $p < 0.05$). Specificity remained constant over time, $p > 0.05$.

The qualitative findings corroborated with these findings suggest that there were: 1) perceived benefits of the training session; 2) comprehension towards the training; and 3) recognition of Velcro crackles immediately after the training. However, at the two-month follow-up interview session, qualitative findings suggest that there were: 1) decline in skill retention; 2) time constraint to practise the newly acquired skill in clinical practice; 3) skill transfer was achieved by some participants; and 4) acknowledgement of the importance of the skill in clinical practice. In addition, qualitative findings suggest that there should be a continuous learning programme through online and interactive training workshop, which should be delivered earlier to healthcare professionals and undergraduate students.

Therefore, this thesis suggests the need for implementing the training of Velcro crackles detection in clinical practice to train health care professionals in

detecting Velcro crackles, thus promoting earlier diagnosis of IPF in clinical settings.

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DECLARATION OF AUTHORSHIP

I, Nor Azura Azmi, declare that this thesis entitled

'Impact of training on Malaysian respiratory physiotherapists' ability in detecting Velcro crackles from pre-recorded lung sounds'

and the work presented in this thesis are my own and have been generated by me as the result of my own original research. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University;
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
- Where I have consulted the published work of others, this is always clearly attributed;
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
- I have acknowledged all main sources of help;
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
- None of this work has been published before submission.

Signed:

Date: 28th October 2021

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Definitions and abbreviations

Velcro crackles	Derived from the two French words velours (velvet) and crochet (hook), which are similar to the sound generated by ripping apart mated strips of Velcro (DeRemee 1969)
Idiopathic pulmonary fibrosis	A specific form of chronic, progressive fibrosing interstitial pneumonia of unknown aetiology and limited to the lungs, (Raghu et al. 2011).
Respiratory physiotherapist	Physiotherapist who is dealing with patients who have respiratory condition

IPF – Idiopathic pulmonary disease

ATS - American Thoracic Society

ERS - European Respiratory Society

HRCT - High-resolution computed tomography

WHO - World Health Organization

CALSA - Computer aided lung sound analysis

ms – Milliseconds

SD – Standard deviation

SE – Standard error

k – Kappa

M-mean

Mdn-median

Chapter 1: Introduction

1.1 Introduction and background

Idiopathic pulmonary fibrosis (IPF) is a progressive lung disease with a poor prognosis that affects general wellbeing (Raghu et al. 2011). It is believed that sounds produced within the lungs may provide useful information to help clinicians identify specific diseases (Vyshedskiy et al. 2005; Flietstra et al. 2011; Bohadana et al. 2014). Clinicians have noted the presence of abnormal lung sounds in IPF and reported the presence of 'Velcro-type' or fibrotic crackles as being a characteristic of the disease (ATS 2000; Dempsey 2006; Cottin and Cordier 2012).

These sounds can be heard using a standard stethoscope, but have yet to be quantified. It has been suggested that using the acoustic characteristics of these lung sounds might be a cost-effective way to diagnose IPF earlier, thus helping in optimising therapy and improving prognosis (Flietstra et al. 2011; Cottin and Cordier 2012). However, very little is known about Velcro crackles recorded in IPF patients under clinical conditions.

Since the incidence of IPF is increasing worldwide (Nalysnyk et al. 2012) and currently there is no curative therapy for this disease ((Raghu et al. 2011), healthcare professionals should be taught and trained to recognise these Velcro crackle sounds during pulmonary auscultation of patients with respiratory conditions (Cottin and Cordier 2012; Cordier and Cottin 2013). The suspicion of a patient having IPF should be raised if they detected the presence of Velcro crackles during auscultation (Cottin and Richeldi 2014). This should lead to an earlier referral to a pulmonologist for diagnosis and therapy (Cottin and Richeldi 2014). Healthcare professionals whom have been trained in Velcro crackles detection could easily monitor the progression of IPF disease in their patients via pulmonary auscultation. Hence, appropriate clinical decisions of disease management could be offered to promote better long-term outcome for patients with IPF.

To the researcher's knowledge, no other studies have investigated the impact of training among healthcare professionals including respiratory physiotherapists in detecting Velcro crackles from patients with IPF. Therefore, this research sets out to investigate the impact of training on Malaysian respiratory physiotherapists' ability to detect Velcro crackles from pre-recorded lung sounds of patients with IPF. To this end, the research was conducted over two studies.

The first study was a preliminary study which explored the impact of training on the reliability of respiratory physiotherapists' ability to identify Velcro crackles from pre-recorded audio files of patients with IPF. This preliminary study was conducted to address the following research questions:

i. Are the same physiotherapists reliable in detecting Velcro crackles in Group A (trained) and B (untrained)?

ii. Are the same physiotherapists reliable in detecting Velcro crackles in Group B, before and after the training sessions?

iii. Are different physiotherapists reliable in detecting Velcro crackles in Group A (trained) and B (untrained)?

ii. Are different physiotherapists reliable in detecting Velcro crackles in Group B, before and after the training sessions?

A test-retest design was used in this preliminary study to evaluate intra and inter-observer reliability of Velcro crackles interpretation when listening to pre-recorded lung sounds files. Twelve participants were randomly assigned into two groups. Then, they were assessed on two separate occasions, with one-week interval between assessment one and two. The level of agreement of intra and inter-observer reliability were calculated for both groups. However, the first study has several limitations. Therefore, a second study was conducted after further improvements and development on its design to encounter those limitations.

The second study which involved a longitudinal mixed methods research design was conducted to address the following research questions:

Research questions for primary quantitative component:

i. Are Malaysian respiratory physiotherapists more reliable in detecting Velcro crackles in the short term following a training session?

ii. Are Malaysian respiratory physiotherapists more reliable in detecting Velcro crackles in the long term following a training session?

iii. Are Malaysian respiratory physiotherapists more accurate, sensitive, and specific in detecting Velcro crackles in the short term following a training session?

iv. Are Malaysian respiratory physiotherapists more accurate, sensitive, and specific in detecting Velcro crackles in the long term following a training session?

Research questions for secondary qualitative component:

i. What are Malaysian respiratory physiotherapists' experiences of detecting Velcro crackles at baseline and after the training?

ii. What are Malaysian respiratory physiotherapists' perceptions towards the training for Velcro crackles detection?

iii. What are Malaysian respiratory physiotherapists' experiences of skill retention and skill transfer in clinical practice at two months follow-up?

In this longitudinal study, 31 participants were assessed at the three occasions which were at the baseline, immediately after the training session and at the two-month follow-up. The quantitative component of this study explored the impact of training on Malaysian respiratory physiotherapists' ability to detect Velcro crackles over time. Meanwhile, the qualitative component using face-to-face semi-structured interview were conducted to explore participants' experiences regarding Velcro crackles detection and perceptions towards the training session. In addition, participants' experiences of skill retention and skill transfer were also explored at the two-month follow-up interview.

1.2 Researcher's perspective on the current study

This study emerges from my professional background as a physiotherapist educator. After graduating my bachelor's degree of physiotherapy from the Universiti Kebangsaan Malaysia in 2007, I worked as a physiotherapist for almost six months and then, I decided to purse my career in academia. I was employed as a physiotherapist educator in one of the public universities in Malaysia in 2008. Since then, I gained experience as an educator through teaching the undergraduate students on the physiotherapy programme before pursuing my PhD study in 2013. As a physiotherapist educator, I am mainly involved in teaching cardiorespiratory physiotherapy courses for second and third year of undergraduate students and also supervise them during clinical placements in cardiorespiratory physiotherapy in their final fourth year of study.

Whilst supervising them, it became apparent that students were having difficulty to apply and integrate their skills and knowledge that they have learned previously during the earlier year of study in the classroom. This concern was reinforced when I observed that the majority of them appeared to have lost certain physiotherapy skills over time when they were treating patients during clinical placements. I realised that there is gap between theory and practice in physiotherapy curriculums and a major revision was needed so that the clinical placements occur earlier during the second year, and continually until the end of the programme. This would promote early learning transfer from classroom into clinical settings, thus help to bridge the gap between theory and clinical practice.

As a physiotherapist educator I realise that it is very important for undergraduates to be able to integrate theoretical knowledge, skills and behaviour into clinical practice and be equipped with clinical competencies especially in their final year. Hence, they will be qualified to be proficient physiotherapists who will be working with patients in clinical practice. This inspired me to research the ability of physiotherapists in detecting Velcro crackle sounds. This research, therefore, was approached from an intellectual need of the researcher's perspective through the lens of a physiotherapist educator to explore and develop greater understanding of the ability of physiotherapists to distinguish specific lung sounds before and after the training intervention. This study aimed to explore greater understanding of the impact of training on Malaysian respiratory physiotherapists' ability in detecting Velcro crackles from pre-recorded lung sounds and thus, contribute important new information to the literature, which could be used to inform future research and even educational policy and practice in Malaysia in the future.

1.3 Malaysian Context

1.3.1 Demography and culture

Malaysia is known as a multi-ethnic, multi-lingual, multi-religious, and multi-cultural country. The national religion is Islam and the official language of Malaysia is Malay language, yet at the same time English is used in the legal system. Malaysia is considered as an upper middle-income country as its citizens benefit from the accessibility of an excellent health care system, sanitation, education system, programmes to reduce poverty, and modern infrastructure (Jaafar et al. 2012). Malaysia had a total population of 32.6 million of which 29.4 million are Malaysian citizens and 3.2 million non-citizens, in the fourth quarter of 2019 (Department of Statistics Malaysia 2019). The male population outnumbered females which is 16.8 million males compared to 15.8 million females in 2019.

The average of life expectancy in 2019 was estimated up to 74.5 years. The old age population of 65 years and over is 6.7% (3 million) in 2019, and a male and female at the age of 65 years are expected to live another 14.6 years and 17.1 years respectively. Therefore, males aged 65 years are expected to live until the age of 79.8 years and females 82.1 years. According to the National Population and Family Development Board (2020), Malaysia is expected to be an ageing nation by 2035 with 15% of its population will be at least 60 years. The increase of aged population is due to urbanisation (Mafauzy 2000) and excellent health care in Malaysia (Ismail et al. 2017) hence, increased likelihood of individuals surviving into later life.

Of the total Malaysian citizen population, the Malays who are the major ethnic group comprise over 69.3%, followed by ethnic Chinese 22.8%, Indian 6.9% and others 1.0% (Department of Statistics Malaysia 2019). These ethnic groups have their own culture, religious beliefs, traditions and ways of life which create a uniquely diverse character of Malaysia (Mustaffa et al. 2014). Culture does significantly involve in multiple functions and interacts with attitudes, social networks and individual factors to influence quality of life of a person within society (Fu 2007). For example, Malays rank honesty as their primary value, Chinese favour courtesy and Indians rank family as their main priority (Fontaine et al. 2002).

Malaysian culture might be categorised as a high context culture, which means that communication is more implicit and less direct compared to many Western cultures in order to avoid shame to others and maintain harmonious relationships among the society members (Kuang 2009). Malaysian culture is very concerned about respect which becomes the norm especially respect towards authority, seniority or elders (Kuang et al. 2012). Malaysian people will attempt to avoid criticising and insulting others or refusing requests (Kuang 2009).

These cultural beliefs might have an influence on health care practice. For example, physiotherapists have high respect towards other health care professionals and they are closely working together as a team in harmonious atmosphere towards providing a better health care for the patients. Besides, in the eastern cultural context, the Malaysian clinician communication of affiliation style that emphasizes on politeness, warmness and showing love and affection has showed the greatest influence on patient satisfaction (Ismail and Omar 2018). Ismail and Omar (2018) found that there was significant positive correlation between affiliation style and patient satisfaction ($r = 0.649$, $p < 0.001$), they also revealed that affiliation style was the best predictor of patient satisfaction ($B = 0.459$, $p < 0.001$) followed by technical skills ($B = 0.215$, $p = 0.031$). Therefore, clinician communication style towards patients when used effectively can educate, empower and promote patient's compliance towards the treatment which may contribute towards improving their quality of life.

1.3.2 Health care system

The health care of Malaysian Ministry of Health has similarities with the National Health Services in the United Kingdom (UK) in that it provides free health care services at the point of delivery. The Ministry of Health services is a government-funded public sector money of which is generated from the general taxation. The Ministry of Health services comprise public hospitals which include small and large district hospitals, and also government health clinics which have been reported to be within 5.3 kilometer of households in community areas (Institute of Public Health 2008).

Public physiotherapy services are available in all the Ministry of Health hospitals yet, only certain government health clinics offer physiotherapy services in Malaysia. People from low socio-economic backgrounds and government workforce prefer to use the public health services because of free health service or the patient pays only a minimal fee (Norsa'adah et al. 2012). However, these public health services are overwhelmed with a lack of health care professionals, overcrowding, and long patient waiting lists (Rasiah et al. 2010). The shortage of health professionals, especially specialists in the public hospitals is because they prefer to work in private hospitals that offer higher salaries (Hassan et al. 2015).

There is a rapid increase of private hospital services in Malaysia, and these private hospitals offer physiotherapy services for their patients. Besides, the independent practice of private physiotherapy clinics is also growing rapidly. Currently, they are 166 private physiotherapy clinics which are located within community areas in Malaysia (Malaysian Physiotherapy Association 2019). Hence, accessing to health care facilities should not be a problem to the people.

Although the costs of treatment are higher in the private health service including private physiotherapy service, they offer easier access, simpler registration and appointments, shorter waiting times and greater continuity of care with better personal attention (Quek 2009). However, Quek (2009) claimed that the private clinics provide treatment at very reasonable costs. Furthermore, Sohail (2003) reported that Malaysian patients were satisfied with the quality of services from the private hospitals that delivered to them.

Currently, there are a total of 2,326 physiotherapists who are practicing in Malaysia compared to 56,037 physiotherapists in the UK (World Confederation for Physical Therapy 2019). It is estimated that the ratio of physiotherapists to the Malaysian's population is 1:15,000 compared to 1:1250 in the UK (World Confederation for Physical Therapy 2019). This indicates that Malaysia is having physiotherapy workforce constraint to cover the growing number of its population.

In Malaysia, accessing physiotherapy at the Ministry of Health is somewhat different from the National Health Service (NHS) system in the UK. Patients should have a referral from general practitioner (GP) to have physiotherapy at the Ministry of Health (World Confederation for Physical Therapy 2019). In the NHS, patients may need a referral from their GP to have physiotherapy, alternatively the patient may also self-referral directly see an NHS physiotherapist (NHS 2018). This self-referral is particularly suitable for people with simple conditions like joint pain or strains (NHS 2018). On the contrary, there is similarity of accessing physiotherapy at private practices as in both countries, people can self-refer to physiotherapists directly.

There are various fields of physiotherapy services in the clinical settings such as neurology, cardiorespiratory, musculoskeletal, pediatric, women's health, geriatric and others. Physiotherapists is one of health professions that have a close contact with patients or clients because they usually spend 30 minutes to one hour of doing physiotherapy treatment per patient during a visit (Malaysian Physiotherapy Association 2018). The frequency of visit usually depends on severity of the condition which may be one to three times weekly for out-patient cases and daily physiotherapy for in-patient cases. This allow a comprehensive assessment, diagnosis, plan, intervention and re-assessment process to be done towards patients during physiotherapy visit.

In the Malaysian Ministry of Health practices, patients who have respiratory conditions for example, may be referred to respiratory physiotherapists as an out-patient or in-patient by GP or pulmonologists to receive physiotherapy treatment, and this referral depend whether the patients' cases in primary, secondary or tertiary health care settings. On the contrary, people who develop signs and symptoms of respiratory condition may self-refer themselves to private physiotherapy practices. At the same time, physiotherapist may write a referral to GP. The GP may refer to pulmonologists for further medical management if needed. During physiotherapy sessions, if physiotherapists detects any signs or symptoms from the patient such as Velcro crackles that might give an early warning of the presence of IPF, they could discuss this with GP or pulmonologists or write a referral to them for further investigation and medical management. Since physiotherapists are in close contact with the patients it is important to educate and train Malaysian respiratory physiotherapists about IPF and how to detect features of Velcro crackles during lung auscultation for an earlier and accurate diagnosis of IPF.

1.3.3 Physiotherapy education

In order to meet the current demand of 21 centuries healthcare practice in Malaysia, physiotherapy graduates should be competence in clinical practice as healthcare workforce (Bhavani et al. 2019). Furthermore, they are expected to have critical thinking, hypothesis generation, integrating theory into practice, analytical skills, prioritising problems, updating on professionalism and providing clear justification about problems and intervention (Sole et al. 2014). In Malaysia, physiotherapy education therefore expanded from diploma to bachelor degree programmes in 2003. Up to date, there are two entry levels education for physiotherapist professional in Malaysia which are three years fulltime of diploma and four years fulltime of honours bachelor's degree qualifications (Malaysian Physiotherapy Association 2019).

These education entry levels for physiotherapists is different from western countries. For example, the graduates in the UK should have a minimum qualification from three years' fulltime of bachelor's degree programme (World Confederation for Physical Therapy 2019). This shows that physiotherapy education in Malaysia is behind and still developing compared to the UK. Currently, there are 12 higher educational institutions that offer bachelor degrees, and 22 institutions that offer diplomas in physiotherapy in Malaysia (Malaysian Qualifications Register 2019). This data shows that less than half of

Malaysian institutions offer physiotherapy programmes compared to the UK which have 74 institutions that have offered bachelor's degree programme. Malaysia is facing a shortage of qualified academics in the physiotherapy field who hold at least master's degree qualification in order to provide more bachelor's degree programmes in physiotherapy (Malaysian Qualification Agency 2013). Hence, there is the necessity of physiotherapy programmes at diploma level in regard to produce more physiotherapy graduates to meet higher demand of physiotherapy workforce in Malaysian healthcare services. However, those graduates with diplomas are encouraged by the Malaysian Physiotherapy Association to pursue a bachelor's degree for the development of the physiotherapy profession.

Both diploma and bachelor's degrees in physiotherapy are governed by the regulatory body of the National Accreditation Body which is called Malaysian Qualification Agency (Malaysian Qualification Agency 2013). The Malaysian Qualification Agency works in partnership with the Allied Health Profession (AHP) Council under the AHP Act 774 in navigating quality assurance of all physiotherapy programmes in Malaysia (Malaysian Qualification Agency 2013). The Malaysian Physiotherapy Association has a role to play through one of its mission statements which is to steer physiotherapy education (Malaysian Physiotherapy Association 2019). The MPA acts as a professional advisory body for developing and reviewing physiotherapy education curriculum in the country (Bhavani et al. 2019). The Malaysian Physiotherapy Association aims to move towards professionalization through continuous professional development and attainment of higher standards of patient care (Malaysian Physiotherapy Association 2019).

The diploma programme aims to provide graduates with the relevant skills and a broad-based knowledge to perform basic physiotherapy diagnoses and apply the right treatment procedures. It is a mid-level qualification comprising theory and practical components which enable them to function effectively and competently (Malaysian Qualification Agency 2013). On contrary, the bachelor's programme aims to provide graduates with in depth knowledge and skills and greater competency in performing physiotherapy assessments and treatment. It is a higher degree qualification comprising theory and practical components which enable them to take responsibility, make professional decisions, adapt and contribute to management, conduct their own research and demonstrate life-long learning capabilities to ensure a successful career in physiotherapy. It prepares graduates for entry into postgraduate studies and research (Malaysian Qualification Agency 2013). The minimum credits for a diploma is 105, whilst for a bachelor's degree the minimum is 136 credits. Bachelor programmes provide higher credits than diplomas in fundamental modules, professional modules, and clinical placements.

Fundamental knowledge and professional modules as well as essential skills relating to physiotherapy education are delivered to students during their first two and three years in diploma and bachelor's degree curriculums respectively before they are ready for clinical placement. The clinical placement modules are delivered in their final year of study: year three for diploma students, and for degree students the second semester of year three and the whole of year four. The modes of curriculum delivery that are recommended by the Malaysian Qualification Agency are lectures, tutorials, practical sessions, interactive learning, case studies, self-directed learning, problem-based learning, blended learning, experiential learning, and clinical placement (Malaysian Qualification Agency 2013). Although various delivery methods are recommended, not all could possibly be implied during teaching and learning process especially the experiential learning of high fidelity simulation due to lack of resources.

In the UK, physiotherapy students are exposed to high fidelity simulation learning. This simulation learning has been integrated throughout the physiotherapy curriculum to assist with skill acquisition and assessment using computerised patients (Smith and Crocker 2017). It allows students to practice skills repetitively until mastery in a safe, non-judgmental environment, as students are not hindered by the fear of harming patients or making mistakes during their practice (Ohtake et al. 2013). Besides, it allows students to practice the skills that they have learned shortly after initial contact with the learning materials during lectures and helps to further solidify their learning content. This promotes reflection upon experiences early in their physiotherapy education and prepares them for reflection in their clinical placement training.

The use of high fidelity simulation has benefits in learning cardiopulmonary content like lung sounds auscultation, as students develop improved self-efficacy and interest in pursuing their career in cardiopulmonary setting after the training (Silberman et al. 2015). Unfortunately, physiotherapy students in Malaysia are unable to engage with simulation learning as it is too costly to have sophisticated life-like mannequins in realistic patient environments. Here, students may only practice their hands-on skills which they have learned on their peers. As a physiotherapy lecturer who teaches undergraduates in the Universiti Kebangsaan Malaysia (UKM), I adopted blended learning as a learning strategy for a cardiorespiratory physiotherapy module in their second year of study. This learning integrates two methods of learning face-to-face lectures, and online interactions using a web based tool (UKMFolio learning management system). For instance, during learning of lung sounds students were given a face-to-face lecture about nomenclatures and the characteristics of lung sounds. Students did their hands-on skill of auscultation on their peers and were further exposed to normal and abnormal lung sounds via audio files during a practical session. Then, the audios of the lung sounds were posted online via UKMFolio. The students then need to detect the lung sounds and discuss their answers. Although the blended learning was implemented, there is still limited learning exposure for UKM students to practice and master the skills that they have learned compared to UK students who practice the skills using a high fidelity simulation before their clinical placement.

Clinical education is a critical component of physiotherapy education programmes, besides fundamental and professional modules. It provides students with opportunities to integrate theoretical knowledge, skills and behaviours into clinical practice and further leads to the development of students' competencies, confidence in clinical reasoning and leadership (World Confederation for Physical Therapy 2011a). Clinical education involves delivery, assessment and evaluation of learning experiences in practice settings that are provided through clinical placements at various sites including public hospitals, private hospitals and community settings (World Confederation for Physical Therapy 2011a). It is recognised as an essential element of the physiotherapist professional entry level education programmes. The Malaysian Qualification Agency (2013) recommends that diploma and bachelor students spend a minimum of 1000 hours (25 credits) and 1200 hours (30 credits) for clinical placements respectively being supervised by qualified physiotherapists.

In the UK, clinical placements are introduced earlier to students during their second year, and continually until the third year. In Malaysia, clinical education occurs in the final year of study after the didactic component of the program has been completed. The diploma students start their clinical placements during their third year of study, while for bachelor's degree students start their clinical during second semester of the third year and the whole of fourth year. However, starting clinical education in the final year of study may have a potential limitation due to a theory/clinical practice gap. They may not be able to retain certain skills that they have learned previously during the earlier year of study when they are doing their clinical practice in the final year. Consequently, students may experience a lack of learning transfer from classroom to clinical setting. Clinical education of the physiotherapy curriculum in Malaysia may need to be revised so that the clinical placements occur earlier during the second year, and continually until the end of the programme. This would enhance transfer of learning to occur immediately from academic curricula into real clinical settings and help to bridge the gap between theory and clinical practice.

Lifelong learning through continuing professional development (CPD) for qualified physiotherapists has become an important element in delivering and improving patient centred care (Department of Health, 2001). CPD is a systematic, continuing structured process of learning via formal and informal activities that enables physiotherapists to maintain and enhance their professional skills, knowledge, behaviours and competence (World Confederation for Physical Therapy 2011b). The requirements of CPD is mandated by registration bodies, professional organisations, or governmental licensing boards (World Confederation for Physical Therapy 2011b). In the UK, members of the Chartered Society of Physiotherapy are required to evidence their engagement in CPD in order to retain their professional registration with the Health and Care Professions Council (Chartered Society of Physiotherapy 2015). Likewise, in Malaysia, physiotherapists are required by the Ministry of Health and Malaysian Physiotherapy Association to engage in CPD activities, and they are awarded credits to meet the organisation's key performance indicator which can be translated into recognition and salary advancement (Ramli and Maslan 2015).

Ramli and Maslan (2015) found that Malaysian physiotherapists acknowledged that CPD is a platform for them to improve clinical competency, acquire new skills through current evidence based practice and gain advanced knowledge for specialisation to ensure effective and up to date delivery of physiotherapy care. Generally, they are motivated to engage in CPD activities, yet restricted by financial, workload, or attitudinal factors (Ramli and Maslan 2015). Similarly, Gunn and Goding (2009) reported that CPD has improved professional competence, confidence, and clinical skills and enabled delivery of physiotherapy management effectively amongst physiotherapists in NHS primary healthcare trusts. However, lack of funding, staff shortages and workload demand are highlighted as the greatest barriers to engage in CPD (Gunn and Goding 2009; Haywood et al. 2013). To overcome these barriers, managers should demonstrate flexibility and alternative ways to provide CPD such as inviting specialist senior staff to run training courses or hosting external seminars and obtaining free places in return (Haywood et al. 2013). Online training packages could also be considered as alternative CPD courses. The advantages of online training are that they enable physiotherapists to engage in the training at their own convenience time and pace with a minimal fee. Therefore, the proposed study will investigate this issue further by exploring Malaysian respiratory physiotherapists' perceptions towards the training for Velcro crackles detection in light of physiotherapy education specific to a Malaysian context.

1.4 Thesis organisation

This thesis begins with this chapter (Chapter 1), which provides a general introduction to the research and overview of the study designs for the two studies that have been conducted in this thesis. Chapter 1 leads to inform subsequent Chapter 2, 3 and 4 which involve the discussion of literature review regarding IPF, lung sounds, and auscultation respectively. Sequentially, these three chapters lead to inform Chapter 5 which reviews in more detail the research methodology used for the preliminary study (study one) and longitudinal mixed methods study (study two). Then, followed by Chapter 6 which highlights the major findings of the data analysis from the preliminary study and the longitudinal mixed methods study. Next, Chapter 6 leads to inform Chapter 7 which presents a detailed discussion of the main findings from both preliminary study and the longitudinal mixed methods study, with particularly relates to the existing available literature of Chapter 4. Finally, Chapter 8 which intertwined all the chapters, highlights the conclusions based on the findings from the study one and study two. Research implications for practice and further recommendations for future research are also highlighted in this chapter 8. A figurative illustration of the thesis organisation is presented in Figure 1.1

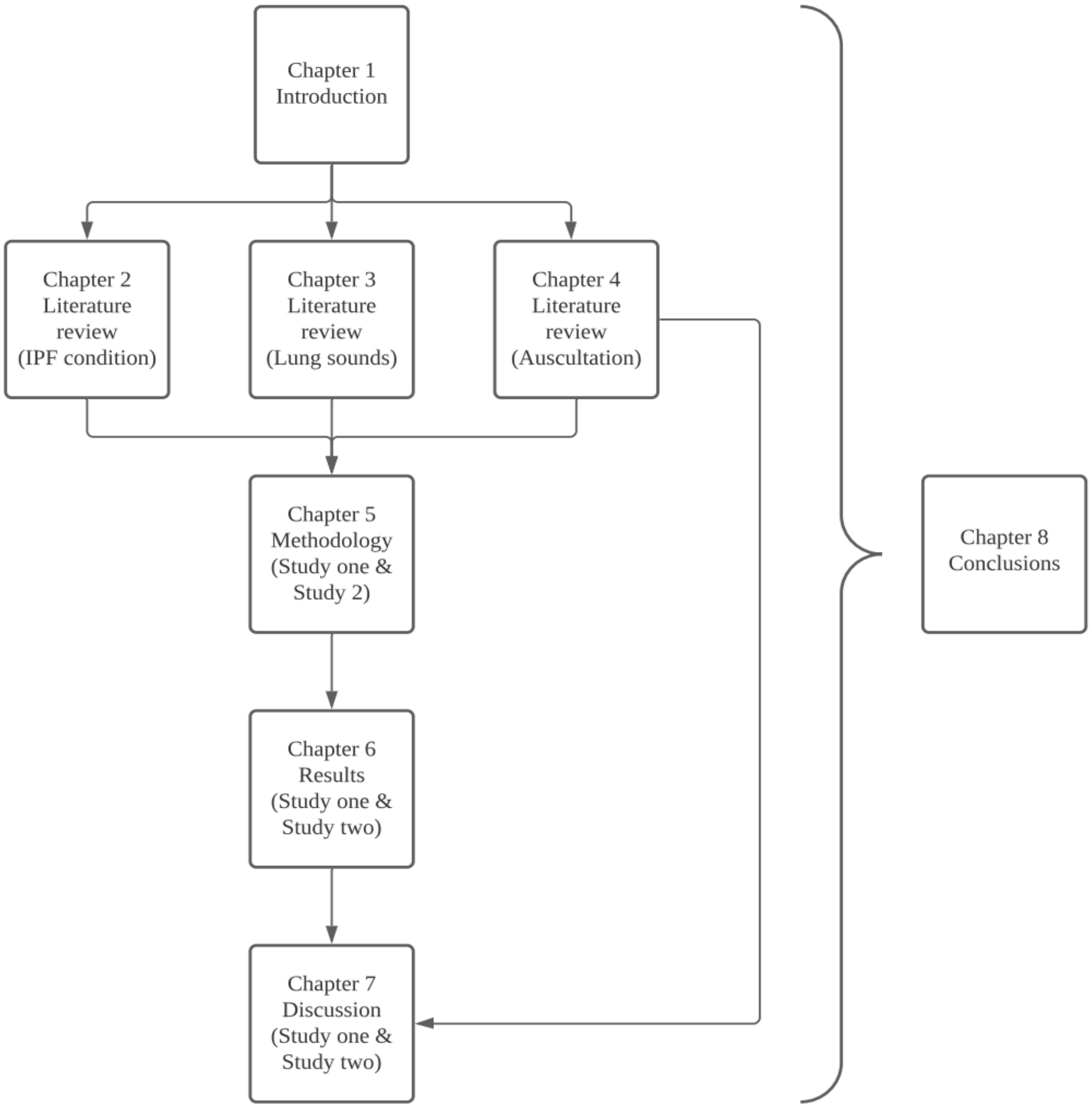

Figure 1.1 Flow of the thesis

1.5 Search strategy

The literature review was carried out using online database which were EBSCO (MEDLINE and CINAHL PLUS), AMED, DELPHIS and EMBASE. To ensure that literature is up to date, most of articles selected were published between year 2000 to 2017. However, due to limited literature regarding reliability of auscultation, IPF and lung sounds, some articles chosen were published before year the 2000. Only full text English-language and peer-reviewed articles were selected and duplicated articles across database were removed.

Major keywords that have been searched include reliability of auscultation, normal lung sounds, abnormal lung sounds, adventitious lung sounds, idiopathic pulmonary fibrosis, Velcro crackles, fibrotic crackles and auscultation training. After merging a major keyword: reliability AND auscultation AND lung sounds; training AND lung sounds AND auscultation, a total of 114 articles were retrieved from the databases from 1989-2017 (Figure 1.2). Fifty articles were excluded because of duplication and grey literature. Then 64 articles were screened for relevancy, and after evaluation of their titles and abstract another 35 articles were excluded due to irrelevant to the specific attention in this thesis. After evaluating the full texts of 29 articles, 15 studies were excluded because they used of non-targeted participants such as a computerised lung sounds analysis to evaluate reliability of detection of lung sounds. Finally, 14 articles were included because of they have focused for reliability of healthcare professionals to detect the abnormal lung sounds.

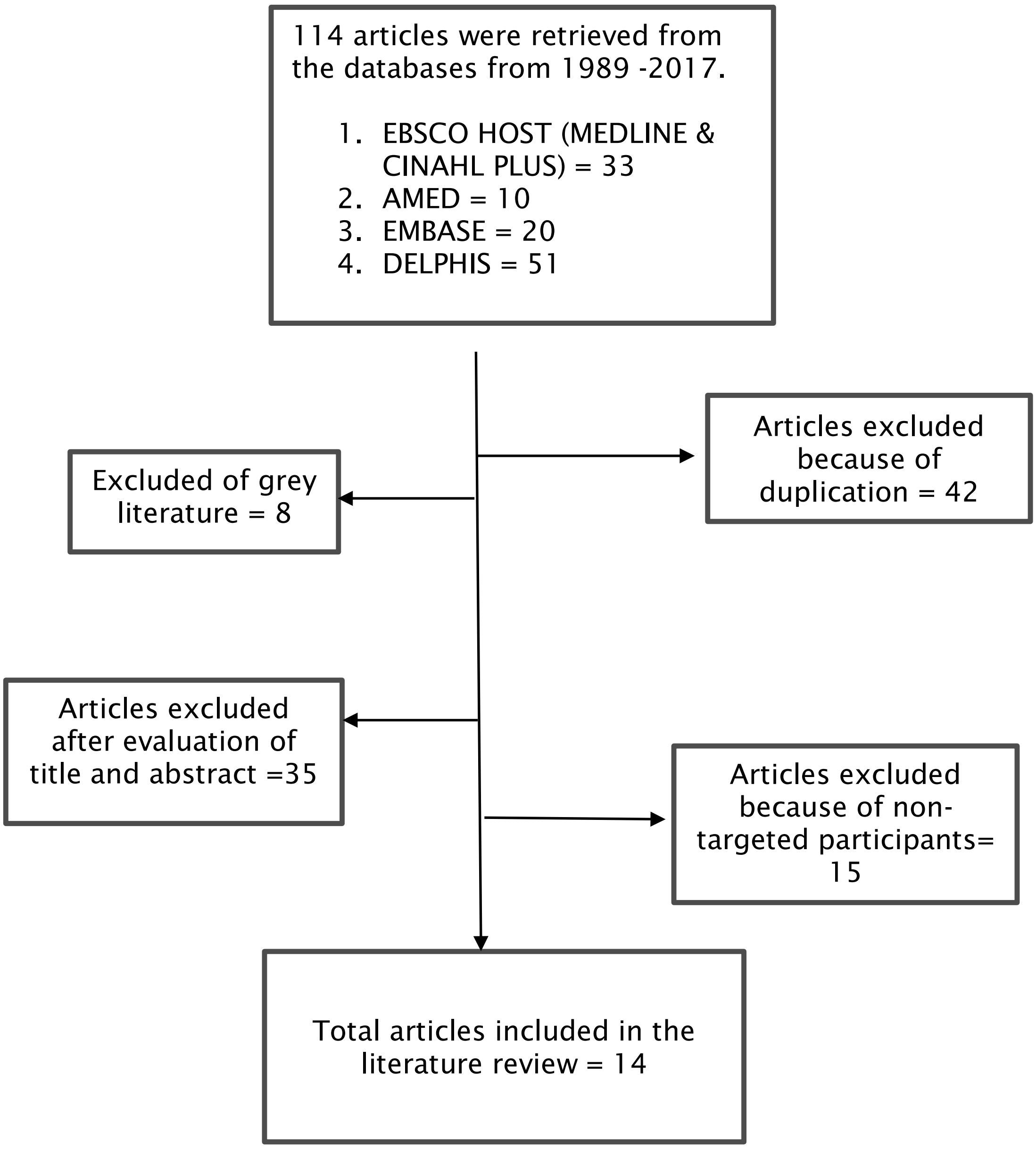

Figure 1.2 Flow chart of literature review search

Chapter 2: Idiopathic pulmonary fibrosis (IPF)

2.1 Introduction

This chapter will address details about the respiratory disease of idiopathic pulmonary fibrosis (IPF) and its progression. The presence of abnormal lung sounds in IPF, which is 'Velcro-type', or fibrotic crackles will be discussed. Finally, the rationale and aim of this research will be highlighted.

2.2 Definition

Idiopathic pulmonary fibrosis (IPF) is defined as a specific form of chronic, progressive fibrosing interstitial pneumonia of unknown aetiology and limited to the lungs, which has a poor prognosis and eventually causing respiratory failure (Raghu et al. 2011). IPF is classified as a major idiopathic interstitial pneumonia by the American Thoracic Society and European Respiratory Society (ATS and ERS) in their official statement on update of the international multidisciplinary classification of idiopathic interstitial pneumonias (Travis et al. 2013).

The ATS and ERS describe IPF as having a heterogeneous progression in patients, and to be irreversible despite therapy (Travis et al. 2013). This means that some patients remain stable for long periods of time, while others suffer with more rapid progression and deterioration. A significant proportion of patients succumbed to an acute exacerbation that will ultimately lead to respiratory deterioration and death (Martinez et al. 2005; Travis et al. 2013). The progression of IPF is therefore unpredictable. It is believed that earlier diagnosis may be beneficial to permit the institution of earlier therapy. There is therefore, an urgent need for new methods that allow early and precise diagnosis in order to permit early treatment to be instituted (Noth and Martinez 2007).

2.3 Incidence of IPF

The incidence of IPF is increasing worldwide including Europe, North America, East Asia and South America and appears to be increasing over time due to increasing of older population over the age of 60 (Hutchinson et al. 2015). In the United Kingdom (UK), incidence of IPF and associated mortality is on the rise and continues to rise in the 21st century (Gribbin et al. 2006; Navaratnam et al. 2011).

Epidemiological studies in the United Kingdom showed an incidence of 4.6 per 100 000 per year between 1991-2003 (Gribbin et al. 2006), which rose to 7.44 per 100 000 per year between 2000-2008 (Navaratnam et al. 2011), and 8.65 per 100 000 per year between 2000-2012 (Maher et al. 2013). Incidence was generally higher in men and the older population (Gribbin et al. 2006; Navaratnam et al. 2011). These findings suggest a progressive increase in the incidence of IPF, with a rise of 50% between 1991 to 2012. IPF is a serious cause of respiratory mortality with 5000 new cases of IPF being diagnosed annually in the UK (Navaratnam et al. 2011).

In the Asian region, studies report an incidence of 1.2 per 100 000 per year for 1997-2007 in Taiwan (Lai et al. 2012), 1.84 per 100 000 per year for 1992-2010 in South Korea (Han et al. 2013), and 2.23 per 100 000 per year for 2003-2007 in Japan (Natsuizaka et al. 2014). These studies reported lower incidence rates of IPF than in the UK. This may be because patients are under-diagnosed with IPF in Asian countries. Furthermore, these studies used data from insurance databases, therefore milder cases of IPF were not being captured during data collection (Lai et al. 2012; Han et al. 2013). In Malaysia, the number of IPF patients that have been diagnosed for IPF at the Institute of Respiratory Medicine was five, seven and six in 2015, 2016, 2017 respectively (Institute of Respiratory Medicine 2018). To the researcher’s knowledge, there have been no published incidence data of IPF available in the Malaysian population. Therefore, it is difficult to know the incidence of IPF in Malaysia. It is hoped that this research will stimulate investigation of IPF disease in Malaysia.

2.4 Prognosis of IPF

Prognosis of IPF is poor, with median survival among patients believed to be from 2.5 to 3.5 years from the time of diagnosis (ATS 2000; Gribbin et al. 2006; Navaratnam et al. 2011). Median survival declines with increasing age particularly in patients older than 70 years of age (Ley et al. 2011; Navaratnam et al. 2011), or who have a history of smoking, respiratory failure, or pulmonary hypertension (Ley et al. 2011).

Although still described as a rare condition, mortality and incidence of IPF in the United Kingdom is on the rise and continues to rise in the 21st century (Gribbin et al. 2006; Navaratnam et al. 2011).

2.5 Risk factors

There are a number of potential risk factors have been described for IPF condition, even though by its definition it is a disease of unknown etiology (Raghu et al. 2011).

2.5.1 Cigarette smoking

A history of smoking is strongly associated with IPF (Baumgartner et al. 1997). This significant association has been observed in patients with a cigarette smoking history of more than 20 pack per years (Miyake et al. 2005; Taskar and Coultas 2006). Smoke inhalation induced a self-sustaining lung injury (Sgalla et al. 2018) and lead to further progression of IPF (Richeldi et al. 2017). Patients who have cigarette smoking history have poorer prognosis of IPF compared to non-smokers (Spira et al. 2004)

2.5.2 Environmental exposures

Multiple environmental exposures have been found to be associated with the risk of IPF (Richeldi et al. 2017; Raghu et al. 2011). Exposure toward metal dust (lead and steel) and wood dust (pine) significantly increase the risk for IPF (Miyake et al. 2005; Taskar and Coultas 2006; Hubbard 2001).

Besides, exposure toward agriculture, farming, livestock, stone cutting, sand and silica have significantly correlated with IPF (Taskar and Coultas 2006). An observation of increased in numbers of inorganic particles in lymph nodes of patients with IPF has been detected during autopsy studies (Kitamura et al 2007).

2.5.3 Microbial agents

Microbial agents including viral, fungal, and bacterial have a potential role in the pathogenesis of IPF and therefore, considered to be risk factors (Chioma and Drake 2017). An imbalance of bacterial community composition has been detected in IPF patients compared to healthy individuals (Sgalla et al. 2018). In addition, viral infections including Epstein-Bar-virus, cytomegalovirus, hepatitis C virus, and human herpesvirus-8, were commonly found in the lungs tissues of IPF patients (Sgalla et al. 2018; Raghu et al. 2011).

Stewart et al. (1999) have observed the protein and DNA of Epstein-Barr virus that usually composite in the alveolar epithelial cells in lung tissues of the IPF patients (Stewart et al. 1999).

2.5.4 Past medical history

Autoimmune diseases

Patients who have past medical history of autoimmune disease like rheumatoid arthritis or scleroderma are likely to have risk for IPF (Vij et al. 2011). Autoimmune diseases are caused by a dysfunctional immune response in which the body produces autoantibodies that can attack the individual's proteins within the lungs, causing inflammation and fibrosis (Donahoe et al. 2015). The accumulation abnormal B-cells which are responsible for the production of autoantibodies are observed within damaged IPF lungs due to repetitive interactions of the lymphocytes with autoantigens (DePianto et al. 2015). Increased accumulation of B-cells correlated with the severity of the disease condition (Xue et al. 2013).

Gastroesophageal reflux disease (GERD)

Abnormal acid gastroesophageal reflux disease (GERD) that presumably associate with micro aspiration has been proven as a risk factor for IPF (Raghu et al. 2011). Abnormal GERD is common in patients with IPF and it is clinically silent in most of

IPF patients (Tobin et al. 1998; Raghu et al. 2006). The alleged role of GERD in IPF remains elusive and it is unknown whether changes in intrathoracic pressure due to poor lung compliant lead to abnormal GERD (Raghu et al. 2011).

Diabetes mellitus

Diabetes mellitus is associated as a causal factor for IPF (Raghu et al. 2011). Gribbin et al. (2009) found that a stronger association between Type 1 and type 2 that used insulin than oral hypoglycaemics with the development of IPF. This finding suggests that clinicians should be alert to the possibility of IPF in patients with diabetes mellitus.

2.5.5 Genetic factors

Genetic susceptibility is related to the development of idiopathic pulmonary fibrosis which characterised by combination of gene variants and transcriptional changes that lead to the loss of epithelial integrity (Sgalla et al. 2018; Richeldi et al. 2018).

Familial interstitial pneumonia (FIP) is identified when two or more members of the same biological family are affected which characterised by rare genetic variants that associated with surfactant dysfunction and telomere biology (Raghu et al. 2011). These genetic variants play potential role in alterations of lung host defence and have strongest risk factor for development of IPF (Richeldi et al.2018). The epithelium site of altered gene production tends to increase in protein concentrations which might enhance injury and impede normal lung repair (Evans et al. 2016).

2.5.6 Ageing

Ageing is a physiological progression to the death that leads to the loss of function and increase weakness (Sgalla et al. 2016). Cellular and clinical age-related changes that primarily affected the alveolar epithelium are associated with the risk for IPF (Fell et al. 2010). Epithelial cell senescence (cessation of cell division) in ageing process induces pulmonary fibrosis via abnormal secretory pattern of the lung epithelium and the increased resistance to apoptosis of myofibroblasts (López-Otín et al. 2013). Xu et al. (2009) found that naturally aged mice appeared to have more severe fibrotic at the lungs in response to environmental stimuli and injury, compared to younger mice.

2.6 Pathophysiology of IPF

2.6.1 Pathology of IPF

Idiopathic pulmonary fibrosis is regarded as a result from repetitive local micro-injuries over time to ageing alveolar epithelium due to multiple interactions of genetic and environmental risk factors (Richeldi et al. 2018). These recurrent micro-injuries of the alveolar epithelium lead to maladaptive healing process where several lung cells develop aberrant behaviours of epithelial–fibroblast communication, the induction of matrix-producing myofibroblasts, considerable extracellular matrix accumulation and remodelling of lung interstitium (Richeldi et al. 2018). Consequently, these mechanisms leading to the development and sustainment of the fibrotic process (Sgalla et al. 2018). These multiple pathological alterations in IPF involve most compartments of the lower respiratory system (Plantier et al. 2018).

During maladaptive healing process, chronic dysregulation of type 2 alveolar epithelial cells (AEC2s) is believed to contribute to renewal of type 1 epithelial cells after lung injury (Desai et al. 2014). These abnormal AEC2s which have impaired renewal capacity are identified with fibroblastic foci which is located adjacent to hyperplastic or apoptotic alveolar epithelial cells in IPF tissue (Selman and Pardo 2002). The premature shortening of AEC2 telomeres is observed in IPF tissue that lead to remodelling and fibrosis (Naikawadi et al. 2016).

In addition, repetitive micro-injuries to ageing alveolar epithelium activates alveolar epithelial cells to secrete various fibrogenic growth factors including transforming growth factor β (TGF β), cytokines and coagulants (Richeldi et al. 2018). This secretion leads to dysregulate epithelial mesenchymal crosstalk recruitment and activation of highly synthetic and contractile myofibroblasts from multiple sources, including resident mesenchymal cell proliferation, pericytes of the lung interstitium, circulating fibrocytes, epithelial mesenchymal transition, and endothelial mesenchymal transition (Recheldi et al. 2018). The deposition of myofibroblasts proliferation increased and altered the extracellular matrix components, with altered biomechanical stiffness of extracellular matrix (Plantier et al. 2018). Hence, it destroys normal alveolar architecture and disturbs gas exchange.

The progression from normal to abnormal extracellular matrix deposition in IPF remains elusive, even though evidence suggests that this abnormal deposition contributes to disease pathogenesis (Booth et al. 2012). These altered extracellular matrix composition and biomechanical stiffness might contribute to fibrosis due to mechanosensitive protein–protein interactions occurring within adhesion of myofibroblasts and extracellular matrix proteins (Tschumperlin 2015; Chen et al. 2016). Lung fibrosis is defined by the replacement of the normal and compliant lung extracellular matrix, which is rich in elastin, with an abnormal matrix that is rich in fibrillary collagen (Horowitz and Thannickal 2016).

There is the occurrence of abnormal lung remodelling of alveolar tissue bronchiolisation which occur in parallel with abnormal extracellular matrix accumulation (Richeldi et al. 2018). This bronchiolisation of alveolar spaces is due to the activation of developmental pathways during regenerative response, which lead to abnormal process of proliferation and migration of alveolar club cells (Clara cells), and other bronchiolar epithelial cells (Sgalla et al. 2018). These cells contribute to re-epithelisation of damaged alveolar epithelium which caused irreversible changes in alveolar spaces architecture (Richeldi et al. 2018).

In addition, there is the presence of honeycomb lesions due to abnormal dilation of alveolar spaces with fibrotic tissue deposition at the epithelium walls that shares characteristics with the airway epithelium (Seibold et al. 2013). It manifested on HRCT as clustered cystic airspaces that predominantly found in the subpleural regions of the lungs (Raghu et al. 2011). Honeycombing is indicated as appearance of destroyed lung parenchyma with piled and thick-walled cyst characteristics which is strongly associated with the presence of “Velcro-type” crackles in the IPF lung (Sgalla et al. 2018).

Distinct lung vasculature alterations also occur in the fibrotic regions of the IPF lungs (Plantier 2018). The vessel density is sharply decreased in the areas of dense fibrosis (Hanumegowda et al 2012). The walls of pulmonary arteries and veins show intimal fibrosis and are thickened (Colombat et al. 2007). The density of capillary is increased especially at the bordering of fibroblastic foci and honeycomb cysts (Hanumegowda et al 2012). Generally, these pathological alterations in IPF, impair the functions of the lungs in patients who have this IPF condition that will be discussed in details in the next section.

2.6.2 Reduced lung compliance and lung volume

Lung compliance is the ability of the lung to stretch and expand which is defined as the change in lung volumes divided by the change in transpulmonary pressure (Plantier et al. 2018). The maladaptive healing process thickens the interstitium with fibrous tissues which lead to the lungs stiffness (Plantier et al. 2018). In addition, the alterations of lipid profile such as reduced phosphatidyl glycerol, increased phosphatidylinositol and increased sphingomyelin levels and alterations of fatty acid composition in pulmonary surfactant also occur in patients with IPF which lead to impaired pulmonary surface activity (Schmidt et al. 2002). These factors restrict inflation of the lung which contribute to the reduction of lung compliance. Reduced lung compliance may correlate with the degree of lung fibrosis that tends to progress with disease (Nava and Rubini 1999).

Reduced lung compliance is likely to associate with an increase in the mechanical load of the respiratory muscles which consequently increases the work of breathing which leads to dyspnoea (Crystal et al. 1997). Furthermore, reduced lung compliance contribute to a restrictive ventilatory defect with reduce the forced vital capacity (FVC) at spirometry test (Sgalla et al. 2018). Generally, the lung volumes which are the total lung capacity and vital capacity are typically reduced in patient with IPF (Martinez et al. 2006). It is believed that reduction in vital capacity of lung volume is constantly associated with an increased risk of fatality in IPF (Martinez 2006).

2.6.3 Reduced diffusing capacity of the lung

The alterations of alveolar-capillary membrane due to fibrotic interstitium lead to impaired oxygen and carbon dioxide gases exchange between alveolar and capillaries as well as ventilation/perfusion mismatch in the lung (Plantier et al. 2018). Thus, reduces the diffusion lung capacity for carbon monoxide (DLCO) in patients with IPF (Sgalla et al. 2016). Reduced lung diffusing capacity is driven by the reduction of alveolar volume and the transfer of constant carbon monoxide in the lungs in IPF. In addition, diffusion lung capacity is highly associated with dyspnoe (Swigris et al. 2012) and survival (Hamada et al. 2007). The amount of fibrotic lesions can progress with time and they are not reversible, which further limits oxygen from alveoli to reach capillaries and removing carbon dioxide from capillaries (Plantier et al. 2018)

2.6.4 Increased dead space ventilation

The fibrotic lesions and honeycomb lesions within the alveoli in IPF disease are poorly perfused although they still receive some ventilation (Strickland et al 1993). This feature leads to the increase of anatomical dead space of ventilation due to the increased volume of conducting airways and increase in ventilation to perfusion ratios at the alveolar dead space (Plantier et al. 2018). Consequently, patients with IPF tend to have increased physiological dead space of ventilation during resting and exercising, which is determined by the increase of ratio of dead space volume to the tidal volume (Miki et al. 2009).

2.6.5 Chronic arterial hypoxaemia

Changes in the mechanical properties of the lungs, pulmonary gas exchange, and lung vasculature contribute to early-onset exertional chronic arterial hypoxaemia and later-onset resting chronic arterial hypoxaemia in IPF (Plantier et al. 2018). This chronic arterial hypoxemia that was found in patients were due to the increase in alveolar-arterial oxygen tension difference in the lungs (Plantier et al. 2018). The alveolar-arterial oxygen tension difference can increase due to ventilation perfusion mismatch (reduced ventilation perfusion ratios) and oxygen diffusion limitation in the lungs (Agusti et al. 1991). Patients who suffer from the chronic arterial hypoxemia tend to have hyperventilation and shortness of breath due to significant impairment of gas exchange during physical exercise in IPF (Plantier et al. 2018). A significant decline in arterial haemoglobin saturation is observed amongst patients with IPF after a six-minute walk test (Nishiyama et al. 2007).

2.6.6 Sign of Velcro crackles

Velcro crackles is considered as a typical acoustic finding of IPF (Pasterkamp et al. 2016). However, the pathological abnormalities underlying the generation of “Velcro-type” crackles remain unclear (Cottin and Cordier 2012). It is suggested that any degree of abnormal deposition of fibrotic tissues in IPF might cause the distal airways to suddenly collapse during expiration, hence generate the Velcro crackles sounds during pulmonary auscultation (Sgalla et al. 2018).

In honeycombing lung regions, it is likely to note that these dilated, distorted airspaces suddenly collapse during expiration and reopen during inspiration causing the generation of the Velcro crackles (Sgalla et al. 2018). Sgalla et al. (2018) found that Velcro crackles strongly correlate with the extent of distinct radiologic features of honeycombing and fibrotic tissues in pulmonary fibrosis. Therefore, Velcro crackles detection via auscultation might be used as an early detection of IPF condition by clinicians especially in primary care of clinical setting, where the advanced diagnostic tool such as HRCT and lung biopsy are not available. Diagnose of IPF at an early stage is a critical matter for safe and effective treatments (Sgalla et al. 2016). It has been found that the delay in referral of patients to a tertiary care centre specialising in interstitial lung disease correlate with poorer survival rate (Lamas et al. 2011).

2.7 Earlier diagnosis for better prognosis of IPF

IPF is the most common of the idiopathic interstitial pneumonias and becoming an important public health problem. Patients typically present with insidious onset, progressive exertional dyspnoea and non-productive cough. However, IPF is often initially misdiagnosed as being a respiratory tract infection or pulmonary oedema until physiological, radiological and histopathological data suggest the presence of interstitial lung disease (Dempsey 2006).

In the early stage of IPF, a chest radiograph may appear normal as changes only become apparent with progression of the disease (Dempsey 2006). Later stages of IPF are characterised by the appearance of an interstitial pneumonia pattern on chest x-rays, and by pathological changes seen during surgical lung biopsy or on chest high resolution computed tomography (HRCT) (ATS 2000; ATS 2002; Raghu et al. 2011).The features of interstitial pneumonia that are usually seen include architectural destruction due to chronic interstitial fibrosis, honeycomb changes and scattered fibroblastic foci within the interstitium of the lung (ATS 2002; Raghu et al. 2011; Travis et al. 2013).

A delay in obtaining a correct diagnosis may lead to ineffective early intervention and resulting in poor prognosis (Hosenpud et al. 1998). Lamas et al. (2011) revealed that delay in referring IPF patients to a specialised centre is associated with a higher mortality rate. The current published guidelines on diagnosis and management of IPF state that chest HRCT is the gold standard diagnostic test, which enables specificity for the recognition of the typical interstitial pneumonia pattern in IPF patients (Raghu et al. 2011). The diagnosis of IPF remains uncertain in the absence of a surgical lung biopsy or HRCT findings of the chest.

2.8 The sign of ‘Velcro-type’ or fibrotic crackles in IPF

In addition to the radiological changes observed, clinicians have also noted the presence of abnormal lung sounds in IPF. They have reported the presence of ‘Velcro-type’ or fibrotic crackles as being typical (ATS 2000; Dempsey 2006; Cottin and Cordier 2012). These fine crackles of Velcro rales were coined by DeRemee (1969) from the two French words velours (velvet) and crochet (hook), which are similar to the sound generated by ripping apart mated strips of Velcro.

Bibasilar Velcro crackles (both of lungs bases) are detected in more than 80% of patients on chest auscultation during inspiration (Borchers et al. 2011). The presence of Velcro crackles, over lower lobes particularly, is associated with ongoing pulmonary fibrotic process in IPF patients (ATS 2000; Dempsey 2006). These crackles will further advance to the upper zones of the lungs as the disease progresses (Cottin and Cordier 2012). Velcro crackles in patients with IPF can be heard constantly throughout the entire inspiratory phase and persisting after several deep breaths (Piirilä et al. 1991; Cottin and Cordier 2012; Cordier and Cottin 2013).

However, recognition of Velcro crackles in IPF is controversial and quite challenging in a clinical setting (Murphy 2008). These fine crackles sounds can be detected easily with a standard stethoscope, but they could be misinterpreted as the fine crackles in congestive heart failure condition, which may then lead to inappropriate intervention given to patient (Murphy 2008). It has been suggested that using the acoustic characteristics of lung sounds might be a cost-effective way to diagnose IPF earlier (Flietstra et al. 2011; Cottin and Cordier 2012). Lung sound acoustic analysis has detected that Velcro crackles in IPF are quite distinct from the fine crackles in other diseases such as heart failure and pneumonia (Murphy 2008). Nevertheless, there is a paucity in literature investigating acoustic analysis of Velcro crackles in clinical setting and quality data on computerised lung sound analysis studies are relatively limited to be assured that this technology can be used in clinical setting in near future (Gurung et al. 2011).

The accuracy of Velcro crackles identification in IPF disease should be properly assessed to avoid risks of misdiagnosis and incorrect intervention. However, currently the main issues in the diagnosis of IPF are the necessity of advanced diagnostic tools including high-resolution computed tomography (HRCT) and lung biopsy, and specialised pulmonologists and experienced multidisciplinary teams in order to obtain a definite diagnosis of IPF, which usually only available in tertiary hospitals (Sellarés et al. 2016). Apparently, patients might have the potential to be misdiagnosed if the healthcare professionals in primary care are less experienced with this disease and in fact it might lead to the delay in referring patients to a tertiary centre. A delay in obtaining a correct diagnosis may lead to ineffective early interventions resulting in a poor prognosis (Hosenpud et al. 1998).

Therefore, it is argued that healthcare professionals, including respiratory physiotherapists, should be taught to detect the sound of these Velcro crackles during pulmonary auscultation so that early detection will facilitate early referral to a pulmonologist for prompt definitive diagnosis of IPF. In addition, detection of these Velcro crackles may help clinicians to monitor the progression of IPF and to provide better clinical decisions in treating patients with IPF. Currently, there is no curative therapy available for IPF and the only aim of the current therapy is to delay the progression of IPF (Sellarés et al. 2016). For this reason, there is a necessity to train the clinicians in detecting Velcro crackles during auscultation in a clinical setting in order to facilitate early detection of IPF.

2.9 Treatment for patient with IPF

Early diagnosis and referral for IPF patients are crucial because there is no curative therapy available in this current time. In fact, the only aim of the current medication is to delay the progression of IPF in most of the cases (Sellarés et al. 2016). Therefore, early management of IPF especially in tertiary centre may reduce mortality rate and improve patient prognosis (Lamas et al. 2011).

The therapeutic approach in IPF should be individualised for each patient, as the progression of IPF is unpredictable for every individual. To date, there are two drugs, which are Pirfenidone and Nintedanib that have been used as pharmacotherapy in slowing the progression of the disease in IPF patients (Raghu et al. 2015; Cordeiro et al. 2016). Commonly, patients may suffer from hypoxemia at rest, with sleep and/or during exertion. Therefore, supplemental oxygen to IPF patients is strongly recommended as mentioned in the treatment guidelines of IPF (Raghu et al. 2011).

Holland et al. (2012) had showed that exercise training particularly pulmonary rehabilitation programme for patients with IPF was associated with an improvement in 6-minutes walk test distance and increased quality of life scores. Patients will be trained to learn the breathing techniques and coping strategies for dyspnoea during the pulmonary rehabilitation programme (Oldham and Noth 2014). Therefore, this therapy should be offered to all patients during the stage of diagnosis to promote better prognosis. Early consideration of lung transplantation is the sole therapy that was strongly recommend by the ATS and International Society for Heart and Lung Transplantation for patients with IPF (Raghu et al. 2011). The decision was made because it was proven that it could prolong the survival rate ranges from 50% to 56% and the 10-years survival rate is 30%.

Since the management of patients with IPF condition is challenging and no therapy can cure this disease, it would be possible for health professionals including general practitioners, physiotherapists and others clinicians to be taught and trained for recognition of Velcro crackles. If these sounds were present in patients with respiratory conditions who are aged over 60 years, the clinicians should be aware that patients might have IPF and prompt investigation in order to diagnosis IPF should be done. Early referral to pulmonologist for therapy management that is tailored to the individual patient should be offered to facilitate better outcome for patient with IPF.

2.10 Summary

Although IPF is a rare lung disease, the incidence is increasing globally including western and Asian countries every year. It is associated with high mortality. Earlier detection of Velcro crackles by health professionals might be useful to facilitate early referral of patients to tertiary centre for definite diagnosis by pulmonologists and multidisciplinary teams. Therefore, appropriate therapy management could be given to patients and further monitoring progression of IPF could be made by listening to Velcro crackles from patients' chest.

Chapter 3: Lung sounds

3.1 Introduction

This chapter will discuss normal and abnormal lung sounds in both healthy individuals and patients with lung diseases respectively.

3.2 Normal lung sounds

Lung sounds heard in the chest during auscultation are affected by the anatomical structures at the site of sound generation (Bohadana et al. 2014). Normal lung sounds which are soft and non-musical can be heard clearly during inspiration and in the early phase of expiration (Bohadana et al. 1978). The creation of normal lung sounds is incompletely understood (Kiyokawa and Pasterkamp 2002; Reichert et al. 2008). However, it is believed that normal lung sounds are probably the result of turbulent airflow generated in large and medium size airways e.g. trachea and proximal bronchi, which produce high velocity air flow (Pasterkamp et al. 1997a; Marques et al. 2006; Bohadana et al. 2014). In contrast, the airflow in small airways and alveoli is laminar and silent due to low velocity air flow (Marques et al. 2006). In addition, lung sounds differ between individuals because airway dimensions correlate with body height, age and gender (Sanchez and Pasterkamp 1993). Thus, body size, age and gender will affect respiratory sounds (Pasterkamp et al. 1997a; Gross et al. 2000).

Lung sounds during inspiration are generated within lobar bronchus (the secondary divisions of the primary bronchi) and segmental bronchus (the tertiary divisions of the secondary bronchi), while the origin of expiratory sounds comes from more proximal locations (Kraman 1980; Bohadana et al. 1988; Kiyokawa and Pasterkamp 2002). Transmission of normal lung sounds are classified into three frequency bands: low (100-300 Hz), medium (300-600 Hz) and high (600-1200 Hz) frequencies (Pasterkamp et al. 1997b). However, their classification is uncertain especially when the sound has frequencies of 300Hz or 600Hz. This is because they classified the same cut off frequency between low to medium (300Hz) and medium to high (600Hz) bands.

3.3 Adventitious lung sounds

The presence of pathological conditions in the lungs and airways may lead to adventitious or abnormal lung sounds. Transmission of higher frequencies with strong expiratory phase in the existence of lung consolidation leads to bronchial breathing which would be heard at the lung periphery (Ceresa and Johnston 2008; Bohadana et al. 2014). On the contrary, lung sounds transmission are diminished or absent when there are fluid or air in the pleural cavity, as in effusion or pneumothorax (Forgacs 1978; Bohadana et al. 2014).

There are also adventitious sounds which are superimposed on normal lung sounds (Reichert et al. 2008). Adventitious sounds can be classified into two categories which are continuous (such as wheezes and rhonchi) and discontinuous (like crackles) sounds. The presence of these sounds usually indicates pulmonary diseases (Sovijärvi et al. 2000a; Reichert et al. 2008). However, the used of diverse nomenclature terminology by healthcare professionals to describe adventitious lung sounds could lead to confusion and imprecision of communication among them (Mikami et al. 1987; Wilkins et al. 1990).

Therefore, the Ad Hoc Committee of the International Lung Sounds Association has proposed the standard nomenclature to be used by healthcare professionals worldwide (Mikami et al. 1987). They suggested that the term 'crackles' should be used to describe discontinuous adventitious lung sounds, 'wheezes' to describe high-pitched continuous adventitious lung sounds and 'rhonchi' to describe low-pitched continuous adventitious lung sounds. The committee has replaced the term 'rale' to 'crackle'. Other terms like dry, wet, sonorous and sibilant are replaced by fine crackle, coarse crackle, wheeze and rhonchi (Table 2.1).

Table 2.1 Nomenclature of lung sounds that recommended by the International Lung Sounds Association

Traditional term	Recommended term by the International Lung Sounds Association
Fines rales/fine crepitations	Fine crackles
Coarse rales/fine crepitations	Coarse crackles
Sibilants/high pitched wheezes	Wheezes
Sonorous/low pitched wheezes	Rhonchus

*Information from Mikami et al. (1987).

Lung sounds during chest assessment tell valuable information especially for patients with respiratory diseases. Each type of adventitious lung sound may suggest a particular respiratory disease, for instance hearing a wheeze may indicate asthma, coarse crackles may indicate chronic bronchitis and fine crackles may indicate pneumonia (Bohadana et al. 2014). Moreover, detection of adventitious lung sounds can help a clinician determine clinical decisions for therapy and also helps monitor the progression of respiratory diseases. However, even though information from lung sounds can be used to diagnose patient with respiratory disease, this should be confirmed precisely with chest radiograph or high resolution computed tomography (HRCT) scan.

In this literature review section, the sounds of wheezes, crackles and squawks will be further discussed since they are the common adventitious lung sounds in respiratory conditions. The crackles sound in particular is associated with IPF condition.

3.3.1 Wheezes

Wheezes are musical and continuous adventitious lung sounds (Sovijärvi et al. 2000a). They are high-pitched with typical frequency over 100Hz and longer than 100ms in duration (Bohadana et al. 1978; Bohadana et al. 2014).

Wheezes are generated when there is a flutter velocity, which is when the gas velocity reaches a critical values due to oscillation of the narrowed airways (Forgacs 1967). The pitch of a wheeze is influenced by the mass and elastic properties of the airway and is not determined by the length of airway (Forgacs 1978). There are two types of wheezes: 1) monophonic, when only single pitch is heard and; 2) polyphonic when multiple frequencies are heard concurrently (Forgacs 1978; Sovijärvi et al. 2000b). Wheezing can be heard on inspiration, expiration or biphasic in patients with obstructive respiratory diseases especially asthma and chronic obstructive pulmonary disease (Forgacs 1967; Bohadana et al. 2014).

3.3.2 Crackles

Crackles are intermittent, non-musical and explosive sounds which are heard often during inspiratory phase rather than expiratory phase (Pasterkamp et al. 1997a; Reichert et al. 2008). The likely mechanism for the generation of crackles is the sudden reopening of abnormally closed airways during inspiration or sudden airways closing during expiration to equilibrate pressures within the airway (Forgacs 1967; Vyshedskiy et al. 2009). This happens as a result of increased elastic recoil pressure (e.g. in pulmonary fibrosis), inflammation (e.g. pneumonitis) or stiffening of small airways due to excessive accumulation of fluid (e.g. in heart failure) (Piirilä and Sovijärvi 1995; Sovijärvi et al. 2000b).

The characteristics of the crackle sounds are likely to depend on the diameter of the airways and associated with the pathophysiology of the surrounding tissue (Piirilä and Sovijärvi 1995). Fredberg and Holford (1983) predicted that crackles produced from smaller airways are in shorter duration (less than 10ms) than those produced from larger airways (more than 10ms).

There are two types of crackles which are recommended by the American Thoracic Society (1977) based on intensity, frequency and duration are coarse and fine crackles. Coarse crackles are loud, having lower frequency (about 350Hz) and longer duration, gravity-independent, usually heard on early inspiration and through expiration, audible at the mouth and may be related to obstructive pulmonary diseases, e.g. chronic bronchitis (Bohadana et al. 1978; Pasterkamp et al. 1997a; Bohadana et al. 2014). In contrast, fine crackles are less loud, having high frequency (about 650 Hz) and short duration, gravity-dependent, heard on mid to late inspiration and rarely on expiration, not transmitted to mouth, and normally associated with restrictive lung diseases, e.g., interstitial lung fibrosis, idiopathic pulmonary fibrosis, asbestos (Bohadana et al. 1978; Pasterkamp et al. 1997a).

Initially, crackles tend to occur in the bases of the lungs and later in the upper zones of the lungs as disease progresses (Sovijärvi et al. 2000b). In addition, fine and coarse crackles may also co-exist in patients with respiratory disorder (Murphy and Vyshedskiy 2010). In healthy people, crackles may sometimes be heard but then eliminated after deep breaths (Bohadana et al. 2014). Evaluation of crackles is likely to have clinical significance in enabling differential diagnosis of respiratory disorders (Piirilä and Sovijärvi 1995; Bohadana et al. 2014).

3.3.3 Squawks

Squawks are short inspiratory adventitious sounds that have a musical characteristics, occasionally accompanied or preceded by crackles (Bohadana et al. 1978; Murphy 2008). Their duration varies between 50 and 400 ms (Reichert et al. 2008) with a typical frequency between 200 and 300 Hz (Bohadana et al. 2014). Squawks are associated with conditions affecting the periphery airways including interstitial lung diseases e.g. hypersensitivity pneumonia and pneumonia in patients who are acutely ill (Bohadana et al. 1978).

The production of squawks is caused by oscillation of the peripheral airways after a sudden opening during inspiration in deflated lung zones and their timing is influenced by the transpulmonary pressure (Sovijärvi et al. 2000b; Bohadana et al.

2014). There is a difference between basic mechanisms of origination of squawks and wheezes in obstructive lung diseases (Reichert et al. 2008). As a result, squawk should only be referred to inspiratory short wheezes especially in patients with interstitial lung diseases. Nevertheless, their respiratory sounds analysis does use the same methods as wheezes (Sovijärvi et al. 2000b).

3.4 Summary

The mechanisms of normal and abnormal lung sounds, which are generated at the chest, are different. Abnormal lung sounds are usually associated with the specific lung diseases. The next chapter will be discussed regarding respiratory disease of idiopathic pulmonary fibrosis (IPF).

Chapter 4: Auscultation

4.1 Introduction

This chapter will discuss auscultation as an assessment tool used by healthcare professionals in terms of its advantages and disadvantages in clinical setting.

4.2 Auscultation as an assessment tool

The conventional method of auscultation using a stethoscope is widely used in clinical practice among health professionals, primarily medical clinicians and physiotherapists, to assess patients with respiratory problems and monitor their condition (Pryor and Prasad 2008; Bohadana et al. 2014) . In contrast to numerous diagnostic tools available, a stethoscope is easily to be used in a variety of clinical setting (Murphy 1981) and it is also expected by the patients (Ceresa and Johnston 2008).

Over the last few decades, contradicting arguments about the values of auscultation in clinical practice have arisen in respiratory sound studies. Some argue that auscultation is relatively cheap, non-invasive, easy, quick and cost effective approach to evaluate lung sounds in patients with respiratory conditions (Murphy 1981; Chen et al. 1998; Ceresa and Johnston 2008). Moreover, it involves less cooperation from the patients and can be repeated as often as needed (Bohadana et al. 2014).

In contrast, other authors have argued that auscultation is a subjective diagnostic method as it highly relies on health professionals' hearing acuity and experience (Sovijärvi et al. 2000c; Murphy 2008). Thus, auscultation can be said as having a poor and limited role in the diagnosis of respiratory conditions especially pneumonia (Wipf et al. 1999; Saeed 2007). Misinterpretation of auscultation findings would lead to inappropriate interventions given to patients, for example patients with IPF are commonly given diuretics as their crackles could be misinterpreted as those of heart failure (Murphy 2008).

In addition, auscultation has been compounded by difficulties with nomenclature because of the inconsistency used of lung sounds terminology amongst health professionals during chest examination (Pasterkamp et al. 1987 ; Robert et al. 1990). Another problem with auscultation would be significant inter- and intra-observer variability within health professionals when characterised lung sounds in patients with respiratory diseases (Pasterkamp et al. 1987 ; Allingame et al. 1995; Jailani and Wong 1998; Murphy 2008; Morrow et al. 2010). These inter and intra-observer variability in describing lung sounds during auscultation may weaken the diagnostic of the abnormal lung sounds for respiratory diseases (Melbye et al 2016).

Regardless of all its limitations, auscultation is still needed, particularly in primary care and the developing world where sophisticated diagnostic instruments are unavailable to diagnose patients' condition (Bohadana et al. 2014).

4.3 Reliability measurement

Reliability is one of the properties of outcome measures which demonstrates the confidence of instrument used in clinical and research settings (Fawcett 2007). Reliability can affect the validity of the instrument therefore, tools that is unreliable will have low validity (Bowling 2014).

Reliability refers to the reproducibility and consistency of the instrument, whether it produces the same results when applied to the same participant by the same researcher at a different period of time, or different participants on one occasion, and free from random error (Bowling 2014). Types of reliability include test-retest reliability, intra-observer reliability and inter-observer reliability. Test-retest reliability is the extent of consistency achieved over a period of time during repeated measurements (Field 2009). Intra-observer reliability is when a single observer reproduces the same results after repeating the same experimental conditions (McHugh 2012). Whereas, inter-observer reliability is the extent of the same agreement obtained by two or more observers during experimental test (Bowling 2014).

4.4 Reliability measurement of auscultation of lung sounds

The agreement among observers towards diagnostic tools is a critical issue in medical statistic and most likely, a perfect agreement among them is seldom achieved (McHugh 2012; Sertdemir et al. 2013). Inconsistency or lack of agreement towards diagnostic tools measurement occur due to variability among observers (McHugh 2012).

During auscultation of lung sounds, Welsby and Earis (2001) suggested that the sound heard is determined by three main factors including respiratory sounds at the chest wall, acoustics of the stethoscope and perception of sounds by the human ear. Auscultation could be considered as a subjective process that depends on an individual's perception of sounds heard at the chest wall (Sovijärvi et al. 2000c). Thus, auscultation via stethoscope is expected to be an unreliable technique in providing diagnostic information due to the significant observer variability and has low agreement amongst observers in current clinical practice (Sovijärvi et al. 2000c; Elphick et al. 2004; Marques et al. 2006; Murphy 2008). Unlike other diagnostic tests such as chest radiograph and HRCT that are more objective in providing diagnostic information of respiratory diseases, auscultation depends highly on the assessors, in particular on how they interpret the patients' lung sounds.

Findings from previous studies have revealed that the reliability of auscultation are affected by the terminology of lung sounds used amongst observers to describe abnormal lung sounds (Pasterkamp et al. 1987 ; Wilkins et al. 1990; Levy et al. 2004), trained and experienced observers in recognition of abnormal lung sounds in respiratory field (Kiyokawa et al. 2001; Prodhan et al. 2008) and environment setting during auscultation process; whether the assessment is being done in a noisy ward or a quiet room (Workum et al. 1986 ; Prodhan et al. 2008).

Table 4.1 Reliability studies of health professionals in auscultating of lung sounds

Author, year and country	Study type	Participant	Outcomes	Key results
Melbye et al. (2016), Europe.	Cross-sectional.	12 observers (six paediatricians and six physicians) were asked to listen to the same 20 pre-recording lung sounds using and classify the lung sounds according to nomenclature (fine and coarse crackles, high-pitched and low-pitched wheezes)	Inter-observer reliability in classifying lung sounds according to the standard nomenclature.	Kappa scores, k: Detailed description of lung sounds (e.g., fine crackles, coarse crackles, low-pitched wheezes and high-pitched wheezes on inspiration and expirations) = ranging between 0.0 – 0.40, indicates poor to fair agreement) Combined categories of crackles = 0.6 (moderate agreement) Combined categories of wheezes = 0.59 (moderate agreement)
Morrow et al. (2010), Africa.	Prospective, test-retest reliability.	10 raters (six physiotherapists; four paediatricians) were asked to listen to 20 pre-recorded breath sounds (five were	Inter and intra-rater reliability of identifying bronchial breath sound in children before and after educational intervention.	Kappa scores, k: Inter-observer reliability = 0.3 (indicates fair agreement) Intra-rater reliability = 0.01- 0.6 (indicates poor to moderate agreement)

		bronchial breathing sounds and 15 were normal lung sounds) which have been recorded using digital stethoscope from infants on two separate occasions (before and after education intervention).	Sensitivity and specificity before and after educational intervention.	Sensitivity: 58% to 78% Specificity: 77% to 72%
Prodhan et al. (2008), America.	Prospective, test-retest reliability to compare conventional stethoscope auscultation with computerised aided lung sound analysis (CALSA).	Three groups of healthcare professionals (one physician, 11 nurses and 11 respiratory therapists) were asked to auscultate the same 11 patients at baseline and then every hour for six hours. At the same time, data recorded by a computerised respiratory sound monitor were analysed by a trained technician. Then these recorded data were listened to by four expert panel.	Inter-observer reliability of wheeze detection in children. Sensitivity	Kappa scores, k: Physician versus nurses=0.76; Physician versus respiratory therapists=0.76; Nurses versus respiratory therapists=0.76 (k scores indicate good agreement); and computerised respiratory sound analysis versus expert panel=0.42-0.54 (k scores indicate moderate agreement) Computerised respiratory sound analysis = 75%; Physician=49%; Nurses=44%; and Respiratory therapists=41%. Computerised respiratory sound analysis

			Specificity	= 76%; Physician=80%; Nurses=89%; and Respiratory therapists=87%.
Elphick et al. (2004), United Kingdom.	Prospective comparison of stethoscope auscultation and computerised aided lung sound analysis (CALSA).	Two paediatricians were asked to examine the same 102 infants using a conventional stethoscope. Meanwhile, another two paediatricians were assessed the same infants' respiratory sounds using computerised aided lung sound analysis (CALSA).	Inter-observer reliability of detecting adventitious lung sounds via auscultation. Inter-observer reliability of detecting adventitious lung sounds via CALSA by different assessors. Intra- observer reliability via CALSA by the same assessor.	Kappa scores, k: Wheeze = 0.18; rattles = 0.53 and crackles = 0.46 (k scores represent poor agreement for wheeze, moderate agreement for rattles and crackles). Wheeze = 0.24; rattles = 0.22 and crackles = 0.44 (k scores indicate fair agreement for wheeze and rattles and moderate agreement for crackles) Wheeze = 0.57; rattles = 0.59 and crackles = 0.56 (All k scores indicate moderate agreement)
			Intra- rater reliability via CALSA (repeated analysis at two months).	Wheeze = 0.79; rattles = 0.77 and crackles = 0.77 (All k scores represent good agreement)
Levy et al. (2004), United Kingdom.	Cross-sectional to compare assessment	Two health professionals (a nurse and physician) were asked to auscultate 31	Inter-observer reliability of detecting wheeze in children.	Correlation scores, r: Acoustic analysis versus physician=0.83 (indicates good correlation);

	between conventional stethoscope auscultation and computerised aided lung sound analysis (CALSA).	children on single occasion using a conventional stethoscope. At the same time, their lung sounds were recorded by CALSA, and data were analysed by a trained technician.		Nurses versus physician=0.49 (moderate correlation).
Kiyokawa et al. (2001), Canada.	Prospective test-retest reliability.	Four physicians listened to 14 pre-recorded audio files of breath sounds on two separate occasions. The lung sounds were recorded using computerised aided lung sound recording and analysis (CALSA).	Inter and intra-rater reliability of detecting crackles.	Kappa scores, k: Inter-observer reliability = 0.6 (indicates moderate agreement) Intra-rater reliability = 0.6 (indicates moderate agreement)
Jailani and Wong (1998), Singapore.	Cross-sectional.	15 physiotherapists were asked to auscultate 10 tape-recorded lung sounds using a conventional stethoscope.	Inter-observer reliability of auscultation of lung sounds.	Kappa scores, k: Normal breath sounds = 0.12; bronchial breath sounds = 0.20; wheeze = 0.51; coarse crackles = 0.11; fine crackles = 0.21 and pleural rub = 0.02 (k scores represent moderate agreement for wheeze, fair agreement for fine crackles

				and bronchial breath sounds and poor agreement for the rest). Overall k = 0.20 (slight agreement)
Allingame et al. (1995), Australia.	Cross-sectional.	Two group of participants; 16 new graduates and 16 experienced physiotherapists auscultated 18 lung sounds from a tape player using a conventional stethoscope on one occasion.	Inter and intra-rater reliability of interpretation of tape-recorded lung sounds.	Poor agreement for inter and intra-rater reliability, k = < 0
Brooks and Thomas (1995), Canada.	Prospective test-retest reliability.	16 participants were allocated into four groups (four physiotherapists in each group) based on their clinical experience. They were asked to auscultate the same 10 patients before and after education session using conventional stethoscope.	Inter-observer reliability of auscultation of lung sounds before and after education session.	Kappa scores, k: i. Determine abnormal from normal lung sounds according to four groups. Pre-education = 0.13-0.48 Post-education = 0.37-0.99 ii. Determine specific abnormal lung sounds, e.g., crackles, wheeze, etc. Pre-education = -0.02 – 0.59 Post-education = -0.30 – 0.77 (k scores indicate poor to moderate

				agreement before the education session but agreement was fair to good after the education session).
Brooks et al. (1993), Canada.	Cross-sectional.	26 specialised physiotherapists were asked to auscultate five lung sounds from an audio recording using a conventional stethoscope.	Inter-observer reliability of auscultating tape-recorded lung sounds.	Kappa score, k: Inter-observer reliability = 0.26 (k score reflects fair agreement).
Baughman et al. (1991),	Cross- sectional study to compare crackles between IPF and sarcoidosis.	Two observers were asked to auscultate the same 11 patients with IPF and 17 patients with sarcoid using a conventional stethoscope. Another two observers were asked to review roentgenograms (12 sarcoid, nine IPF). They were asked to grade their findings on a four-point scale for fibrosis (4 quadrants) or crackles (fine/coarse crackles; timing;	Inter-observer reliability of auscultation (fibrosis) and chest roentgenograms (fibrosis).	Kappa score, k: Inter-observer reliability based on score using a four-point scale of crackles/fibrosis= 0.46, auscultation; 0.45, roentgenograms. (k scores indicate moderate agreement). Overall agreement of score using a four-point scale: i. chest roentgenograms: 70% (sarcoid); 75% (IPF) ii. auscultation: 94% (sarcoid); 58% (IPF)

		loudness; profusion).		Agreement of fibrosis in chest roentgenograms: 75% agreement on the presence or absence of fibrosis. Agreement of crackles in auscultation: 75% agreement on the presence or absence of crackles using auscultation. 82% agreement on profusion and loudness.
Aweida and Kelsey (1990), Canada.	Cross-sectional.	27 non-specialised physiotherapists were asked to auscultate five lung sounds from a tape-recording using aconventional stethoscope.	Inter-observer reliability of auscultating tape-recorded lung sounds.	Kappa score, k: Inter-observer reliability = 0.22 (k score indicates fair agreement).
Spiteria et al. (1988), United Kingdom.	Cross- sectional.	24 physicians were allocated into six groups in which each group were examined the same four patients using aconventional stethoscope.	Inter-observer reliability of detecting adventitious sounds in respiratory diseases.	Kappa score, k: Wheeze = 0.51, pleural rub = 0.51 and crackles = 0.41 were moderate agreements, and bronchial breathing = 0.32 fair agreement.

Workum et al. (1986), America.	Prospective test-retest reliability.	Two participants (a physician and a trained technician) were asked to auscultate 64 asbestos-exposed workers directly using a conventional stethoscope. After six weeks, they listened again to the same lung sounds which had been audio recorded.	Inter and intra-rater reliability of detecting crackles via in-vivo chest auscultation and tape-recorded auscultation.	Kappa score, k: Inter-observer reliability (in-vivo) = 0.73 (functional residual capacity (FRC)); 0.57 (residual volume (RV)) Inter-observer reliability (tape-recorded) = 0.69 (FRC); 0.53 (RV) Intra-rater reliability (tape-recorded): FRC= 0.77 & 0.58; RV = 0.79 & 0.39

Table 4.1 summarises 14 studies within the literatures in this field regarding inter and intra-observer reliability of lung sounds auscultation among health professionals. The search strategy for this literature review has been discussed in Chapter 1 under subsection 1.3. The search of literatures was extended from the year 1986 to 2017. There is no latest study on the reliability of healthcare professionals in detecting abnormal lung sounds found after the year 2016. It is difficult to predict why this work has not been done recently, but it is worth saying that this might be because researchers are less interested due to the advancement of technology. So, the demands of work to investigate the computerised lung sounds analysis are higher compared to the traditional human auscultation in detecting abnormal lung sounds from patients with respiratory conditions. Hence, the interest to investigate the reliability of healthcare professionals in detecting abnormal lung sounds has declined.

In addition, it is reflected from the review of literature that auscultation of lung sounds has changed over the last 30 years. This shows that the technology used for auscultation process particularly in recording and analysing lung sounds has evolved, from using a conventional stethoscope to using an electronic stethoscope. In addition to that, now that the electronic stethoscope has been equipped with signal processing using computerised technique to analyse lung sounds for patients with respiratory diseases. However, the reliability and feasibility of the computerised lung sounds recording and analysing tool to be used as bedside methods in clinical setting are still being developed (Marques et al. 2006; Flietstra et al. 2011; Marques et al. 2014). Furthermore, this sophisticated computerised lung sounds analysis might not always be accessible to healthcare professionals particularly in primary care and the developing countries. Therefore, the regular auscultation process using standard stethoscope should be continued to be taught and practised among healthcare professionals in clinical settings.

It can be seen from the reviewed literature in Table 4.1 most studies done have used kappa statistic (*k*) to measure the magnitude of agreement between or within observers in their reliability studies of auscultation. Most studies revealed that inter and intra-observer reliability of healthcare professionals to be poor to moderate when detecting abnormal lung sounds from tape-recorded or in vivo chest auscultation (Spiteria et al. 1988; Aweida and Kelsey 1990; Baughman et al. 1991; Brooks et al. 1993; Allingame et al. 1995; Brooks and Thomas 1995; Jailani and Wong 1998; Elphick et al. 2004; Morrow et al. 2010; Melbye et al. 2016). In contrast, only a few studies found good agreement of intra and inter-observer reliability among physicians when detecting abnormal lung sounds via standard auscultation or audio files (Workum et al. 1986 ; Kiyokawa et al. 2001; Prodhan et al. 2008). Even though there was a good agreement among physicians in identifying the presence or absence of crackles, but the failure in detection of fine, medium and coarse crackles was significant (Kiyokawa et al. 2001). Therefore, detection of adventitious lung sounds may not be solely rely on auscultation as the only assessment method. Other assessment tools including chest radiograph and HRCT of the lungs may be required to confirm the diagnosis in clinical practice.

4.4.1 Impact of sound quality on observer reliability

In general, reliability of auscultation interpretation among health professionals was found to be poor to moderate agreement within literature. This is not surprising as auscultation depends on health professionals' own hearing and ability to differentiate between different lung sound patterns (Sovijärvi et al. 2000c). In addition, human auditory recognition of crackles can be diminished by several masking effects for example, higher intensity of breath sounds masked crackles more effectively than low intensity breath sounds, fine crackles are more clearly and easily recognised than coarse crackles and large amplitude crackles are more audible than those of small amplitude (Kiyokawa et al. 2001). As a result, identification and characterisation of crackles are quite challenging during normal auscultation. Furthermore, the stethoscope has a frequency response which attenuates frequency of the lung sound about 120Hz and above and human hearing acuity is not sensitive enough to detect the lower frequency band that remains (Sovijärvi et al. 2000c).

Some of those studies (Table 4.1) used tape-recorded lung sounds for auscultation and not in vivo auscultation (Aweida and Kelsey 1990; Brooks et al. 1993; Allingame et al. 1995; Jailani and Wong 1998). This may increase difficulties in detecting abnormal lung sounds (Aweida and Kelsey 1990; Brooks et al. 1993). The abnormal lung sounds came from the tape-recorder may be compromised and not as authentic as compared to direct chest auscultation. In addition, the method used in those studies particularly in listening to the lung sounds is arguable and uncommon. The fact that participants were asked to listen to the tape-recorded lung sounds with the use of a stethoscope by placing its bell to the speaker of the tape-recorder, the researcher believes that this is unusual and improper. The pre-recorded lung sounds heard by the participants might be interfered by the extraneous noise from the surrounding, and in fact the transmission of the sounds through stethoscope might be compromised. Therefore, due to these reasons the reliability of the findings of those studies might be affected and in fact questionable. There might be a better way for participants to listen to the pre-recorded lung sounds from the tape-recorder such as by using a headphone or earphone, which was done in the present studies of this thesis.

4.4.2 Impact of study design on observer reliability

Studies that have found good agreement of intra and inter-observer reliability measured by kappa statistic with yielded k values above 0.60 (Workum et al. 1986 ; Kiyokawa et al. 2001; Prodhan et al. 2008) when detecting abnormal lung sounds can be criticised for various reasons. These studies' design only focused on the detection of presence or absence of wheezes (Kiyokawa et al. 2001; Prodhan et al. 2008) and crackles (Workum et al. 1986), not on the classification in their categories such as fine or coarse crackles and high or low pitch wheezes. Furthermore, all of the observers participated in these studies were well trained in pulmonary medicine, thus expected to have more often agreement than those without training.

In a study by Baughman et al. (1991), two trained observers assessed the presence or absence of crackles in patients with IPF and sarcoidosis. There was a good agreement within the two observers, which was 75% agreement. Nonetheless, inter-observer reliability of auscultation measured by kappa statistic using categorisation of a four-point scale for crackles found moderate agreement, k=0.46 (Baughman et al. 1991). This indicates that inter-observer agreement is better when there is only one category such as the presence or absence of adventitious sounds (Piirilä and Sovijärvi 1995). Unlike assessments done in clinical practice, clinicians had to categorise the lung sounds that they heard during auscultation into categories of fine or coarse crackles and high or low pitch wheezes instead of just identifying whether they are present or not. Therefore, the findings from those studies might not reflect what is expected in the real clinical practice.

4.4.3 Impact of environment on observer reliability

In addition, good agreement of observers' reliability can be affected by environment setting. Chest auscultation and recording of lung sounds were performed in a standardised and optimised environment of quiet rooms (Workum et al. 1986) and sound-insulated chambers (Kiyokawa et al. 2001) and not in clinical settings. These factors could contribute to the good agreement of observers in detecting abnormal lungs due to no interference of extraneous noise during auscultation. These findings therefore may not occur in real clinical situations where auscultation is usually done in noisy and busy environments such as hospital wards, emergency departments or intensive care.

Although Prodhan et al. (2008) performed lung sounds auscultation and recording in a paediatric intensive care unit, consideration to minimise the effect of noisy environment was taken into account. The procedure was performed in a large room in the intensive care unit where there were five beds that were separated by curtains from each other. Recognition of abnormal lung sounds will be more challenging if it was performed in a noisy and busy clinical settings (Kiyokawa et al. 2001). Further criticisms are that the recordings and auscultation of lung sounds were only performed in one specific chest location especially at basal area and not generalised to other parts of lung areas (Workum et al. 1986 ; Prodhan et al. 2008), and the crackles used in the audio files for detection were simulated crackles which had been generated by mathematical functions and not actual crackles from patients (Kiyokawa et al. 2001). Therefore, the findings from those studies may not be generalised in clinical settings.

4.4.4 Impact of nomenclature used amongst healthcare professionals on observer reliability

There was considerable inter and intra-observer variability among different healthcare professionals including physicians, nurses, physiotherapists and residents when detecting adventitious lung sounds via tape-recorded or in-vivo chest auscultation (Wilkin et al. 1990) (Table 4.1). One of the factors that may contribute to the significant observer variability is the variation of nomenclature used by healthcare professionals (Wilkins et al. 1990).

Wilkins et al. (1990) carried out a cross sectional survey of lung sound nomenclature survey 277 participants (233 pulmonary physicians and 54 physicians). They were asked to listen to eight tape recorded lung sounds and wrote 'free form' answers. The majority of the participants did not use a qualifying nomenclature to describe the seven adventitious lung sounds.

Therefore, the use of a standardised and consistently accepted nomenclature that is recommended by the International Lung Sounds Association of lung sounds (Mikami et al. 1987) is needed to describe adventitious lung sounds among groups of different healthcare professionals. Ultimately, coherence and precision of nomenclature used between groups of healthcare professionals are essential during assessment of patients with pulmonary diseases to avoid miscommunication and to inform better clinical decisions in providing appropriate treatment. Furthermore, these standardised nomenclatures should be taught on all undergraduate students' curriculums and also in-service training for all healthcare staff.

4.4.5 Impact of prior experience on observer reliability

A few studies have shown that clinical experience has no effect on reliability in detecting adventitious lung sounds via auscultation (Brooks et al. 1993; Allingame et al. 1995; Brooks and Thomas 1995). Inter-observer reliability measured by the kappa statistic found that there were similar scores in both specialised physiotherapists (k=0.26) and non-specialised physiotherapists (k=0.22) which reflect fair agreement in detecting adventitious lung sounds (Aweida and Kelsey 1990; Brooks et al. 1993).

However, in these studies there were relatively small sample sizes which may affect the external validity of their findings (Bowling 2014). Under powered studies may have a higher risk of resulting in a type II error which may lead to an underestimation of reliability (Brooks and Thomas 1995). Thus, the findings from these studies have limited their generalisability to the wider population of interest due to poor external validity (Bowling 2014).

Furthermore, two of these studies have used the bell of the stethoscope, instead of the diaphragm to auscultate lung sounds from tape-recording (Aweida and Kelsey 1990; Brooks et al. 1993). This is an unusual clinical practice for lung sounds examination among physiotherapists. The finding of fair inter-observer reliability in these studies gave an insight that it is essential to use other objective measurement tools instead of a stethoscope alone when examining patient with respiratory conditions.

4.4.6 Impact of training and educational intervention on observer reliability

Training and education sessions have definite effect in reliability of auscultation. Brooks and Thomas (1995) found that there was a statistically significant improvement of inter-observer reliability in detecting adventitious lung sounds after an education session in new graduate physiotherapists ($p<0.0001$). In general, they found that inter-observer reliability improves from poor to fair agreement prior to education to fair to almost perfect agreement afterword amongst groups of physiotherapists. The findings indicate that participants appeared to benefit from the education session. However, these findings may not be generalised to the general population of physiotherapists due to the small sample size and also participants were all recruited from the same institution.

On the other hand, Morrow et al. (2010) found that there was no reliability improvement following the education session. The findings of inter-observer reliability were similar at baseline and after the education session, which was fair agreement. However, they found that sensitivity of participants in detecting bronchial breathing sounds was increased from 58% at baseline to 74% following the education session and minimal change in specificity. It was argued that maybe the quality and quantity of the education sessions were unable to help participants to interpret bronchial breathing precisely. Indeed, acquisition of competence and expertise in clinical skill require continuous up to date educational training throughout the career (Benner 2001).

In general, there is consistency within the literature that the inter and intra-observer reliability of interpretation of auscultation findings among healthcare professionals is poor to moderate agreement (Marques et al. 2006). The more categories to be considered during the assessment for example grading or timing of sounds, the poorer the agreement among observers will be (Workum et al. 1986 ; Piirilä and Sovijärvi 1995; Melbye et al. 2016). This suggests that the interpretation of auscultation findings are difficult and vary among healthcare professionals (Piirilä and Sovijärvi 1995). Elphick et al. (2004) and Morrow et al. (2010) suggested that stethoscope auscultation is unreliable for assessing respiratory sounds and therefore, clinical decisions cannot rely solely on these. Furthermore, they confirmed that standard auscultation using stethoscope cannot be used as a gold standard outcome measure to assess before and after treatment interventions in clinical research (Elphick et al. 2004; Morrow et al. 2010).

Although there is criticisms of standard auscultation, it remains clinically useful and provides essential information when done by a knowledgeable and trained health professional with the support from quantitative computerised acoustic technology in clinical setting (Murphy 2008). This has been supported by a study of Levy et al. (2004) which found that there was a highly significant correlation between acoustic analysis of wheeze score and the wheeze score of the physician ($r=0.83$; $p<0.0001$) in detecting wheeze among young children.

The findings from the literature seem to have consensus that the majority of healthcare professionals have little regards for chest auscultation (Murphy 2008). Moreover, the presence of adventitious lung sounds including crackles, wheezing and rhonchi have considerable overlap in common conditions such as asthma, pneumonia, chronic obstructive pulmonary disease, IPF and congestive heart failure which may cause difficulty to identify states of the diseases (Vyshedskiy et al. 2005; Murphy 2007; Vyshedskiy et al. 2009; Flietstra et al. 2011). As a result, this can lead to misinterpretation of auscultation findings especially in a rare and chronic lung disease like IPF. Crackles that are presence in IPF could be misinterpreted from those in congestive heart failure and pneumonia which can lead to the inappropriate treatment given (Murphy 2008). As a consequence, patients with IPF may suffer from serious and unwanted side effects such as dehydration due to diuretics administration or adverse reaction to an antibiotic administration (Murphy 2008; Flietstra et al. 2011).

4.5 Problem statement

Globally, incidence of IPF is rising (Hutchinson et al. 2015) and its mortality rates also appear to be rising (Marshall et al. 2018; Algranti et al. 2017) with consequential increasing of economic burden on global health care (Diamantopoulos et al. 2018). Therefore, there is an urgent need for an early and precise identification of IPF amongst patients in order to assist them with better prognosis and optimise treatment option at an early stage of the condition (Barratt et al. 2018). The main issues in the diagnosis of IPF are the necessity of advanced diagnostic tools including high-resolution computed tomography (HRCT) and lung biopsy, and specialised pulmonologists and experienced multidisciplinary teams in order to obtain a definite diagnosis of IPF, which usually only available in tertiary hospitals (Sellarés et al. 2016). Apparently, patients might have the potential to be misdiagnosed if the healthcare professionals in primary care are less experienced with this disease and in fact it might lead to the delay in referring patients to a tertiary centre (Murphy 2008). A delay in obtaining a correct diagnosis may lead to ineffective early interventions resulting in a poor prognosis (Hosenpud et al. 1998).

Currently, there is no curative therapy available for IPF and the only aim of the current therapy is to delay the progression of IPF (Sellarés et al. 2016).

Therefore, an accurate diagnosing of IPF at an early stage is a critical matter for safe and effective treatments to help IPF patient with a better prognosis (Sgalla et al. 2016). Cottin and Recheldi (2014) revealed that an early identification of Velcro crackles during lung auscultation assessment of patients is a key element of early diagnosis in IPF disease. Besides, Sellarés et al. (2016) found that Velcro crackles were distinguished in all of the patients who have a final diagnosis of IPF during lung auscultation in their study, and this indicates that detecting of Velcro crackles might give an early warning of the presence of lung fibroses for an early diagnosis of IPF. For this reason, it is essential that any health professional including those in primary healthcare who may come into contact with a patient, may need to receive training on how to identify the characteristics of Velcro crackles during pulmonary auscultation for an earlier diagnosis of IPF. Consequently, patients who have presented Velcro crackles during auscultation and suspected for IPF can be referred to receive pulmonary rehabilitation programme at an earlier stage. This appropriate clinical decision in IPF management may enhance a better prognosis for patients and lead to a better quality of life for their remaining years.

Finding from the literature review shows a high percentage of the studies (Table 4.1) were focused on inter and intra-observer reliability in the detection of adventitious lung sounds in patients with common respiratory illness including asthma, asbestos and lower respiratory tract disease (Workum et al. 1986 ; Pasterkamp et al. 1987 ; Spiteria et al. 1988; Brooks and Thomas 1995; Elphick et al. 2004; Levy et al. 2004; Prodhan et al. 2008; Morrow et al. 2010) while the rest of them investigated the reliability of detection adventitious lung sounds using tape-recoded sounds selected from an-audio tape/book learning resource. To the best of the researcher's knowledge, only one single study has investigated inter-observer reliability in detection of crackles in patient with sarcoidosis and cryptogenic fibrosing alveolitis/IPF (Baughman et al. 1991). Therefore, there is a paucity of available data from previous studies on the impact of training on inter and intra-observer reliability in detection of presence Velcro crackles in a rare lung disease like IPF. Moreover, the accuracy of healthcare professionals in detecting Velcro crackles in patients with IPF has never been properly assessed. It is critical that all health professionals to be accurate, sensitive, specific and at the same time they are agree with one another in detecting Velcro crackles so that such decisions are precise and consistent. Hence, an appropriate clinical decision could be made.

It is a critical need for any health professional in Malaysia specifically respiratory physiotherapists who may treat a patient to receive the training on how to detect Velcro crackles. It is a necessity for respiratory physiotherapists in Malaysia to acquire this skill, since there is an existence of theory and clinical practice gap in physiotherapy education during their pre-qualifying programme. This skill training of Velcro crackles detection could be delivered through CPD courses which is in line with one of the World Confederation for Physical Therapy strategic outcomes 2017-2021 in order to promote excellence in physiotherapy education and practice (World Confederation for Physical Therapy 2017). Furthermore, the constraint of physiotherapy workforce in Malaysia (Nordin et al. 2011) should be countered by the well-trained respiratory physiotherapists especially at the primary care to optimise clinical services of patient care and pulmonary rehabilitation for IPF condition. This training could enhance them to be more accurate, sensitive, specific and reliable in identifying Velcro crackles in order to facilitate early detection of IPF in clinical setting, provide better clinical decisions and lead for a better quality of life for patients with IPF.

As a result, it is recommended that future research should evaluate the reliability of health professionals' detection of Velcro crackles in IPF patients. This research aims to evaluate the impact of a training session on the reliability of Malaysian respiratory physiotherapists' detection of Velcro crackles in IPF patients recorded in clinical conditions, thus may contribute important new data to the existing limited literature in this area. The preliminary study (study one) will explore the impact of a training session on observer reliability in detecting Velcro crackles. This work will focus on respiratory physiotherapists who currently working in respiratory field in one institution which is the Universiti Kebangsaan Malaysia Medical Centre.

Meanwhile, the second study will further improve and develop its design and sample size to overcome several limitations from the preliminary study. Participants will be recruited from various institutions (n=4) in Malaysia to enhance the sample size of study. Furthermore, there is a paucity of data on the long-term effects of abnormal lung sounds detection training among clinicians. To the researcher's knowledge, only Morrow et al. (2010) have conducted eight weeks follow-up assessment of inter-observer reliability amongst participants. Therefore, a longitudinal mixed-methods study design will explore the impact of training on Malaysian respiratory physiotherapists' ability to detect Velcro crackles over time.

The overall aim of the research is to increase the understanding regarding the impact of a training session on Malaysian respiratory physiotherapists' ability to detect Velcro crackles from pre-recorded lung sounds of patients with IPF. To achieve this aim, the following specific research aims for the study one and study two are proposed.

The specific aims in the study one will be:

i. To evaluate intra-observer reliability of the Velcro crackles in IPF patients within same physiotherapist in Group A (trained for Velcro crackles detection) and B (untrained).

ii. To determine intra-observer reliability of Velcro crackles before and after training sessions within same physiotherapists in Group B.

iii. To assess inter- observer reliability of the Velcro crackles in IPF patients among physiotherapists in Group A (trained) and B (untrained).

iv. To examine inter- observer reliability of the Velcro crackles before and after training sessions among physiotherapists in Group B.

Next, the specific aims of the primary quantitative component in the study two will be:

i. To evaluate the short-term effect of a training session on inter-observer reliability of Malaysian respiratory physiotherapists in detecting Velcro crackles from patients with IPF.

ii. To determine the long-term effect of a training session on inter-observer reliability of Malaysian respiratory physiotherapists in detecting Velcro crackles from patients with IPF.

iii. To investigate the short-term effect of a training session on Malaysian respiratory physiotherapists' accuracy, sensitivity and specificity in detecting Velcro crackles from patients with IPF.

iv. To examine the long-term effect of a training session on Malaysian respiratory physiotherapists' accuracy, sensitivity and specificity in detecting Velcro crackles from patients with IPF.

The specific aims of the secondary qualitative component in the study two will be:

i. To explore Malaysian respiratory physiotherapists' clinical experiences of Velcro crackles detection at baseline and after the training session.

ii. To explore Malaysian respiratory physiotherapists' perceptions of the training session for Velcro crackles detection.

iii. To explore respiratory physiotherapists' experiences of skill retention and skill transfer in clinical practice at two months follow-up.

4.6 Summary

In general, the findings from the literature have discovered that auscultation using a conventional stethoscope is controversial. However, healthcare professionals have always performed respiratory auscultation and it is a practical assessment in clinical settings. Therefore, there is a need of proper training session for healthcare professionals that might potentially improve their reliability of auscultation to identify abnormal lung sounds in patients with respiratory conditions. Moreover, the incidence of IPF worldwide seems to be increasing over time and there is a need to train healthcare professionals to detect Velcro crackles during auscultation and help with earlier diagnosis of IPF in clinical settings.

Chapter 5: Methodology

5.1 Introduction

This chapter will describe the methods used for two studies which are study one and two. Study one involves a preliminary of reliability study which was to explore the ability of respiratory physiotherapists in detecting Velcro crackles in patients with IPF. Study two is an extension of study one which used a longitudinal mixed methods research design to further explore the impact of a training session on Malaysian respiratory physiotherapists' competency to detect Velcro crackles in patients with IPF. The following sections will discuss in detail the work that has been performed in this research.

5.2 Study One: A preliminary study of the impact of training on reliability of respiratory physiotherapists' detection of Velcro crackles in IPF patients.

5.2.1 Research aims

The primary aim of the research was to investigate the impact of training on the reliability of respiratory physiotherapists' detection of Velcro crackles in IPF patients.

The specific aims in this study were:

i. To evaluate intra-observer reliability of the Velcro crackles in IPF patients within same physiotherapist in Group A (trained for Velcro crackles detection) and B (untrained).

ii. To determine intra-observer reliability of Velcro crackles before and after the training sessions within same physiotherapists in Group B.

iii. To assess inter- observer reliability of detecting Velcro crackles in IPF patients among physiotherapists in Group A (trained) and B (untrained).

iv. To examine inter- observer reliability of the Velcro crackles before and after the training sessions among physiotherapists in Group B.

5.2.2 Research questions

The research questions were as below:

5.2.2.1 Intra-observer reliability study

i. Are the same physiotherapists reliable in detecting Velcro crackles in Group A (trained) and B (untrained)?

ii. Are the same physiotherapists reliable in detecting Velcro crackles in Group B, before and after training sessions?

5.2.2.2 Inter-observer reliability study

i. Are different physiotherapists reliable in detecting Velcro crackles in Group A (trained) and B (untrained)?

ii. Are different physiotherapists reliable in detecting Velcro crackles in in Group B, before and after training sessions?

5.2.3 Research hypothesis

The main hypothesis of the study was that there will be good reliability (k>0.61) of respiratory physiotherapists' detection of Velcro crackles in IPF patients.

Other hypotheses were:

i. There will be good reliability (k>0.61) of the intra and inter-observer detection of Velcro crackles in IPF patients after the training.

ii. There will be an improvement in reliability (k>0.61) of the same group physiotherapists' detection of Velcro crackles in IPF patients after the training session.

The elements in this reliability study included:

a. Identification or recognition of crackle sounds.

b. Categorisation of any crackle sounds identified (coarse crackles and/or fine crackles).

c. Nature of the crackle sounds (Velcro in nature or non-Velcro).

5.2.4 Research design

A test-retest design was used in this study to evaluate intra and inter-observer reliability of lung sound interpretation when listening to pre-recorded lung sounds files. This reliability design was selected over cross-sectional design because of the researcher aimed to investigate the impact of Velcro crackles training on reliability of participants in detecting Velcro crackles over time. This might indicate the extent to which the results obtained by multiples observers agree for similar after the training and the extent to which the results can be reproduced when the research is repeated under the same conditions (Bowling 2014). These findings might be valuable for clinical practice where therapists should have similar agreement amongst them, as well as they are consistent when interpreting the lung sounds over time in respiratory patients for better clinical decision making and better patients outcomes. In contrast, cross-sectional design measures outcomes only at a point in time across a sample population and it usually used to measure prevalence of outcomes (Bowling 2014), hence it unable to answer this research questions.

Participants were randomly assigned into two. Participants in Group A were given a training session to listen to Velcro crackles, while those in Group B were did not receive any training prior to the first assessment session. One week after the first assessment, participants from group B received the same training as Group A. Then, a second assessment was repeated in Groups A and B.

During Assessment 1, all participants in both Group A and B were given two sets of audio pre-recoded lung sounds consisting of 20 lung sounds for each set. These same pre-recorded lung sounds files were presented twice in two CDs in order to test intra-observer reliability. Group A was given two CDs which were

Test 1-A & Test 2-A and Group B was also given two CDs which were Test 1-B & Test 2-B. The same pre-recorded lung sounds files were given to both groups. Later, during Assessment 2 in week two, they were given another two sets of CDs with 20 recording lung sounds files each (Test 3-A & Test 4-A for Group A; Test 3-B & Test 4-B for Group B). Again, these same pre-recorded files were also presented twice to both groups. Participants were asked to listen to two sets of pre-recorded lung sounds files from two CDs within one-week duration at their convenience and to record their findings using the assessment form (Appendix A) given during each Assessment; 1 and 2. The time interval between Assessment 1 and 2 was one week in duration.

Intra-observer reliability

Intra-observer reliability of the Velcro crackles sounds within the same physiotherapist in Group A (trained) and B (untrained) were tested using two data sets of recording files, which were presented twice during Assessment 1: Test 1-A & Test 2-A for Group A; Test 1-B & Test 2-B for Group B. Intra-observer reliability for the same physiotherapists in Group B, before and after training were evaluated using two data sets which were presented twice during each assessment: Test 1-B & Test 2-B at Assessment 1, before training; and Test 3-B & Test 4-B at Assessment 2, after training session. Intra-observer reliability for Group A during Assessment 1 and 2 were assessed using data sets from: Test 1-A & Test 2-A at Assessment 1; and Test 3-A & Test 4-A at Assessment 2.

Inter-observer reliability

inter-observer reliability was assessed among different physiotherapists in Group A (trained) and B (untrained) using data sets from: Test 1-A & Test 2-A for Group A at Assessment 1; and Test 1-B & Test 2-B for Group B at Assessment 1. Inter-observer reliability for group B before and after training were tested using data sets from: Test 1-B & Test 2-B at Assessment 1, before training; and Test 3-B & Test 4-B at Assessment 2, after training session. Finally, inter-observer reliability for Group A during Assessment 1 and 2 were assessed using data sets from: Test 1-A & Test 2-A at Assessment 1; and Test 3-A & Test 4-A at Assessment 2.

5.2.5 Participants

Participant recruitment occurred at the Universiti Kebangsaan Malaysia Medical Centre (UKMMC), Kuala Lumpur, Malaysia. Physiotherapists with a minimum of two years of clinical practice in respiratory physiotherapy were eligible to participate. These physiotherapists were chosen because they have had time to gain clinical experience in listening to lung sounds. Fourteen respiratory physiotherapists at UKMMC were eligible to take part.

5.2.6 Recruitment

Recruitment was done via Suhaila Shohaimi (Head of the Physiotherapist Unit) at the Universiti Kebangsaan Malaysia Medical Centre. She agreed to hand out information packs to her staffs. Fourteen information packs consisting of a letter of invitation (Appendix B), a participant information sheet regarding the study (Appendix C), a reply slip (Appendix D) and a stamped, addressed envelope were administered to potential participants.

This allowed the invited physiotherapists to make an informed decision on whether they were interested and willing to participate in the study. In addition, they were given an opportunity to contact the researcher for further information. Interested physiotherapists who returned the reply slip to the researcher and agreed to participate were contacted via telephone to arrange a suitable time to meet them. Eligible physiotherapists who met the requirements of the inclusion and exclusion criteria signed a consent prior to participating in this study (Appendix E).

5.2.7 Sample size

There were 14 respiratory physiotherapists at the UKMMC who were eligible to participate in this study. It was expected that very few physiotherapists did have sufficient experience in respiratory care to be eligible, as this is a specialised field.

Therefore, the aim was to recruit up to 14 participants as a convenience sample. A power calculation was not appropriate because this was exploratory study.

5.2.8 Inclusion criteria

- Qualified physiotherapist with a minimum of 2 years of experience in respiratory physiotherapy.
- Qualified physiotherapist who was currently practicing clinically in the respiratory field.

5.2.9 Exclusion criteria

- Anyone using internal or external hearing aid devices. This may impair their interpretation of Velcro crackles detection during listening to the pre-recorded lung sounds files
- Anyone over 50 years (to minimise risk of age-related hearing impairment). Hearing impairment may reduce their ability to detect Velcro crackles during listening the pre-recorded lung sounds files.
- Physiotherapist who has not practicing respiratory physiotherapy. This is because they have no enough experience in interpreting lung sounds from auscultation.

As this study needed for physiotherapists to detect the Velcro crackle sounds from the lung sounds recordings, physiotherapists with a hearing aid or hearing impairment might not be suitable and were excluded in this study. This is because they might not be able to distinguish the abnormal and normal lung sounds precisely during the assessments. This is important to control the confounding factor and to protect internal validity of the study findings.

5.2.10 Random assignment

Random assignment was used to assign the sample size that has been drawn, into two groups in this study. Participants were stratified by number of years of working experience in respiratory physiotherapy and matched them into two groups. These procedures were done to prevent confounding variable which may distort the findings of this study (Bowling 2014). Strata one included senior respiratory physiotherapists with at least 5 years of experience (senior) and strata two included junior respiratory physiotherapists with a minimum of 2 years to 4 years of experience in respiratory field. The classification of clinical experience is based on the recommendation by Brooks and Thomas (1995).

There were 14 respiratory physiotherapists who were currently eligible to participate in this study. Only 12 participants agreed to take part in this study. There were two participants in strata one (senior) and 10 participants in strata two (junior). Then, random numbers were generated by computer using an excel program towards each strata (senior and junior). Each participant was assigned with a random number by the program.

They were randomly assigned into two groups (A and B) with six participants in each group. The first participant from strata one (senior) and the first five participants from strata two (junior) were allocated into Group A (trained participants). Meanwhile, the next second participant from strata senior and the remaining five participants from strata junior were allocated in Group B (untrained participants).

5.2.11 Lung sound data

The lung sound data used in this reliability study have been provided by Professor Luca Richeldi and were previously recorded from 56 patients with respiratory disease. Lung sounds were recorded using the Littmann 3200TM electronic stethoscope (3M, USA) which was held manually over six different anatomical locations on the patients' posterior thorax and axilla. Six different anatomical chest locations for auscultation were marked with electro-metallic markers on the chest posteriorly and laterally (Table 5.1). Recordings were made by a single assessor using the electronic stethoscope in a quiet room with the patient sitting on chair. The patient was asked to breathe deeply through the mouth during recordings. The diaphragm of stethoscope was kept as still as possible during recordings to minimise added noise.

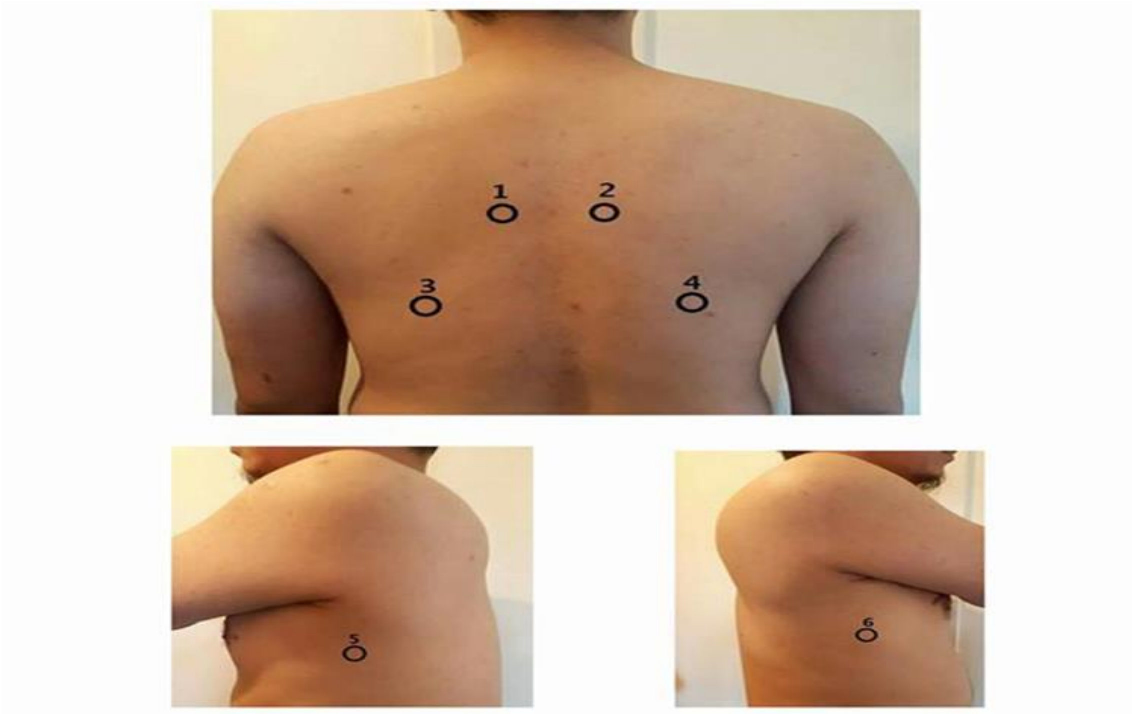

Figure 5.1 Anatomical location of lung sounds recordings

Table 5.1 Anatomical location of lung sounds recordings

Chest	**Locations of recordings**
Posterior	1. Left middle thorax at 2 cm from the paravertebral line, in the fourth or fifth intercostal spaces.
	2. Right middle thorax at 2 cm from the paravertebral line, in the fourth or fifth intercostal spaces.
	3. Left lung base at 5 cm from the paravertebral line and 7cm below the scapular angle.
	4. Right lung base at 5 cm from the paravertebral line and 7cm below the scapular angle.
Lateral	5. Left of the fourth and fifth intercostal space at mid axillary line
	6. Right of the fourth and fifth intercostal space at mid axillary line

These six different anatomical locations of the chest were used for lung sounds recording as recommended by the European Respiratory Society which have proved to be the most relevant by the investigators (Rossi et al. 2000). A single recording was made for 15 seconds at each marked location. There were pre-recorded audio files from 28 patients described as "fibrotic" by the radiologists who interpreted their HRCT scans, and 28 "non-fibrotic" patients who were matched for age and sex. Forty pre-recorded sound files were used in this study based on the expected time commitment possible for each physiotherapist. These sound files included 20 recordings from patients described as fibrotic and 20 from non-fibrotic patients.

There were 20 lung sounds recording files (from 10 fibrotic (Velcro crackle sounds) and 10 non-fibrotic patients (consist of 5 normal lung sounds, 2 wheezes and 3 coarse crackles) downloaded into a CD by the researcher. These same 20 files were presented twice in another CD and were given to participants to assess during Assessment 1. There were 20 lung sounds files in each CD. In total, there were two CDs with 40 recording files were given to each participant at Assessment 1. During Assessment 2, another 20 recording files (from 10 fibrotic (Velcro crackle sounds) and 10 non-fibrotic patients (consist of 5 normal lung sounds, 2 wheezes and 3 coarse crackles) were also presented twice in two CDs to the participants. In total, each participant was asked to assess 40 recording files at Assessment 2. The decision to include the stated numbers of different lung sounds as above due to the clarity and quality of available pre-recorded lung sounds received from Professor Luca Richeldi.

The CDs of pre-recorded lung sounds were chosen over in-vivo auscultation during lung sounds assessment in this study after considering the limitation of the stethoscope itself, that has been discussed in section 4.4.1 and other factors. It is because the stethoscope has a frequency response that diminishes frequency components of the lung sound signal above 120Hz, and the human ear is not very sensitive to the lower frequency band (Sovijarvi et al. 2000c). Therefore, the used of CDs could help the participants to detect the lung sounds in this study. Moreover, the used of CDs allowed all participants in this study to listen to the similar and consistent lung sounds acoustic throughout the assessments. Once the participants become familiar or expect with recognition of the Velcro crackle sounds, they will become more attentively while listening to detect Velcro crackles in real practice via stethoscope.

5.2.12 Data collection procedure

Written informed consents from participants were obtained prior to data collection. The researcher collected demographic data and information about their experience with IPF patients as well as Velcro crackles (Appendix F). During assessment one, a training session for Velcro crackles detection was only given to Group A (trained). All willing participants were given approximately 30 minutes of training presented via PowerPoint slides by the researcher. Training slides consist of information about IPF disease, definition and characteristics of Velcro crackles, relevance of the phase of respiration which Velcro sounds usually occurred and examples of Velcro crackles sounds, normal lung sounds and other abnormal lung sounds. Participants were opened to discussion and clarify their inquiries related to the IPF and Velcro crackles. Then, participants were allowed to listen to a number of pre-recorded Velcro crackles, other abnormal lung sounds and normal lung sounds for comparison from a CD using Audacity Software in desktop or laptop to prior to the assessment. There were 13 files of recorded lung sounds including Velcro crackles (5 files), normal lung sounds (2 files), wheezes (2 files), coarse crackles (2 files) and plural rub (2 files) (each file lasting for 15 seconds) in the training CD. Participants were allowed to listen to them repeatedly using the standard over-ear headphones provided until they were confident to start the assessment. Participants were trained in a group during their lunch hour break. During training, the auditory and visual information of the Audacity software was used to ensure deeper understanding and familiarisation of characteristics of different lung sounds. Participants were able to listen and watch the lung sound waves simultaneously which might able to stimulate their audio and visual sensory. These input will further enhance their skill acquisition in detecting Velcro crackles. The disadvantage of using this audio and visual information is that, it could not be apply in real practice during pulmonary auscultation. Normally, clinicians use a standard stethoscope in clinical practice, thus there is no opportunity for them to have this visual information during pulmonary auscultation. Clinicians totally have to rely on their hearing acuity and skill competency to distinguish Velcro crackles or other abnormal the lung sounds.

Immediately after the training session, 20 recording files of lung sounds were given to Group A to be assessed within one-week time. There were two CDs (Test 1-A & Test 2-A) with the same 20 files, which were presented twice but in a different order of arrangement. These two CDs were given to each participant for them to listen to at their convenience time. Meanwhile, participants from Group B (untrained group) also received the same sample of 20 files as in Group A. These same 20 files were also presented twice in two CDs (Test 1-B & Test 2-B) for Group B. In total, each participant at Assessment 1 assessed 40 recording files.

Participants were invited to listen to the recordings in the environment of their choice (home/ hospital). Participants were asked to download the Audacity Software and the simple instruction sheet (Appendix G) was to given to them on how to listen to the recorded files using Audacity Software prior to listening. This software could be freely accessed and downloaded from audacity.sourceforge.net onto their personal computers. Participants were given standard over-ear headphones to be used while listening to the recorded lung sounds. They were asked to listen to the files from the two CDs and performed the task in a consistent order (complete the CD1 and then CD2), then record their findings each time, using the assessment 1 and 2 form given respectively. The task must be in a consistent order to prevent confusion during completing the assessment and to ensure all the participants were consistent when answering the tasks. They were also informed by the researcher to complete this assessment independently without having discussion with their colleagues to prevent bias. They were then requested to identify the presence or absence of crackles, quantify the type of crackles (coarse, fine or both) as well as recognise them as Velcro in nature. The data forms were collected from participants once they have completed their assessment.

After one week from Assessment 1, participants from Group B were provided with the same training as Group A prior to Assessment 2. However, no additional training session was given to Group A. Then, another sample of 20 files of lung sounds recording were given to Group A (Test 3-A & Test 4-A) and Group B (Test 3-B & Test 4-B). Again, two CDs with the same 20 files presented twice but in a different order of arrangement were given for them to listen to. In total, each participant was asked to assess 40 recording files during Assessment 2. The same procedure as described earlier was repeated in assessment two (Figure 5.2). After they completed their assessment, the researcher again collected the data forms, CDs and headphones from participants. The time interval between Assessment 1 and 2 was one week in duration.

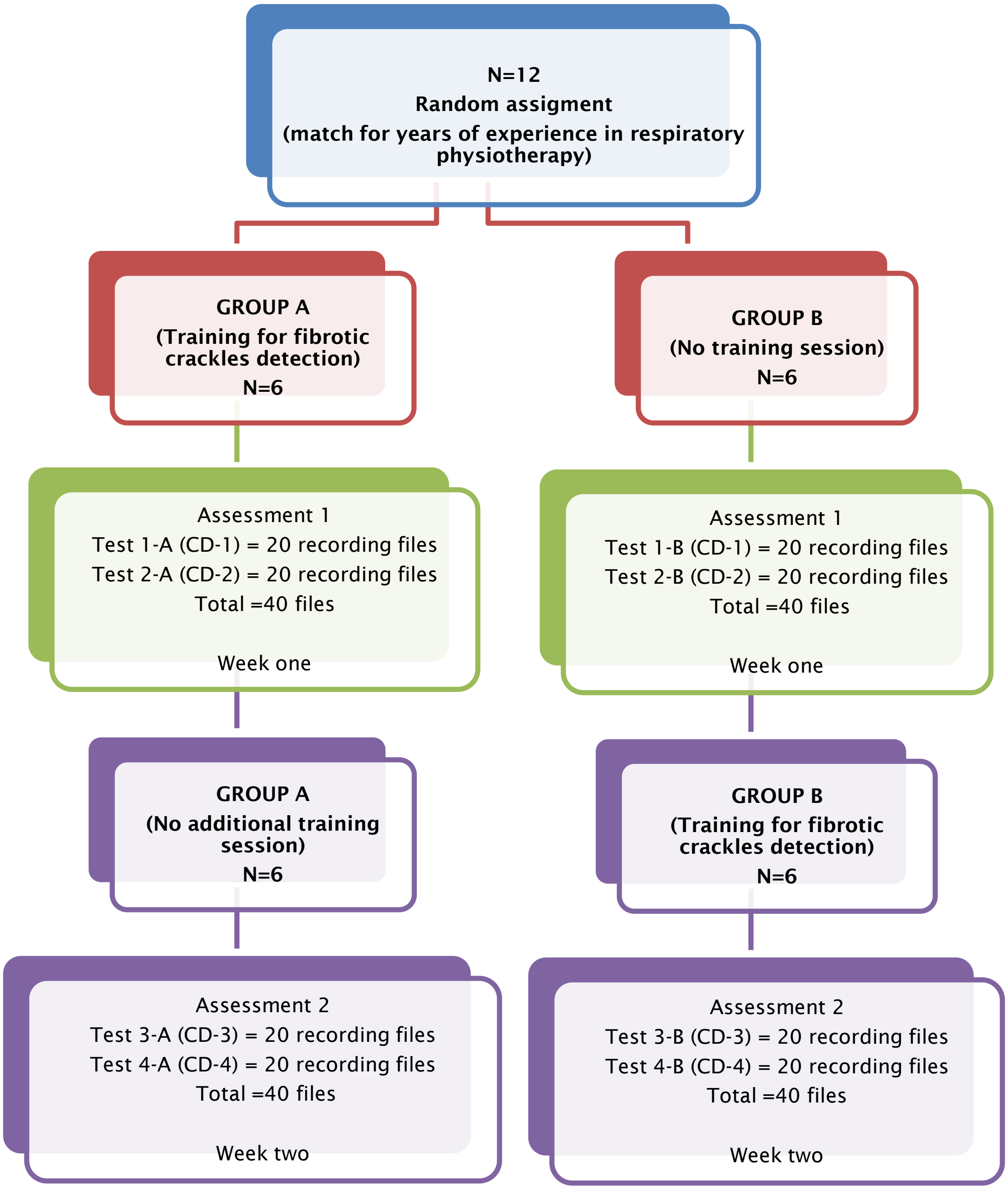

Figure 5.2 Workflow of the study procedure (study one)

5.2.13 Public involvement

Public involvement is becoming an increasingly important feature of health research, globally (Staniszewska et al. 2018). INVOLVE which is a national advisory group that supports greater public involvement and is part of the National Institute of Health Research (NIHR) in the UK, defined public involvement in research as doing research 'with' or 'by' people who use services rather than 'to', 'about' or 'for' them. It is an active partnership (INVOLVE 2012). It is an active partnership between patients, carers, and members of the public with researchers that influence and shape research (National Institute of Health Research 2021).

There are many opportunities for members of the public who are actively involved in research project such as a working researcher to identify with the research topics, making sure the research methods proposed are appropriate for patients, helping to create a recruitment plan, providing feedback on the proposed participant questionnaires and methods of collecting information to ensure the questions appropriate and easy to understand, and offering advice as members of a project (National Institute of Health Research 2019). Hence, public involvement in the health research helps to improve the relevancy of the research questions that are asked, or inform choices about research tools and outcome measures, and decide appropriate approaches to data collection, analysis, and interpretation within research (Boote et al. 2010; INVOLVE 2009).

However, there is an identified range of ongoing barriers to public involvement including public awareness, attitudes, resources, infrastructure, recognition, reward and payment, and resources and training. Although public involvement positively influences and shapes research, there is a range of barriers identified such as limited awareness of opportunities, resistant attitudes towards involvement, inconsistent levels of resources, systems that work in different ways, patchy training and support, and variable organisational implementation (Staniszewska et al. 2018).

Public involvement work was conducted prior to the study. The objective was to ensure the protocol was feasible and to refine the procedure of this study. The feasibility is important to ensure the clarity of the instruction to participants and to establish an appropriate procedure during testing. Two volunteers who were currently working in respiratory physiotherapy research from the Faculty of Health Sciences, University of Southampton were recruited. The findings from this preliminary study were however not included in the main study.

Some changes were made in the questionnaires' design. One participant complained about having difficulties to keep track of her answers in the questionnaires because there were too many columns and rows. For that reason, the rows in the questionnaires were alternately shaded darker to clearly distinguish between one another. Other than that, participants have noticed twice-repeated number of file recording in the columns of the questionnaires. Therefore, a change was made by replacing the correct file recording's number. In general, both participants reported that this test was easy to do and both of them took approximately 30 minutes to complete each session of the test, approximately one hour for both sessions.

5.2.14 Data Analysis

Information from the questionnaires were uploaded manually. Statistical analysis was carried out using the IBM Statistical Package for Service Solution (SPSS) software version 21. Demographic data including age, gender, year of qualified as a physiotherapist and experience with IPF patients and Velcro crackles were analysed using descriptive statistics.

5.2.14.1 Kappa Statistic

In this study, the same 20 recording files were presented twice for participants to listen to in order to calculate intra-observer reliability. Intra-observer reliability of the Velcro crackles within the same physiotherapist for Group A (trained) and B (untrained) during Assessment 1 were calculated using data sets from: Test 1-A & Test 2-A for Group A; Test 1-B & Test 2-B for Group B. Intra-observer reliability for the same physiotherapists in Group B, before and after training were evaluated using data sets from: Test 1-B & Test 2-B at Assessment 1, before training; and Test 3-B & Test 4-B at Assessment 2, after training session. Intra-observer reliability for Group A during Assessment 1 and 2 were assessed using data sets from: Test 1-A & Test 2-A at Assessment 1; and Test 3-A & Test 4-A at Assessment 2.

On the other hand, inter-observer reliability study was assessed among different physiotherapists for group A (trained) and B (untrained) using data sets from: Test 1-A & Test 2-A for Group A; and Test 1-B & Test 2-B for Group B. Inter-observer reliability for group B, before and after training were tested using data sets from: Test 1-B & Test 2-B at Assessment 1, before training; and Test 3-B & Test 4-B at Assessment 2, after training session. Finally, inter-observer reliability for Group A during Assessment 1 and 2 were assessed using data sets from: Test 1-A & Test 2-A at Assessment 1; and Test 3-A & Test 4-A at Assessment 2.

Data collected in this study were categorical in nature (normal and abnormal lung sounds, fine and coarse crackles, and Velcro and non-Velcro crackles). For this reason, a non-parametric test of kappa agreement was used to measure inter and intra-observer reliability on detection of Velcro crackles in patients with IPF in this study. The kappa statistic is a non-parametric quantitative analysis which gives a value of magnitude of agreement between or among observers (Viera and Garrett 2005). The kappa coefficient is determined by the difference between how much agreement is actually present (observed agreement) compared to how much agreement is expected to be present by chance alone (expected agreement) (Viera and Garrett 2005). As a result, it indicates the proportion of agreement beyond that expected by chance (Sim and Wright 2005).

This study involved more than two observers to detect Velcro crackles which multiple observers, therefore the generalisation of unweight kappa was considered most suitable to be used in this study to measure agreement among multiple observers (Fleiss 1971). The unweighted kappa coefficient (*k*) was calculated to measure the degree of agreement among multiple observers on nominal or categorical scale variables for example to determine presence or absence of adventitious lung sounds in patient with IPF (Fleiss 1971; Hanley

1987). The quantitative data in this study were nominal and categorical variables, thus unweight kappa which is non-parametric test was used for data analysis in this study. The researcher manually calculated the kappa using excel which based on the work of Fleiss (1971) using kappa equation:

$$k = \frac{\bar{P} - \bar{P}_e}{1 - \bar{P}_e} \qquad (1)$$

The quantity $\bar{P} - \bar{P}_e$ measures the degree of agreement actually attained above chance, and $1 - \bar{P}_e$ measures the degree of agreement attainable over and above that what would be predicted by chance. k values is a normalised measure of total agreement which is corrected for the amount expected by chance (Fleiss 1971).

P□ is the total extent of agreement measured by the mean of the proportion of agreeing pairs out of all the observers' possible pairs of assignment and P_i represent the proportion of agreement for the $_i$th observation. Therefore, equation for P□ is:

$$\bar{P} = \frac{1}{N} \sum_{i=0}^{N} P_i \qquad (2)$$

$$\bar{P} = \frac{1}{Nn\,(n-1)} \left(\sum_{i=1}^{N} \sum_{j=1}^{k} n_{ij^2} - Nn\right) \qquad (3)$$

where N represent the total numbers of observations, n the number of observers and k the number of categories of the scale. The subscript $_i$ represent the observations and the subscript $_j$ represent the categories of the scale. Therefore, n_{ij} represent the number of observers who assigned the $_i$th observation to the $_j$th category, P_i is the proportion of agreement for the $_i$th observation and P_j is the proportion of all assignments that were to the $_j$th category.

P□$_e$ is the mean proportion of agreement which the observers made their assignments randomly and P_j is the proportion of all assignments which were to the $_j$th category. The equation for P□$_e$ is:

$$\bar{P}_e = \sum_{j=1}^{k} p_{j^2} \qquad (4)$$

The extent of agreement for categorical data is based on the interpretation by Landis and Koch (1977) which is used to interpret this study findings. Landis and Koch (1977), have recommended the extent of agreement to ensure nomenclature consistency to describe magnitude of agreement of kappa coefficient (*k*) and this extent of agreement is frequently cited in reliability studies (Viera and Garrett 2005; Prodhan et al. 2008; Morrow et al. 2010). Kappa coefficient indicates poor agreement for $k < 0$, slight agreement 0.01-0.20, fair agreement 0.21-0.40, moderate agreement 0.41-0.61, substantial agreement 0.61-0.80 and almost perfect agreement 0.81-1.00 (Landis and Koch 1977).

5.2.14.2 Standard Error of Kappa

Standard error of kappa (SE_k) quantifies how much estimation of variability there is in kappa across samples and during repeated samples. Fleiss (1971) gives the standard error of kappa for multiple observers under the null hypothesis of no agreement. For this reason, he stated that it is practical to accept the absence of real agreement among the *n* observers because of their inability to differentiate one observation from another. Calculation of standard error of kappa is based on the recommendation by Fleiss (1971), where Var($_k$) represents the variance of kappa:

$$\text{Var}\ (k) = \frac{2}{Nn\ (n-1)} (\frac{\sum_j p_{j^2} - (2n-3)(\sum_j p_{j^2})^2 + 2(n-2)\sum_j p_{j^3}}{(1-\sum p_{j^2})^2} \qquad (5)$$

Therefore, standard error of kappa is:

$$\text{SE}_{(K)} = \sqrt{\text{Var}\ (k)} \qquad (6)$$

where Var_k is an estimate of average variability or how far of a set of data is spread out (Field 2009). p_j represents the inability of observers to distinguish one observation from another of overall rates of assignments under the hypothesis of no agreement. The SE_k of kappa is partially dependent upon sample size. In general, the more the number of observations measured by the observers, the smaller is the expected standard error of kappa which means the estimate of agreement is likely to be precise (McHugh 2012).

5.2.14.3 Sensitivity and Specificity

The sensitivity and specificity calculations for the presence or absence of Velcro were based on the findings of patients' HRCT scan as a gold standard. The HRCT scans have been interpreted by the radiologists. The sensitivity and specificity are usually used in medical literature to determine the accuracy of a diagnostic test against some existing gold standard (Pallant 2010). Sensitivity refers to the proportion of actual cases which have a positive result on a measurement tool (true positive rate) (Bowling 2010). The equation of sensitivity is:

$$\text{Sensitivity} = \frac{\text{True positives}}{\text{True positives+False negatives}} \qquad (7)$$

True positives refer to the test that is correctly identified patient with the disease, whereas false negatives refer to the patient with the disease that go undetected (Lalkhen and McCluskey 2008).

Meanwhile specificity refers to proportion of people who are not cases and have a negative test result on the tool (true negative rate) (Pallant 2010). Specificity is a measure which correctly identifies those non-affected people with the measure and is able to discriminate the measure (Bowling 2010). The equation of specificity is:

$$\text{Specificity} = \frac{\text{True negatives}}{\text{True negatives+False positives}} \qquad (8)$$

True negatives refer to the test that has correctly detected people without the disease and false positives refer to the those without the disease but are incorrectly identified as test positive (Lalkhen and McCluskey 2008).

5.2.14.4 Accuracy

Accuracy refers to the closeness (rate of correct and incorrect predictions) of a measurement to a standard or true value (Kohavi and Provost 1998). It is a proportion of the true positives and true negatives upon the total number of cases (Metz 1978). The equation of accuracy is:

$$\text{Accuracy} = \frac{\text{True positives} + \text{true negatives}}{\text{True positives} + \text{False positives} + \text{False negatives} + \text{True negatives}} \tag{9}$$

5.2.15 Ethical considerations

The study has been conducted in accordance with the ethical principles of doing a potential good and avoiding harm in protecting participants (Bowling 2010). Ethical approval was obtained from the Faculty of Health Sciences Ethics Committee, University of Southampton (Ethics Number: 9752) (Appendix H) and the Research Ethics Committee, Universiti Kebangsaan Malaysia (Ethics Number: NN-176-2014) (Appendix I) to enable commencement of the data collection.

All potential participants were provided with an information pack including participant information sheet that clearly explained the study, an invitation letter and a reply slip. This allowed the invited potential participants to inform their decision on whether they were interested and willing to participate in the study. Potential participants who were interested in taking part, returned the reply slip. They were then contacted via telephone by the researcher to arrange a suitable time to meet them. Interested participants who met the requirements of the inclusion and exclusion criteria provided informed consent prior to participating in this study. They were required to sign a consent form indicating agreement to participate. In addition, it was emphasised that they were free to withdraw from the study at any time.

5.2.16 Data protection

With regards to confidentiality and data protection, the data collected were kept strictly confidential and the anonymity was preserved using a unique identity code that was used throughout the study for all documentation. All electronic data were stored securely in password protected personal computer or network file store space of the university throughout the research process. Only the researcher and her supervisors have the rights to access the data. All 'hard copies' of data including records of participants' details, consent forms and lung sounds assessment forms were stored in a locked filing cabinet that only the researchers have access to. Data will be kept for 10 years in compliance with the data protection policy of the University of Southampton. The study ensures that any data viewed in any conference or presentation will always remain anonymous.

5.3 Study Two: The impact of training on respiratory physiotherapists' ability to detect Velcro crackles in patients with idiopathic pulmonary fibrosis: A longitudinal mixed method study.

5.3.1 Study Aims

The general aim of study two was to explore the impact of a training session on Malaysian respiratory physiotherapists' ability to detect Velcro crackles from pre-recorded lung sounds of patients with IPF over time. The specific aims for primary quantitative component and secondary qualitative component were details below.

5.3.1.1 Quantitative component (primary component)

i. To evaluate the short-term effect of a training session on inter-observer reliability of Malaysian respiratory physiotherapists in detecting Velcro crackles from patients with IPF.
ii. To determine the long-term effect of a training session on inter-observer reliability of Malaysian respiratory physiotherapists in detecting Velcro crackles from patients with IPF.

iii. To investigate the short-term effect of a training session on Malaysian respiratory physiotherapists' accuracy, sensitivity and specificity in detecting Velcro crackles from patients with IPF.

iv. To examine the long-term effect of a training session on Malaysian respiratory physiotherapists' accuracy, sensitivity and specificity in detecting Velcro crackles from patients with IPF.

5.3.1.2 Qualitative component (secondary component)

i. To explore Malaysian respiratory physiotherapists' clinical experiences of Velcro crackles detection at baseline and after the training session.

ii. To explore Malaysian respiratory physiotherapists' perceptions of the training session for Velcro crackles detection.

iii. To explore respiratory physiotherapists' experiences of skill retention and skill transfer in clinical practice at two months follow-up.

5.3.2 Research questions

The research questions for quantitative component and qualitative component were as below.

5.3.2.1 Quantitative component

i. Are Malaysian respiratory physiotherapists more reliable in detecting Velcro crackles in the short-term following a training session?

ii. Are Malaysian respiratory physiotherapists more reliable in detecting Velcro crackles in the long-term following a training session?

iii. Are Malaysian respiratory physiotherapists more accurate, sensitive and specific in detecting Velcro crackles in the short-term following a training session?

iv. Are Malaysian respiratory physiotherapists more accurate, sensitive and specific in detecting Velcro crackles in the long-term following a training session?

5.3.2.2 Qualitative component

i. What are Malaysian respiratory physiotherapists' experiences of detecting Velcro crackles before and after the training?
ii. What are Malaysian respiratory physiotherapists' perceptions towards the training for Velcro crackles detection?
iii. What are Malaysian respiratory physiotherapists' experiences of skill retention and skill transfer in clinical practice at two months follow-up?

5.3.3 Research hypotheses

The hypotheses for quantitative component were:

i. There will be substantial agreement ($k \geq 0.61$) of the inter-observer's detection of Velcro crackles in IPF patients short-term following the training session.
ii. There will be a substantial agreement ($k \geq 0.61$) of the inter-observer's detection of Velcro crackles in IPF patients long-term following the training session.
iii. There will be a difference in Velcro crackles detection before and after the training session.
iv. There will be a difference in Velcro crackle detection between short-term and long-term effect of the training session.

5.3.4 Research paradigms

Research in general is an inquiry process designed that involves systematic and scientific approach of finding answers to questions (Welman and Kruger 2002). Selection of an appropriate philosophical worldview or paradigm is a critical step in determining the effective way to conduct the current research study. Research paradigms comprise of a basic set of beliefs or assumptions that act as a guide to the researcher to design and conduct a research (Guba and Lincoln 2005). Four paradigms are identified, namely post-positivism, constructivism, advocacy and participatory, and pragmatism (Creswell and Clark 2007).

Post-positivism paradigm is typically associated with quantitative approaches that involve deductive methodology, and ontological position of post-positivism views that the reality is singular and independent of our constructs (Creswell and Clark 2007). Researchers make claim for knowledge based on cause and effect thinking, and reject or failure to reject hypotheses (Creswell and Clark 2007). The post-positivism epistemology assumes that there are distance and impartiality of relationship between researcher and that being researched, which based on detailed observations and objective measures of variables using instruments to verify the theories (Creswell 2003). In contrast, constructivism paradigm is often associated with qualitative approaches that involve inductive process of research (Creswell 2003). The ontology of constructivism views that the reality is multiple or subjective, and constructed by how the participants view and interpret the world in their respective context (Guba and Lincoln 1994). An epistemological assumption of constructivism believes that to have better understand the process and knowledge presented by the participants, the researchers need to get inside the participants' world, establishing closeness in relationship (Creswell 2014). Advocacy and participatory paradigms are often associated with quantitative approaches (Creswell 2003). These worldviews are influenced by political agenda and researchers who are actively collaborating with participants. They work together to help those who experience injustices which aim to improve society and change the social world for the better (Creswell and Clark 2007).

Pragmatism is commonly associated with mixed methods research which offer an alternative paradigm to those post-positivism and constructivism (Tashakkori and Teddlie 2010), and it sidesteps the contentious issues of truth and reality (Creswell and Clark 2007). Pragmatists believe that reality is not static, it is constantly changing and evolving through actions, and human actions are originated from their past experiences and beliefs which are found in their consequences (Morgan 2014). In this sense, human take actions based on the possible consequences of their action, and their actions results help to predict the consequences of similar actions in the future (Kaushik and Walsh 2019). Pragmatism ontology accepts that there can be single and multiple realities that are open to research inquiry (Creswell and Clark 2011). In this sense, researchers are free to test their hypotheses and provide quotes from multiples perspectives (Creswell and Clark 2007). Besides, the epistemology standpoint for pragmatism believes that knowledge is always based on experience (Kaushik and Walsh 2019) and it accepts practicality where researchers collect data by “what works” using multiple methods of data collection including both quantitative and qualitative data to address research questions (Creswell and Clark 2007).

Due to its pluralistic, pragmatism paradigm is primarily suitable for philosophical worldview to underpin this current study. In addition, pragmatism focusses on the consequences of research by placing importance on the question asked rather than the methods used (Creswell and Clark 2007). The researcher embraces pragmatism as the paradigm over another because of its problem centred philosophy that allow to employ the best research methods, and help to answer most of the research questions effectively in the current study. In this sense, pragmatism allows the researcher to be free from practical constraints by the “forced choice dichotomy between post-positivism and constructivism paradigms” with their particular research method (Creswell and Clark 2007). Furthermore, this pragmatism paradigm also allows the role of the researcher who approached this study through the lens of a physiotherapist educator, especially in developing the research questions and discovering the research phenomenon by interpreting the findings that are related to participants’ perceptions towards the training programme of Velcro crackles detection.

Besides, this paradigm works best with a mixed methods research which use both quantitative and qualitative approaches in a single study to understand the problem of the current research. Therefore, mixed methods research design was deemed most suitable in order to gain a greater understanding on the impact of training on Malaysian respiratory physiotherapists’ ability to detect Velcro crackles in light of their perceptions and experiences towards the training. This could not be achieved by quantitative cause-and-effects design or qualitative design alone. The researcher believes that the transformation of evidence from the current research to clinical practice could be optimised through integration of both quantitative and qualitative data through mixed methods research. Each method will be complimentary to each other, thus allowing for a more robust analysis that takes advantages of the multiple approaches and data gathered (Tashakkori and Teddlie 2010).

5.3.5 Mixed methods research design

Mixed methods research is a research approach in which the researchers collect, analyse and integrate both quantitative and qualitative data in a single study, and then draw interpretations based on the integration of both data to understand research problems (Creswell 2015). This second study was set up as a longitudinal mixed methods designed to explore the impact of training on Malaysian respiratory physiotherapists' ability to detect Velcro crackles over time. More than one method was adopted within this single study, which were quantitative and qualitative components.

This longitudinal mixed methods study design was selected over single quantitative method (e.g. experimental study) or qualitative method (e.g. case study) because the researcher aimed to explore two different perspectives within a single study: (1) to investigate the impact of training on ability of participants to detect Velcro crackles over time; (2) explore participants' experiences and perceptions towards Velcro crackles detection and the training over time. Therefore, the mixed methods design was considered to be suitable for this study because it helps answer research questions in this study which cannot be answered by qualitative or quantitative approaches alone (Tashakkori and Teddlie 2010). Besides, it provides strength that offset the weaknesses of both quantitative and qualitative research (Creswell and Clark 2007). It is argued that quantitative research is weak in understanding the context in which people talk, and qualitative research makes up for this weakness (Creswell and Clark 2007). In contrast, it is argued that qualitative research created by bias due to personal interpretations made by the researcher, and quantitative research does not have this weakness (Creswell and Clark 2007). The quantitative and qualitative components in mixed methods design involved the collection and analysis of both quantitative and qualitative data, as well as the integration of these two forms of data by having one build on the other which adds depth and richness to the data (Creswell and Clark 2011).

This study design has two sessions of data collection. Session one included Assessment 1 and Interview 1, and Assessment 2 and Interview 2 which were approximately 60 minutes in duration. Session two included Assessment 3 and

Interview 3 at two-months follow-up which was approximately 30 minutes duration. In general, the duration for data collection for session one and two was approximately one hour and 30 minutes in total.

A quantitative component of the inter-observer reliability study was used to evaluate the short-term and long-term effect of a training session on respiratory physiotherapists' ability to detect Velcro crackles from lung sound recordings. Before Assessment 1, participants were asked to complete a demographic form regarding years of working experience, number of referral cases of IPF to respiratory consultant per month, and any formal training of Velcro crackles detection that they have received previously. Then, they were asked to complete three assessments which were Assessment 1 before the training session, Assessment 2 after the training session, and Assessment 3 at two-months follow-up. These assessments consist of a set of lung sound recording files containing 25 lung sounds including 16 files sound which were the Velcro crackles from patients with IPF. In total, there were three CDs (CD1 for the Assessment 1, CD2 for the Assessment 2 and CD3 for the Assessment 3) with the same set of 25 files but in a different order of arrangement to avoid order bias.

A qualitative component of the study was employed to explore respiratory physiotherapists' experiences of Velcro crackles detection and their perceptions of the training session. The interview sessions were done after participants have completed Assessment 1 (Interview 1) and Assessment 2 (Interview 2). The third interview was conducted after Assessment 3 at two-months follow-up to explore whether there has been a transfer of this skill into clinical practice. A face to face, semi-structured interview was chosen to explore in-depth respiratory physiotherapists' experiences of Velcro crackles detection and their perceptions towards the training session. Data collection sessions were held at an out-patient clinic, within a physiotherapy department. The interviews' data were audio-recorded and uploaded into an audio file on a password protected desktop computer.

5.3.5.1 The Concurrent triangulation design

Concurrent data collection approaches may be used to validate two different forms of data, to combine the data for comparison, or to address different types of questions (Creswell and Clark 2007). Hence, the concurrent triangulation design that involves using quantitative and qualitative components is adopted in this study. Generally, it involves the simultaneous, but separate collection and analysis of quantitative and qualitative data so that the researcher may best understand the research problem (Creswell and Clark 2007).

The point of interface for this mixed methods study was mixed at the interpretation or discussion phase (Creswell and Clark 2011). The components of the two data sets (quantitative and qualitative data) were analysed separately in the results phase and then merged during the discussion phase, which enhanced integration between quantitative and qualitative data by comparing or combining their results. This is because the two components answered the research questions from two different perspectives or two different questions which were: 1) What are the physiotherapists' ability to detect Velcro crackles? (for quantitative component); and 2) What are their perceptions towards the training session? (for qualitative component). The interpretation phase involves discussing the extent to which the data triangulate and this is valuable as it provides a better understanding of the research problem in this study by offering more in depth details of evidence. Moreover, the concurrent triangulation mixed method design will help to confirm, cross-validate, and corroborate findings at the interpretation phase (Hanson et al. 2005). The purpose of triangulation design is to obtain different but complementary data on the same topic (Morse 1991).

In concurrent triangulation design the data collection starts with one research approach, followed by the other as a result of the study's logistic priorities (Creswell and Clark 2011). The typology approach of mixed methods design for this study was a QUAN + QUAL concurrent triangulation study design, where the quantitative component and qualitative component have equal weights (Figure 5.3). Therefore, this approach was considered most appropriate for this study as it promotes the gathering of a rich combination of quantitative and qualitative data regarding the impact of training on Malaysian respiratory physiotherapists to detect Velcro crackles in patients with IPF. In this study, the quantitative component investigated the short-term and long-term effects of the training session on respiratory physiotherapists' ability to detect Velcro crackles. Meanwhile, the qualitative component explored physiotherapists' experiences and perceptions of Velcro crackles training via semi-structured interviews. Therefore, the interviews were necessary to explore experiences and perceptions of Malaysian respiratory physiotherapy towards training that were unable to obtain from the quantitative assessment, in order to provide a thorough understanding of these relevant features. Both quantitative and qualitative data were collected at the same of three time-point in this study (pre-training, post-training, and two-month follow-up), hence reflect the equal weights for both components.

The advantage of utilising this approach is that it enables acquisition of in-depth data from two different perspectives by obtaining more knowledge and information particularly relating to participants' ability to detect Velcro crackles and their perceptions towards the training, which could not be gathered as fully if using a single method. Hence, this allows greater understanding about the data obtained by mixing both quantitative and qualitative components in a single study. Furthermore, employing this mixed method design could help to identify any inconsistencies that are discovered within quantitative and qualitative data, thus enhanced the reliability of the interpretation of the data (Meijer et al. 2002).

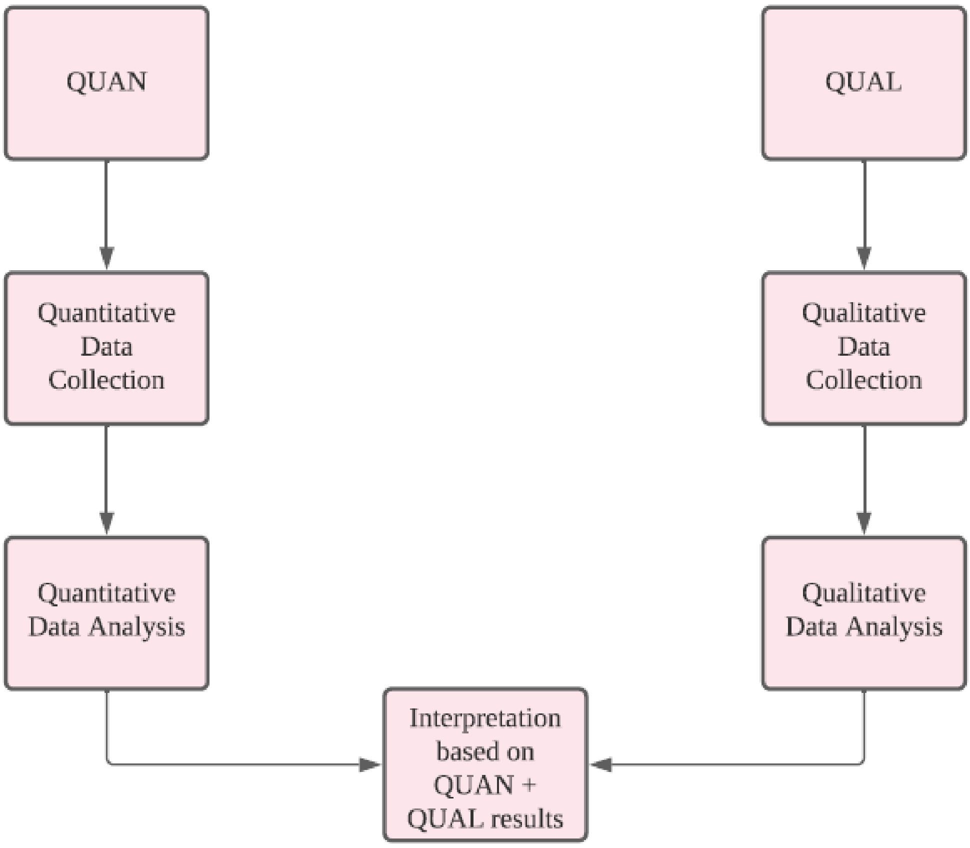

Figure 5.3: The mixed methods concurrent triangulation design for the study

5.3.6 Setting and subject selection

Recruitment took place at the Hospitals of Ministry of Health Malaysia (Kuala Lumpur General Hospital) and private physiotherapy centres (Pantai Integrated Rehab. Services, Your Physio, and Columbia Asia Hospital) in Malaysia. It was estimated that there were 40 respiratory physiotherapists who were currently working in these sites.

Respiratory physiotherapists refer to the physiotherapists who are working in respiratory care for the patients with lung diseases such as asthma, pneumonia, pulmonary fibrosis, chronic obstruction pulmonary disease and other lung conditions. Their role crosses boundaries from acute and critical care, to chronic disease management and rehabilitation in order to improve quality of life amongst patients with lung diseases. Respiratory physiotherapists evaluate the lung conditions via chest assessment, provide intervention such as breathing exercise, breathing retraining and control, secretion removal and physical exercise to improve the lung conditions and involve in patient education (Keilty 2005).

5.3.7 Inclusion criteria

The inclusion criteria of study two were same as in study one (refer section 5.2.8)

5.3.8 Exclusion criteria

The exclusion criteria excluded:

- Anyone who has previously participated in the researcher's preliminary study of impact of training on physiotherapists' ability to detect Velcro crackles in patients with IPF (study one).

Other exclusion criteria were same as in study one (refer section 5.2.9)

5.3.9 Sample size

There were eight to ten respiratory physiotherapists who were working in Kuala Lumpur General Hospital and private physiotherapy centres (Pantai Integrated Rehab. Services, Your Physio and Columbia Asia Hospital). Therefore, it was estimated that 40 respiratory physiotherapists were currently eligible to participate in this study. It was expected that very few physiotherapists have sufficient experience in respiratory care to be eligible as this is a specialised field (Keilty 2005).

Determination of sample size for the number of participants was calculated based on the work of Gwet (2012):

$$\mathbf{r = 2/cv}$$

cv refers to coefficient of variation which indicates ratio of the standard error to extent agreement. Calculation for the sample size for this study used the values of the standard error and the agreement obtained from the preliminary study of inter-observer reliability that has been conducted by the researcher. Therefore,

cv = standard error/ agreement

cv = 0.06/0.59

cv = 0.10

Estimation of sample size, r=2/cv

r =2/0.1

r = 20 raters

The expected 40% drop-out rate of participants should be considered due to the 2 months follow-up assessment. Participants might be changed the work place or withdraw from this study due to long-term follow-up period. Thus, the sample size was calculated with an anticipated attrition of 40% based on the calculation by Freeman and Julius (2008):

$$N = n/1\text{-}p$$

n refers to estimation of initial sample size (20) and p refers to percentage of participants to drop-out (40%).

N = 20/1-0.4

N = 33

Therefore, the aim was to recruit up to 33 participants as a convenience sample.

5.3.10 Participant recruitment

Recruitment packs were given to potential participants by the managers of physiotherapy units in Kuala Lumpur General Hospital, Pantai Integrated Rehab. Services, Your Physio and Columbia Asia Hospital. The process of participant recruitment in this study two was the same as in the study one (please refer to section 5.2.6). Participants were given with an invitation letter (Appendix J), the information sheet of the study (Appendix K), reply slip (L) and consent form (M).

5.3.11 Lung sound data

The same lung sound data that have been provided by Professor Luca Richeldi, which have been previously used in the study one (preliminarily study), were also used in this second study (please refer to section 5.2.11).

This second study used 25 pre-recorded lung sound files which based on the time taken to process each one and the expected time commitment possible for each physiotherapist. A set of pre-recorded files containing of 25 lung sounds were given to participants at every each of assessment (pre-training, post-training and two-month follow-up assessments). Of the 25 files, 16 of them are Velcro crackles and nine files are non-Velcro crackles. The researcher has tested all of the lung sounds files to ensure that they are noticeably different. These recordings of Velcro crackle sounds are based on gold standard HRCT scans that have been interpreted as fibrotic lungs by the radiologists. In total, there were three CDs (CD1, CD2 and CD3) with the same set of 25 files but in different orders of arrangement for participants to listen during pre-training, post-training and two-month follow-up assessments respectively.

5.3.12 Data collection method

5.3.12.1 Quantitative component

Assessment forms specifically for Velcro crackles detection were used for data collection in the quantitative component (Appendix N) during pre-training, post-training and two-month follow-up assessments. Participants were asked to listen to the 25 lung sound recordings and record their findings using these assessment forms. They were required to identify the presence or absence of crackles, classify the type of crackles and recognise them as Velcro crackles or not. The data forms were collected from participants once they have completed their assessments. The feedback of all these assessments were given to participants after the second interview session at the two-month follow-up.

5.3.12.2 Qualitative component

Semi-structured, face-to face interviews were used for data collection for the qualitative component. This method of interview was used because it encourages participants to freely express their own opinion, perceptions and ideas which is beneficial to the study (Knight 2002) whilst achieving the objectives of the research. In addition, it offers flexibility where the researcher was able to probe interviewee's responses on the issues that arise and therefore help gained clarification and in-depth data (Seale 2012). The semi-structured interviews also allowed for the discovery of information that was important to participants but might not have previously been thought of by the researcher (Gill et al. 2008). This type of approach was used because it helped to define the areas to be explored using several keys questions, but also allowed divergence of ideas and responses of interviewee in more detail.

The interview was conducted in Malay which is participants' first language. It was important to conduct the interview in participant's first language as to encourage participants to speak more widely and openly as well as express their ideas in detailed regarding their views (Denscombe 2007). An interview schedule (Appendix O) was developed based on the aim and objectives of this study in order to address the research questions. In this study, the interview schedule was to explore respiratory physiotherapists' experiences of Velcro crackles detection and their perceptions towards the training session.

The interview questions were developed medium in length, understandable, neutral and open ended (such as how, what and why questions), which could facilitate participants to express freely their thoughts and ideas regarding the topic in detail and depth (Cohen et al. 2007). Hence, this would promote rich data on deeper understanding of phenomenon and detail insights from participants than would be obtained from purely quantitative methods (Gill et al. 2008).

During the interview session, the pre-designed questions were asked to participants, but unnecessarily important to follow the order of question list as this was modified in line with the direction of participants' discourse where necessary. However, the interview was prioritised on main questions and prompts, so that the researcher could control the discussion by focusing on those that were most relevant to the study. This was to ensure the interview was done within the stated time. Furthermore, at the end of each interview, participants were given an opportunity to raise additional issues that they have thought about or make further contributions which has not been dealt with by the researcher. This could often lead to the discovery of new information for the study.

5.3.13 Data collection procedure

Written informed consent from participants were obtained prior to data collection. Participants were asked to provide the informed consent immediately before completing the demographic form and the researcher was present when the informed consent was provided. The researcher collected the demographic data using a questionnaire (Appendix P). After that, they were given CD1 consisting of 25 files of lung sound recordings to listen to during pre-training assessment. During the assessment, participants were using a laptop or desktop computer, which has Audacity Software downloaded on it to listen to the lung sounds recordings. They were using standard over-ear headphones while listening to the recorded lung sounds which were provided for them. They were asked to listen to the files from CD1 and record their findings (presence or absence of Velcro crackles) each time using the assessment form given. Then, the researcher collected the assessment form once they have completed. Figure 5.4 depicts the flow chart of study procedure.

After completing pre-training assessment, participants were interviewed (Interview 1) by the researcher. There was a face to face, semi-structured interview to explore their experience of Velcro crackles detection before the training session. Then, participants were given approximately 30 minutes of training regarding how to detect Velcro crackles. There was an improvement made for the training packages in study two which is more comprehensive and consists of the latest evidence information of IPF compared to previous training. This training was presented via PowerPoint slide presentation to the group of participants. The content of the training package included topics on introduction and pathophysiology of IPF, incidence and risk factors of IPF, signs and symptoms of IPF, prognosis and challenge of IPF, investigation for IPF, auscultation procedure, Velcro crackles detection, characteristics of Velcro crackles and abnormal lung sounds, samples of pre-recorded lung sounds (2 files of normal lung sounds and 5 files of abnormal lung sounds which included Velcro crackles, coarse crackles, wheezes and normal lung sounds were given to participants) and physiotherapy management for IPF patients. During listening to the samples of pre-recorded lung sounds, participants were asked to listen to Velcro crackles sounds repeatedly and compared them to the normal and other abnormal lung sounds using audio and visual information software of Audacity until they were satisfied. The advantages and disadvantages of using this Audacity software in this study have been discussed in section 5.2.12. Participants were open to discuss their inquiries at the end of the training session (please refer to Appendix Q regarding the content of the complex training package). This training session was given to participants in a group.

Immediately after the training session, participants were asked to complete the post-training assessment. CD2 consists of 25 lung sound files in a different order of presentation was given to them to listen to and complete the assessment form given once again using the same procedure as in the pre-training assessment. After that, participants were interviewed for the second time (Interview 2) by the researcher to explore their experiences of Velcro crackles detection following the training and the training session. A five-minute break was given to participants before the interview session, to allow them to rest and to prevent stress during the data collection. The interview session was audio-recorded by the researcher. Data collection was done at the out-patient clinics of the Physiotherapy Unit. Overall, the time taken for data collection of pre-training assessment, post-training assessment, and interview sessions (1 and 2) was approximately 90 minutes.

Once the interview session was finished, the researcher gave a ‘research diary’ (Appendix Q) to the participants for them to record certain information including: 1) cases of patients with IPF and their identity number that they have referred to respiratory consultants; and 2) any leave (such as sick leave or annual leave) which they have taken during 2 months duration. They were asked to keep this research diary until the next two-month follow-up assessment session. The purpose of research diary was to document how many correct referrals of patients with IPF that the participant has referred to a pulmonologist. This was aligned with the research aims which were to investigate the effect of a training session on Malaysian respiratory physiotherapists' competency in detecting Velcro crackles from patients with IPF and to explore whether there has been a transfer of the skill that has been learned in the training session (Velcro crackles detection) into clinical practice. The rationale to collect the number of sick days was to monitor a factor that might influence the retention of the skill at the two-month follow-up. For example, participants would have less amount of experience of assessing patients with IPF if they have taken a large amount of sick leave which might affect the results at two-month follow-up.

Prior to the two-months follow-up assessment, participants were contacted by phone or email to set an appointment. On the day of data collection, the researcher collected the time diary from participants. CD3 consists of 25 lung sounds recording files as before was given to participants for them to listen to and record their findings using the same assessment form given as before. Again, the same procedure as in pre-training and post-training assessments were repeated. Once they have completed the two-month follow-up assessment, the researcher collected the data form. After that, participants were being interviewed by the researcher for the third time (Interview 3). This face to face semi-structure interview was to explore whether there has been a transfer of this skill (Velcro crackles detection) into clinical practice. Data collection was done in the out-patient clinics of Physiotherapy Unit. Overall, the time taken for data collection of two-month follow-up assessment and interview session was approximately 30 minutes.

In general, duration for data collection for pre-training, post-training and two-month follow-up assessments was estimated as approximately two hours. This gave ample time for interview sessions (approximately 45 minutes) where there was a larger number of questions and prompts. The researcher had done the training and rehearsed the interviewing process before beginning the study to ensure the efficiency of the interview process. In addition, during the interviews the researcher had prioritised the main questions and prompts and controlled the discussion by focusing on those that were most relevant to the study. This was to ensure the interviews were done within the stated time.

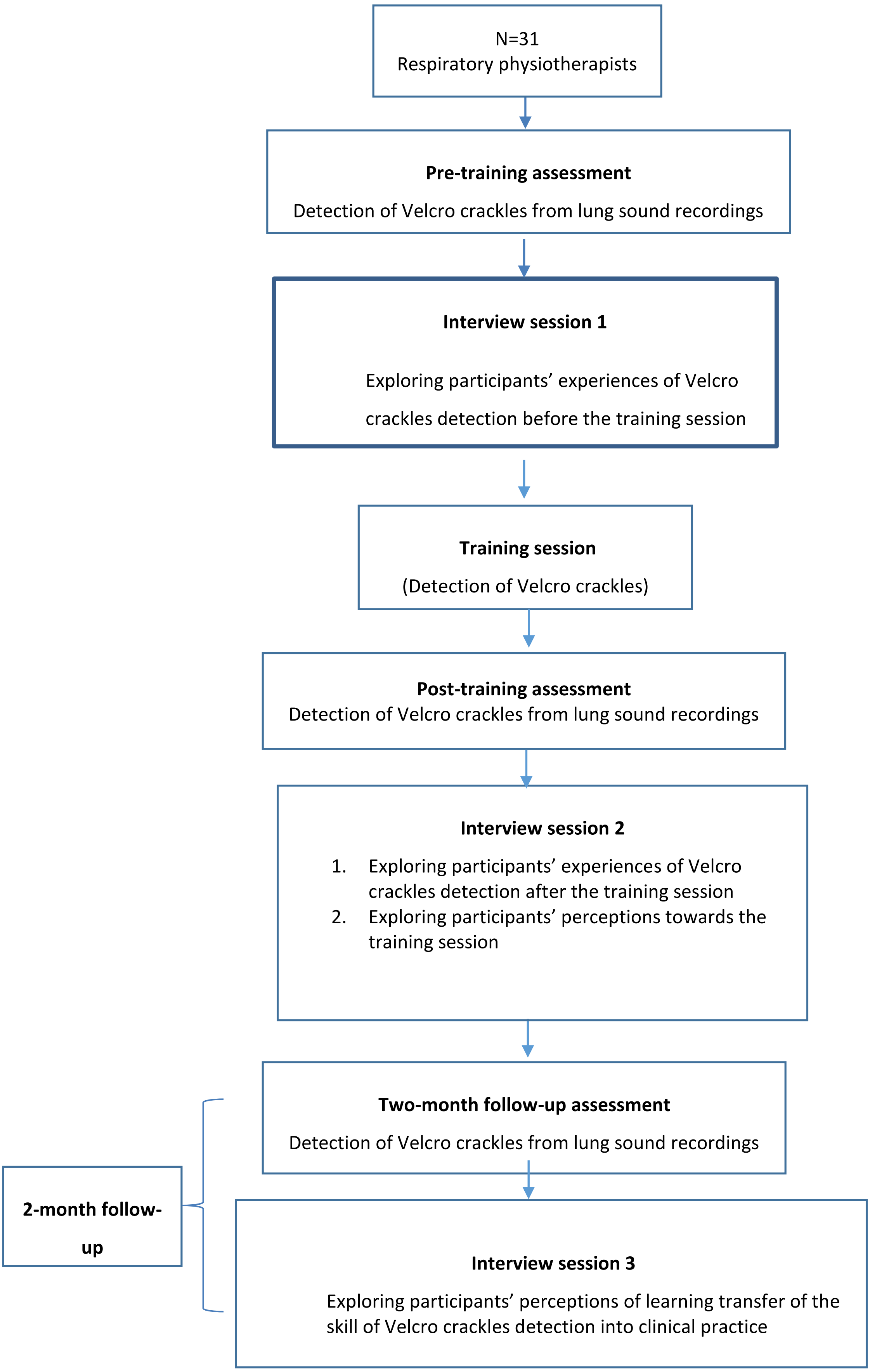

Figure 5.4 Flow chart of the study procedure (study two)

5.3.14 Public involvement

Public involvement work has been conducted prior to the main study (please refer to section 5.2.13 for detailed discussion about public involvement). The objective was to ensure the protocol was feasible and help to refine the procedure of this study. This is important to ensure clarity of the instruction to participants and to establish efficient protocol during assessment procedure. In addition, this pilot work helped the researcher to familiarise with the qualitative data collection during the interview sessions in this study. Two volunteers who were working in respiratory physiotherapy research from the Faculty of Health Sciences, University of Southampton were recruited. The findings from this pilot study were however not included in the main study.

There was no amendment made in the assessment form and interview schedule. Participants were able to complete the assessment form and answered all the interview questions clearly. In general, both participants reported that this test was simple and practical to do and both of them took approximately 120 minutes to complete all assessments, training, and interviews.

5.3.15 Data Analysis

5.3.15.1 Quantitative component

Demographic data including age, gender, years qualified as a physiotherapist, number of referral cases of IPF to respiratory consultant per month, and any formal training of Velcro crackles detection that they have received previously were analysed using descriptive statistics using the IBM Statistical Package for Service Solution (SPSS) software version 21.

The same calculation for kappa agreement in study one was used to measure the inter-observer reliability on detection of Velcro crackles in this study two (please refer to section 5.2.14.1 and 5.2.14.2). In addition, the same calculations for sensitivity, specificity, and accuracy in study one were used in this study two (please refer section 5.2.14.3 and 5.2.14.4)

The z statistic was used to compare kappa values at pre-training and post-training assessment, and also post-training and two-month follow-up assessments. A significance level of $p<0.05$ was chosen.

All the data from the assessments were tested for normality. As the normality assumption was violated, non-parametric tests were used to analyse the data. The Friedman test was used to analyse scores of Velcro crackles detection at three related time points, which was at the pre-training, post-training, and two-month follow-up assessments. A significance level of $p<0.05$ was chosen.

Then, a non-parametric test of the Wilcoxon Signed Rank was used to analyse a series of pairwise comparisons, e.g., comparing two related scores of Velcro crackles detection between pre-training and post-training assessments. A significance level of $p<0.05$ was chosen.

The Mann-Whitney test was used to compare scores of two independent group of level of experiences (senior and junior groups). A significance level of $p<0.05$ was chosen.

Spearman's rho analysis was used to measure the correlation between scores of Velcro crackles and years of clinical experiences. Besides, it was also used to measure the correlation between scores of Velcro crackles detection and days of leave. A significance level of $p<0.05$ was chosen.

5.3.15.2 Qualitative component

In this study, thematic analysis as adopted by Braun and Clarke (2006) was used to analyse the qualitative data. Braun and Clarke (2006) define thematic analysis as "a method for identifying, analysing and reporting themes within data". Thematic analysis is a flexible and straightforward technique for data analysis which can be used in all stages of research and within various theoretical frameworks (Braun and Clarke 2006) to give better understanding of the research problem (Hardy and Bryman 2004).

Thematic analysis was chosen in this study rather than other methods such as grounded theory due to its flexibility and it is relatively an easy and quick method to learn for a novice researcher who used qualitative component in the study (Braun and Clarke 2006). Besides, thematic analysis best fits within mixed methods research design (Creswell and Clark 2007) that is used in this study to address the study problems, and this analysis allows the researcher to interpret the themes within the context of training intervention and in terms of the outcome of the participants (Creswell and Clark 2007) for examples, discussing the responses of participants towards the training of Velcro crackles detection. This approach was used in this study since it is able to establish a link between research objectives and the findings produced from the raw data (Braun and Clarke 2006). Moreover, it is a highly useful tool that can potentially provide a rich and detailed, yet complex account of data (Braun and Clarke 2006). During thematic analysis, the themes are created in this study based on a 'top down' coding scheme where the researcher starts the coding process with some codes in mind, that is based on literature review (Tashakkori and Teddlie 2010).

In contrast, grounded theory involves the researcher to derive theory of a process or interaction grounded in the views of participants in a study (Creswell 2003). Leedy and Ormrod (2001) clarifies that grounded theory research begins with data that develops into a theory, and requires the theory to be emerged from the data collected in the field rather than taken from the research literature. Besides, its process is massive and complex which is called constant comparative method (Leedy and Ormrod 2001). This process involves collecting data from several sources for example, interviewing participants or witnesses, reviewing historical videotapes or records, observations while on-site, then analysing the data, and repeating the process to enrich the understanding (Creswell 2003). Analysis of data in a grounded theory involves inductive coding, axial coding, selective coding that create codes based on the qualitative data to develop a theory (Leedy and Ormrod 2001). Therefore, grounded theory analysis requires time and needs a lot of reflection which is not suitable to be adopted in this study that has a limited time frame to be completed.

The analysis in this study followed six steps of thematic analysis by Braun and Clarke (2006): 1) familiarising with the data; 2) generating initial codes; 3) searching for themes; 4) reviewing themes; 5) defining and naming themes; and 6) producing the report. The process began at the level of preparing and organising when the researcher started converting the raw data for analysis by transcribing all the audio-records interviews and typing the transcription verbatim. The transcribed interview data were entered into computer assisted qualitative data analysis (CAQDAS) software which is NVivo. This software helped to store, retrieve, and organise the data during coding and analysis processes. The interviews were transcribed word by word by the researcher. Then, each transcript in Malay language was translated into the target language (English) by the researcher and backward translation from English to Malay without having seen the original text was also done but conducted by a person other than the researcher. All the transcribed data were checked and reviewed several times by the researcher.

Familiarisation with the data was done in which the transcribed data were read and re-read at least two or three times to get an overview of the phenomena and familiarise with the data through being immersed in the data. The researcher also compared the transcript with the recorded interview to ensure its accuracy. Next step was the generation of initial codes which were the interesting features of the data (Braun and Clarke 2006). Important words based on the research questions of qualitative component were highlighted and comments as well as thoughts were written throughout the process of thematic analysis. All these were coded systematically across the entire data set. Data were collated according to their relevancy to each code.

After coding process, themes were identified by collating codes and gathering all data relevant to each potential theme. These themes were sorted for commonalities and differences across the interview samples as whole. Then, themes were reviewed thoroughly in relation to the coded extracts and defined to generate clear names. Themes were captured to develop chronological on participants' perceptions towards Velcro crackles detection and training program through different stages of data collection (pre-training, post-training, and at two-month follow-up interviews). Finally, a report of the analysis which included examples and relating back of analysis to the research questions were produced.

5.3.15.3 Trustworthiness

Trustworthiness in qualitative research means methodological soundness and adequacy (Holloway and Galvin 2016). Trustworthiness is defined as the degree of confidence that the researchers have that their qualitative data and findings are credible, transferable, dependable, and confirmable (Andrew et al. 2009). Several steps were taken during the data collection and analysis process to allow the trustworthiness of data of the qualitative component in this study. To establish credibility, all the three interview sessions were conducted by a single person who is the researcher in this study. This may allow the consistency of words or statements used when questioning and probing the participants by the same researcher during the data collection process.

During interview process, the researcher took the responsibility to ensure that all the questions within the interview scheduled have been covered in order to gain rigorous qualitative data. The backward translation from English to Malay without having seen the original text was conducted by NM who is a researcher and competent in both Malay and English languages with physiotherapy background. This was to ensure that the meaning of the data was not lost in the process that leads to data trustworthiness (Regmi et al. 2010). Besides, member checking was done in which participants were given the transcriptions of theirs for validation and amendment. However, no changes were made by participants. The member checking process involved reviewing and checking the transcripts to allow trustworthiness of the qualitative data (Birt et al. 2016).

Next, the researcher conducted independent coding with a second person (AS) who has a physiotherapy research background. This technique was done to eliminate researcher bias which may have influenced the results if the coding was done by the researcher alone. Moreover, it allowed credible findings of qualitative results. This coding process followed the approach adopted by Braun and Clarke (2006) to generate initial codes from the interview transcripts which has been discussed in section 5.3.15.2 above. Important narrative responding to the research questions were highlighted and comments were written across the entire qualitative data set during the process of independent coding. Finally, both the researcher and AS met to discuss our findings of the generated codes and we further collated the data accordingly to their relevancy for each code until we achieved agreement. For example, a participant's opinion towards the training on how to detect Velcro crackles was extracted as,

*'This training was **(very helpful for me)**, and I found it much easier to answer the lung sounds assessment this time. I have gained **(new knowledge and skills about the Velcro crackles).** Well…I **(definitely can distinguish types of crackles)** whether they were coarse or fine when listening to the pre-recorded lung sounds assessment and **(able to detect Velcro crackles which have high pitch sound.)***

In this case therefore, we agreed that the initial generation codes were **'helpful'**, **'new knowledge and skill'**, **'confident'** and **'distinguish Velcro crackles'**. These codes were compared based on differences and similarities for the all the interview transcripts and sorted into themes and sub-themes. All the codes were reviewed by the researcher and her colleague, AS to ensure that they are valid and credible findings.

In addition, to enhance the trustworthiness and the credibility of a qualitative data findings, peer debriefing process was further conducted during the thematic data analysis (Janesick 2007). Two qualified individuals (AZ and AS) who are lecturers and researchers with physiotherapy background were involved in reviewing and assessing the transcripts, and discussions were used to emerge the categories and themes during peer debriefing. This technique ensures the appropriateness and completeness of theme detection and prevents bias during data analysis (Janesick 2007).

5.3.16 Ethical consideration

Ethical approval was obtained from the Faculty of Health Sciences Ethics Committee, University of Southampton (Ethics number: 23380) (Appendix R) and the Medical Research and Ethics Committee Malaysia (NMRR-16-2545-33501) (Appendix S). All participants were provided with an information sheet of the study's details in a language that they can understand. They were also required to sign a consent form indicating agreement to participate. It was emphasised that they were free to withdraw from the study at any time without providing a reason for doing so.

This was a simple listening exercise with minimal risk for causing psychological and physical discomfort or distress. Potentially some participants might find using headphones uncomfortable which might cause physical distress during assessments of lung sounds, or they might find psychological distress when answering the questions during interview sessions. Participants were given five minutes rest period within the assessments to alleviate physical distress due to using headphones. If they still feel distress during the assessments or interviews, they might stop at any time.

5.3.17 Data protection

With regards to confidentiality and data protection, the data collected were kept strictly confidential and participant's anonymity was preserved using an identity code which used throughout the study. However, participant who reports any professionally negligent behaviour during interviews, the researcher was required to breach the confidentiality to ensure patient safety. Potential participants have been informed of this risk to anonymity in participant information sheet before giving consent. All the electronic data and hard document protection were used the same procedure in the study one (please refer to section 5.2.16).

5.4 Summary

This chapter has discussed the methodology used including study design and study procedures in order to achieve the aims of the two studies: 1) Study one, preliminary study, and 2) study two, a longitudinal mixed methods study. The procedure of research protocol on data collection of these two studies has been presented. In addition, the procedure for data analysis including demographic data, quantitative and qualitative data have also been discussed. Finally, discussion of relevant ethical issues and data protection which are in line with the policy of the University of Southampton were presented. The next chapter will present the results from the analysis of data in these two studies.

Chapter 6: Results

6.1 Introduction

In this chapter, the findings of study one and two will be presented. Firstly, the response rates of the study will be described. Subsequently, the results of the demographic variables providing characteristics of the sample will be presented. Finally, the key findings of inter and intra-observer reliability of health professionals' detection of Velcro crackles in patients with IPF is then presented.

6.2 Study one: A preliminary study of the impact of training on reliability of respiratory physiotherapists' detection of Velcro crackles in IPF patients.

6.2.1 Response rates

There were 14 respiratory physiotherapists at the UKMMC who were eligible to participate in this study. Therefore, 14 recruitment information packs of the study have been administered to all of them. Overall, 12 out of 14 respiratory physiotherapists have returned the reply slip and agreed to take part in the study. This results to the response rate of 86%. There was no drop out of participant reported during data collection. All of 12 participants were able to complete two occasions of assessment sessions during data collection.

6.2.2 Demographic characteristics and experience with IPF

Demographic data of participants' characteristics are presented in Table 6.1 to describe the whole sample in this study. As depicted in Table 6.1, almost all participants were female respiratory physiotherapists (92%) and only one male respiratory physiotherapist who took part in the study. The participants' age range from 25 to 35 years old and their number of years as qualified physiotherapist range from 3 to 13 years since graduating from an undergraduate physiotherapy programme. The majority of participants were junior respiratory physiotherapists who have experience between 2 to 4 years in respiratory physiotherapy practice (83%). There was a small percentage of proportion among participants who have had experience in treating patients with IPF condition. In addition, the majority have never heard of the term of Velcro or Velcro crackle and none of them have reported that they were be able to recognise the Velcro crackle if they hear that crackle.

Table 6.1 Participants' demographic characteristics and experience with IPF (N=12)

Variable	Mean	Standard deviation	Frequency (n)	Percentage (%)
Age	29.83	3.33		
Number of years of qualified as physiotherapist	5.17	1.53		
Number of years of experience in respiratory physiotherapy	3.50	1.09		
5 years and above (senior)			2	17
2 years to 4 years (junior)			10	83
Gender				
Female			11	92
Male			1	8
Experience with IPF patient				
Yes			3	25
No			9	75
Heard about Velcro crackle				
Yes			2	17
No			10	83
Recognition of Velcro crackle				
Yes				
No			12	100

The findings show that characteristics of participants between two groups are almost similar for both trained and untrained groups (Table 6.2). Almost all participants were junior respiratory physiotherapists for both groups and have never heard the term Velcro crackle. In addition, the majority of them in these two groups have had no experience with IPF patients. All of the participants were unable to recognise the Velcro crackle.

Table 6.2 Characteristics of participants between trained and untrained group (N=12)

Variable	Trained Group (n=6)	Untrained Group (n=6)
Respiratory Physiotherapist		
5 years and above (senior)	1	1
2 years to 4 years (junior)	5	5
Experience with IPF patient		
Yes	2	1
No	4	5
Heard about Velcro crackle		
Yes	1	1
No	5	5
Recognition of Velcro crackle		
Yes		
No	6	6

6.2.3 Intra-observer reliability

Table 6.3 presents kappa values for intra-observer reliability for trained and untrained groups during Assessment 1. The majority of the participants from Group A (67%), who received the training session prior to Assessment 1 were found to have high kappa values that indicate substantial to perfect agreement (k=0.67 to 1). In contrast, all participants from untrained Group B scored fair to moderate agreement of reliability (k=0.29 to 0.54). The standard error (SE) kappa of agreement for both groups are Group A ranged from 0.11 to 0 and Group B from 0.11 to 0.15.

Table 6.4 shows kappa values for intra-observer reliability for Group A and B that received the training session prior to Assessment 2. The majority of participants from Group A (67%), were found to have high kappa values that indicate substantial to perfect agreement (k=0.62 to 0.81). The SE kappa of agreement for Group A ranged from 0.12 to 0.16. Meanwhile, 50% of participants from Group B were found to have high kappa values that reflect substantial to perfect agreement (k=0.71 to 0.9). Intra-observer reliability was improved for all participants in Group B, from fair to moderate before training to moderate to perfect agreement after the training session. The SE kappa of agreement for Group B ranged from 0.09 to 0.15 during Assessment 2.

Intra-observer reliability for participants in Group A ranged from moderate to perfect agreement during both Assessment 1 and 2 (Table 6.3 & 6.4). In general, there was a relative variability of kappa values within participants in Group A and Group B during Assessment 1 and 2.

Table 6.3 Kappa values for intra-observer reliability for Group A (trained) and Group B (untrained) participants in detecting Velcro crackles during Assessment 1

Participant	Group A (trained)		Participant	Group B (untrained)	
	k	SE		*k*	SE
11	0.783	0.142	21	0.42	0.152
12	0.588	0.13	22	0.286	0.118
13	0.476	0.153	23	0.346	0.114
14	1	0	24	0.434	0.122
15	0.673	0.133	25	0.538	0.128
16	0.817	0.112	26	0.48	0.132

Table 6.4 Kappa values for intra-observer reliability for Group A and Group B participants in detecting Velcro crackles during Assessment 2

Participant	Group A (trained)		Participant	Group B (trained)	
	k	SE		*k*	SE
11	0.804	0.124	21	0.71	0.146
12	0.531	0.144	22	0.576	0.14
13	0.583	0.135	23	0.904	0.089
14	0.617	0.163	24	0.58	0.14
15	0.648	0.134	25	0.9	0.097
16	0.81	0.122	26	0.52	0.149

6.2.4 Inter-observer reliability

Table 6.5 shows the findings from the analysis of inter-observer reliability of detecting Velcro crackles in patients with IPF for Group A (trained) and Group B (untrained) during Assessment 1. Kappa values of Group A represented moderate agreement for both tests (Test 1-A & Test 2-A) according to Landis and Koch (1977). In contrast, kappa values for group B indicated poor agreement for both tests (Test 1-B & Test 2-B). Overall, there were approximately 0.4 differences in score of kappa values between trained and untrained groups for both test 1 (Test 1-A & Test 1-B) and 2 (Test 2-A & Test 2-B). The SE kappa agreement for both groups, group A and B were similar for both tests.

During Assessment 2 (Table 6.6), inter-observer reliability for group B had improved from poor to moderate agreement amongst participants following the training session in both tests (Test 3-B & Test 4-B) (Figure 6.2). There were approximately 0.4 differences in score of kappa values before and after the training. However, the values for SE kappa agreement were similar before and after the training sessions for Group B at all tests. In addition, inter-observer reliability was found to be slightly higher in Group B than Group A during Assessment 2 in which both groups had received their training on detection of Velcro crackles (Table 6.6). Nevertheless, reliability for both groups indicated moderate agreement (k = ranged from 0.575 to 0.59) amongst trained participants in detecting Velcro crackles. Both Group A and B scored similar SE of kappa.

Generally, inter-observer reliability for Group A indicated moderate agreement amongst trained participants during both Assessment 1 (Table 6.5) and 2 (Table 6.6) (Figure 6.1). Nonetheless, the reliability was slightly low during Assessment 2 than Assessment 1. There was also a decrease in values of SE kappa during Assessment 2.

Table 6.5 Kappa values for inter-observer reliability between Group A (trained) and Group B (untrained) participants in detecting Velcro crackles during Assessment 1

	Group A (trained) Assessment 1			Group B (untrained) Assessment 1	
Test	***k***	**SE**	**Test**	***k***	**SE**
Test 1-A	0.585	0.064	Test 1-B	0.194	0.051
Test 2-A	0.589	0.068	Test 2-B	0.176	0.051

Table 6.6 Kappa values for reliability of Group A and B participants in detecting Velcro crackles during Assessment 2.

	Group A (trained) Assessment 2			Group B (trained) Assessment 2	
Test	***k***	**SE**	**Test**	***k***	**SE**
Test 3-A	0.575	0.062	Test 3-B	0.592	0.06
Test 4-A	0.579	0.06	Test 4-B	0.592	0.06

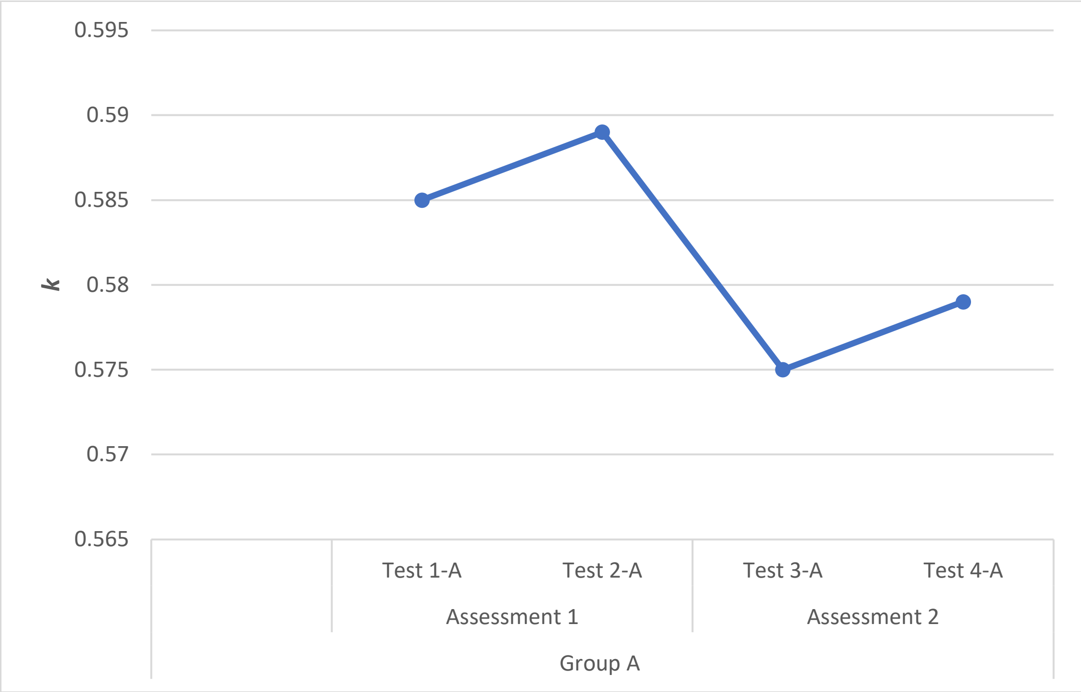

Figure 6.1 Kappa values for reliability of Group A in detecting Velcro crackles during Assessment 1 and Assessment 2

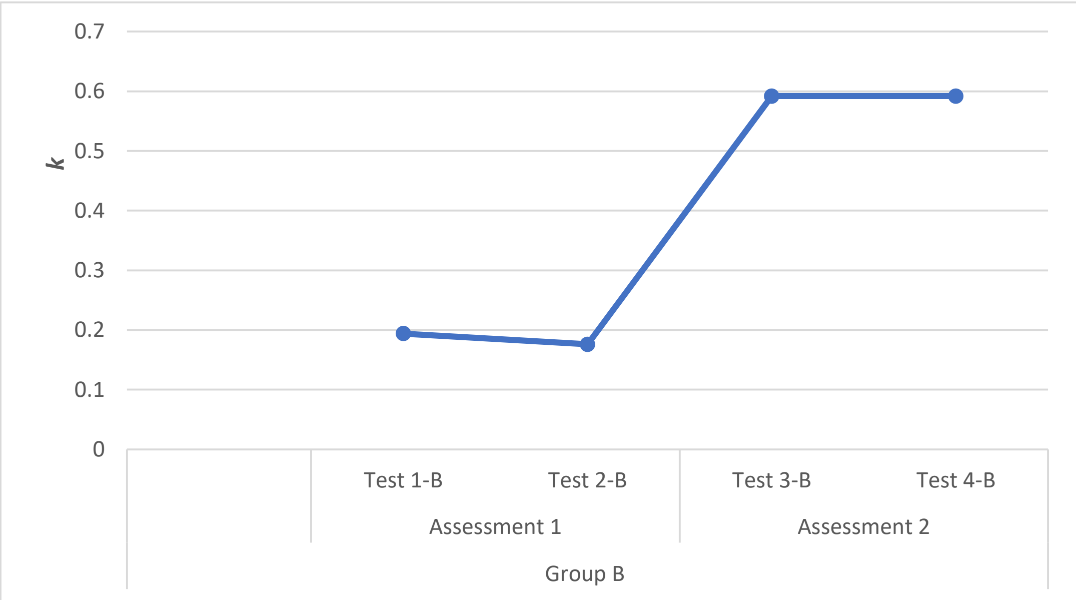

Figure 6.2 Kappa values for reliability of Group B in detecting Velcro crackles during Assessment 1 and Assessment 2

Table 6.7 demonstrates kappa scores for inter-observer reliability for participants in Group A (trained) and Group B (untrained) based on variables including recognition of crackle sounds, categorisation of crackles sounds, and nature of crackles during Assessment 1. Reliability was relatively high for all variables in Group A (k=0.589 – 0.773). Mostly, kappa values for all variables at both tests indicate moderate to substantial agreement among participants in Group A after the training (Figure 6.3). On the contrary, reliability was very low for all variables in Group B during both tests (k=0.227 – 0.475) which reflect fair to moderate agreement among participants. Recognition of crackles variable yielded the highest reliability for both Group A and B, compared to the other two variables. Their kappa values represent substantial agreement for Group A and moderate agreement for Group B.

During Assessment 2 (Table 6.8), inter-observer reliability for all variables in Group B was found to be higher than those in Assessment 1 (Table 6.7) (Figure 6.4). The kappa values during Assessment 2 represent moderate to substantial agreement among participants following the training session (k=0.592 – 0.745). There was high reliability, which is substantial agreement for two variables; recognition of crackle sounds, and nature of crackle sounds for both tests in Group B during Assessment 2. In addition, kappa values were found to be slightly higher for all variables in Group B than Group A during Assessment 2 (Table 6.8). Inter-observer reliability for all variables of group B reflect moderate to substantial agreement among participants (k=0.59 – 0.746). Likewise, kappa values for all variables of Group A also represent moderate to substantial agreement among participants (k=0.579 – 0.72). Reliability for recognition and nature of crackles sounds variables were found to be higher than categorisation of crackles variable for both Group A and B during Assessment 2.

Inter-observer reliability for Group A was relatively low for almost all variables during Assessment 2 (Table 6.8) than Assessment 1 (Table 6.7). Kappa scores for almost all variables were found to be slightly reduced, which represent moderate to substantial agreement among participants. Nevertheless, the only variable during Assessment 2 (Test 3-A) which is nature of crackles sounds was found to be slightly increased in kappa values (k=0.72). In general, kappa scores for all variables during Assessment 1 and 2 indicate moderate to substantial agreement of reliability among participants. Reliability for recognition and nature of crackles sounds variables were found to be higher than categorisation of crackles variable in both assessments.

Table 6.7 Kappa values for reliability of Group A (trained) and B (untrained) participants in detecting Velcro crackles on a particular category during Assessment 1

	Group A (Trained) Assessment 1				Group B (Untrained) Assessment 1			
	Test 1-A		Test 2-A		Test 1-B		Test 2-B	
	k	**SE**	***k***	**SE**	***k***	**SE**	***k***	**SE**
Recognition of crackle sounds	0.665	0.059	0.742	0.063	0.475	0.053	0.434	0.061
Categorisation of crackle sounds	0.605	0.063	0.589	0.068	0.254	0.052	0.227	0.05
Nature of crackle sounds	0.648	0.061	0.773	0.06	0.229	0.049	0.241	0.049

Table 6.8 Kappa values for reliability of Group A (trained) and B (trained) participants in detecting Velcro crackles on a particular category during Assessment 2

	Group A (Trained) Assessment 2				Group B (trained) Assessment 2			
	Test 3-A		Test 4-A		Test 3-B		Test 4-B	
	k	**SE**	***k***	**SE**	***k***	**SE**	***k***	**SE**
Recognition of crackle sounds	0.633	0.058	0.7	0.058	0.7	0.058	0.713	0.058
Categorisation of crackle sounds	0.599	0.061	0.579	0.06	0.592	0.059	0.592	0.059
Nature of crackle sounds	0.72	0.06	0.705	0.059	0.746	0.06	0.713	0.058

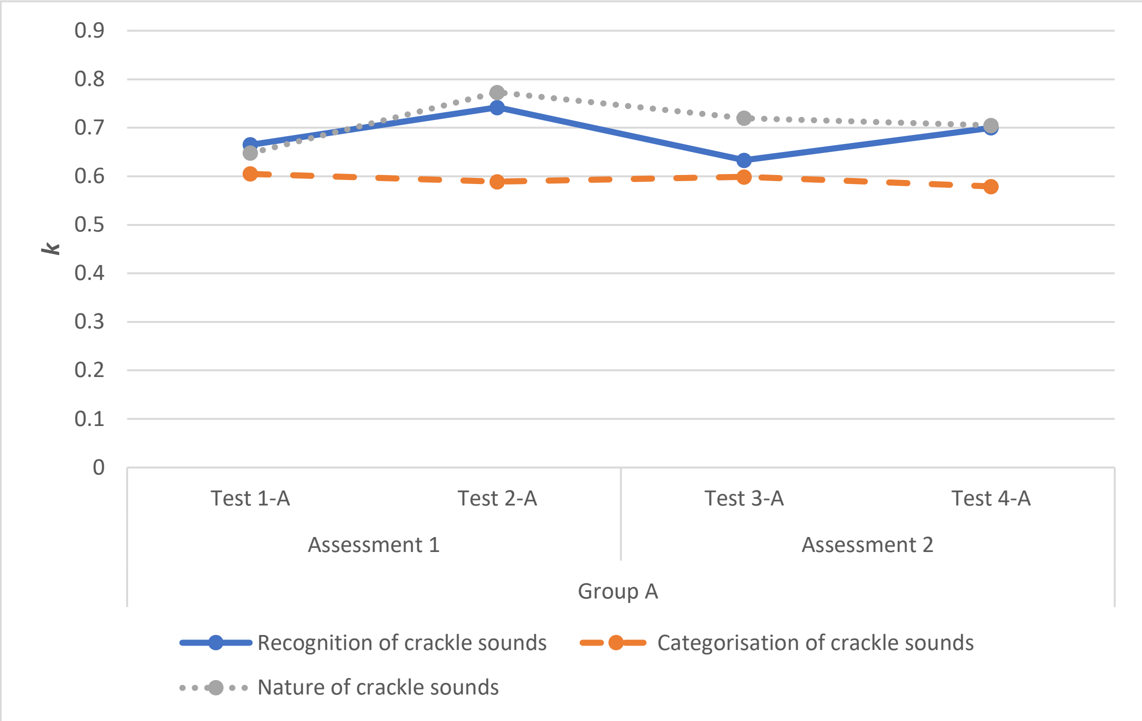

Figure 6.3 Kappa values for reliability of Group A in detecting Velcro crackles on a particular category during Assessment 1 and Assessment 2

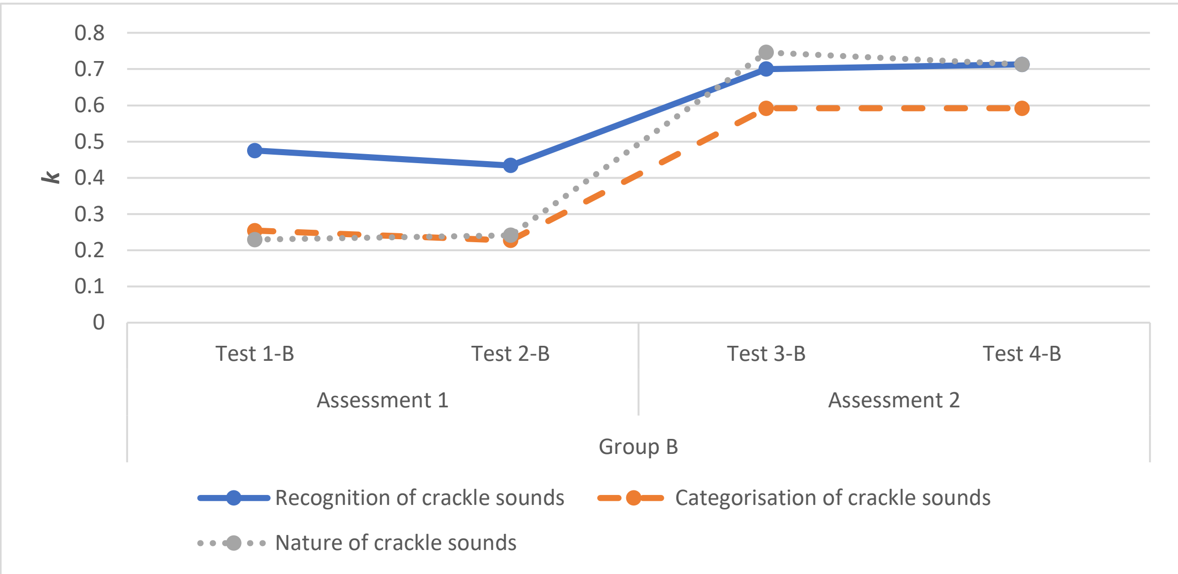

Figure 6.4 Kappa values for reliability of Group B in detecting Velcro crackles on a particular category during Assessment 1 and Assessment 2

6.2.5 Accuracy, sensitivity and specificity

Table 6.9 demonstrates percentages of accuracy, sensitivity, and specificity for Group A (trained) and Group B (untrained) during Assessment 1. Accuracy score was higher in Group A (88%) than Group B (53%) during Assessment 1. The accuracy score differed approximately by 35 points between trained and untrained group. There were approximately 54 to 63 points differences in sensitivity scores demonstrated between Group A and B for both tests. Sensitivity yielded high percentage for Group A, which received training session prior to Assessment 1 (Figure 6.5). On the contrary, sensitivity scores percentages were found to be low for Group B, which was untrained for Velcro crackles detection. Although, there was only a minimal difference of specificity scores between Group A and Group B that is approximately 13 to 20 points, yet specificity scores for Group B (75% to 77%) were still lower than Group A (90% to 95%).

Table 6.9 Sensitivity and specificity for Group A (trained) and Group B (untrained) during Assessment 1

	Group A (Trained) Assessment 1		Group B (Untrained) Assessment 1	
	Test 1-A (%)	Test 2-A (%)	Test 1-B (%)	Test 2-B (%)
Accuracy	88.33	88.33	52.5	53.33
Sensitivity	85.19	79.62	22.22	25.93
Specificity	90.91	95.45	77.28	75.76
True positive	88.47	93.48	44.44	46.67
False positive	11.53	6.52	55.56	53.33
True negative	88.24	85.14	54.83	55.56
False negative	11.76	14.86	45.16	44.44

Table 6.10 presents percentages of accuracy, sensitivity and specificity between Group A (trained) and Group B (trained) physiotherapists during Assessment 2. Accuracy scores were approximately similar between Group A and B. Following the training session, accuracy responses rate for Group B had increased from 53% at Assessment 1 to 88% at Assessment 2 (Figure 6.6). This increment was approximately 35 points after the training session.

Sensitivity scores were similar in percentages (80% to 85%) for all tests in both groups. Likewise, specificity scores were also found to be quite similar for all tests in both groups. After the training session in Assessment 2 of Group B, the percentages of sensitivity and specificity scores for all tests have increased (Figure 6.6). There were approximately 58 to 59 points increments in the scores of sensitivity scores and 16 to 18 points increments in specificity scores for Group B before and after the training session.

In addition, the percentages of sensitivity and specificity for Group A over time between Assessment 1 (Table 6.9) and Assessment 2 (Table 6.10) were found to be fairly similar in their percentages (Figure 6.5).

Table 6.10 Sensitivity and specificity for Group A (trained) and Group B (trained) during Assessment 2

	Group A (Trained) Assessment 2		Group B (Trained) Assessment 2	
	Test 3-A (%)	Test 4-A (%)	Test 3-B (%)	Test 4-B (%)
Accuracy	87.5	88.33	87.5	88.33
Sensitivity	80	83.33	80	85
Specificity	95	93.33	95	91.67
True positive	94.11	92.6	94.11	91.07
False positive	5.88	7.41	5.88	8.93
True negative	82.61	84.85	82.61	85.94
False negative	17.39	15.15	17.39	14.06

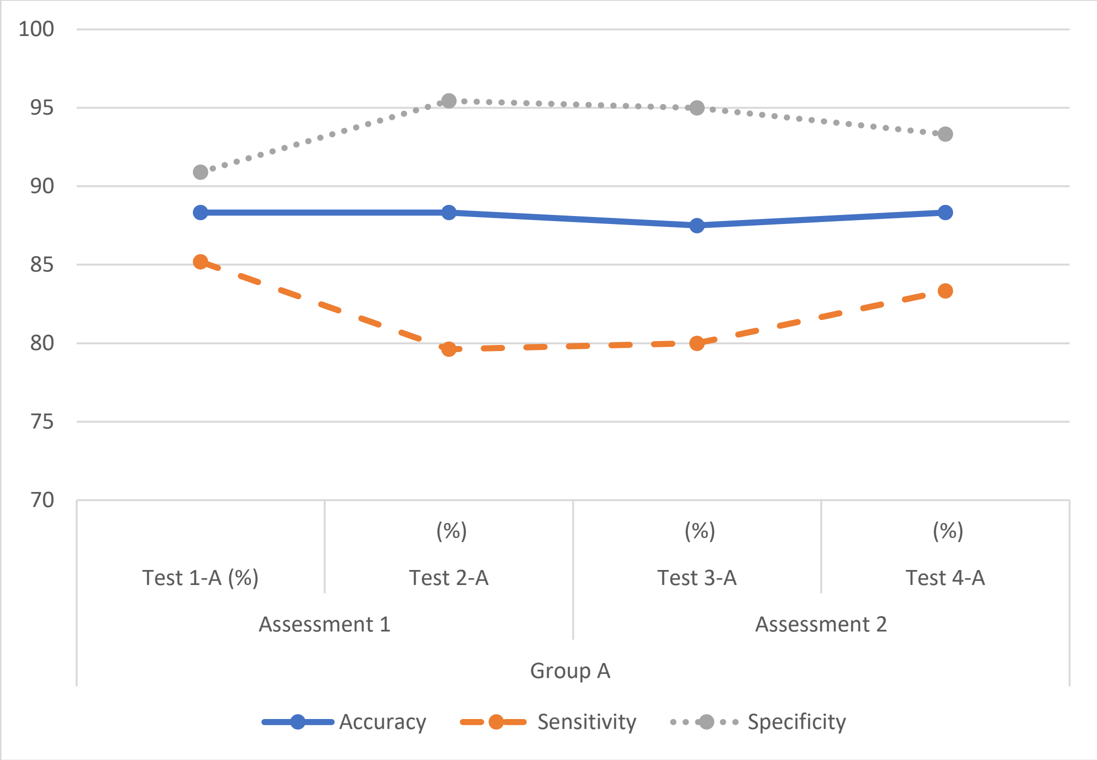

Figure 6.5 Sensitivity and specificity for Group A during Assessment1 and Assessment 2

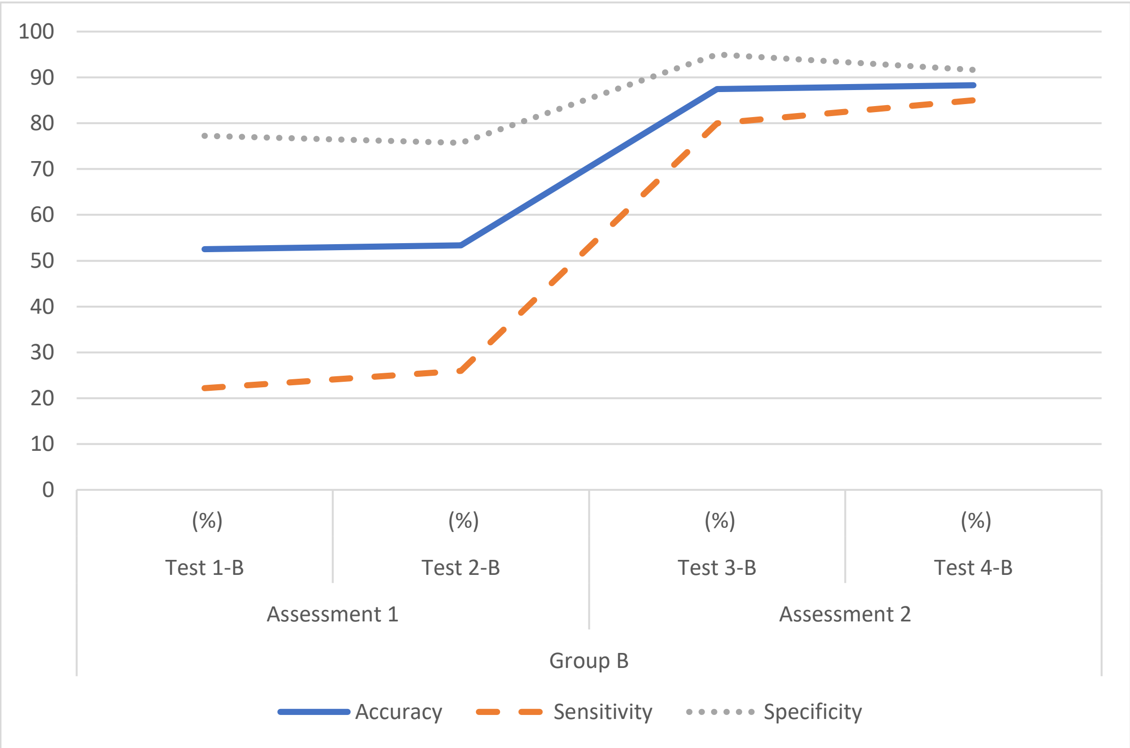

Figure 6.6 Sensitivity and specificity for Group B during Assessment1 and Assessment 2

6.2.6 Summary of the findings from study one

This section has presented the main findings from the data analysis of study one. The findings from study one showed that intra-observer reliability for the trained Group A indicates substantial to perfect agreement, in contrast there were fair to moderate agreement for the untrained Group B during Assessment 1. However, intra-observer reliability for the Group B improved, from moderate to perfect agreement after the training session during Assessment 2. Meanwhile, inter-observer reliability score for the trained Group A reflects moderate agreement, whereas the untrained Group B represents poor agreement during Assessment 1. Nonetheless, inter-observer reliability for Group B improved to moderate agreement at Assessment 2 after receiving the training session.

Accuracy, sensitivity and specificity were higher in Group A (trained) than Group B (untrained) during Assessment 1. Nevertheless, accuracy, sensitivity, and specificity were improved in Group B after the training session, at Assessment 2. The next section will present the findings from study two.

6.3 Study two: The impact of training on respiratory physiotherapists' ability to detect Velcro crackles in patients with idiopathic pulmonary fibrosis: A longitudinal mixed method study.

6.3.1 Results from the quantitative component of assessment form

6.3.1.1 Response rates

Overall, there were 40 respiratory physiotherapists at the Kuala Lumpur General Hospital (n=20), Pantai Integrated Rehab. Services (n=15), Your Physio (n=5), and Columbia Asia Hospital (n=5) in Malaysia were eligible to participate in this study. Therefore, 40 recruitment information packs of the study have been administered to all of them. A total of 31 out of the 40 respiratory physiotherapists have returned the reply slip and agreed to take part in the study. There were 10 respiratory physiotherapists from the Kuala Lumpur General Hospital, 15 physiotherapists from the Pantai Integrated Rehab. Services, three physiotherapists from the Your Physio, and three physiotherapists from the Columbia Asia Hospital who volunteered to participate in the study. This results to the response rate of 77%. There was no drop out of participant reported during data collection. All of 31 participants were able to complete three occasions of assessment sessions during data collection.

A flow diagram of CONSORT (consolidated standards of reporting trials) recommendations (Schulz et al. 2010) has been developed for reporting the flow of participants through each stage of data collection process in this study in order to clarify the numerical history of the study's participants (Figure 6.7).

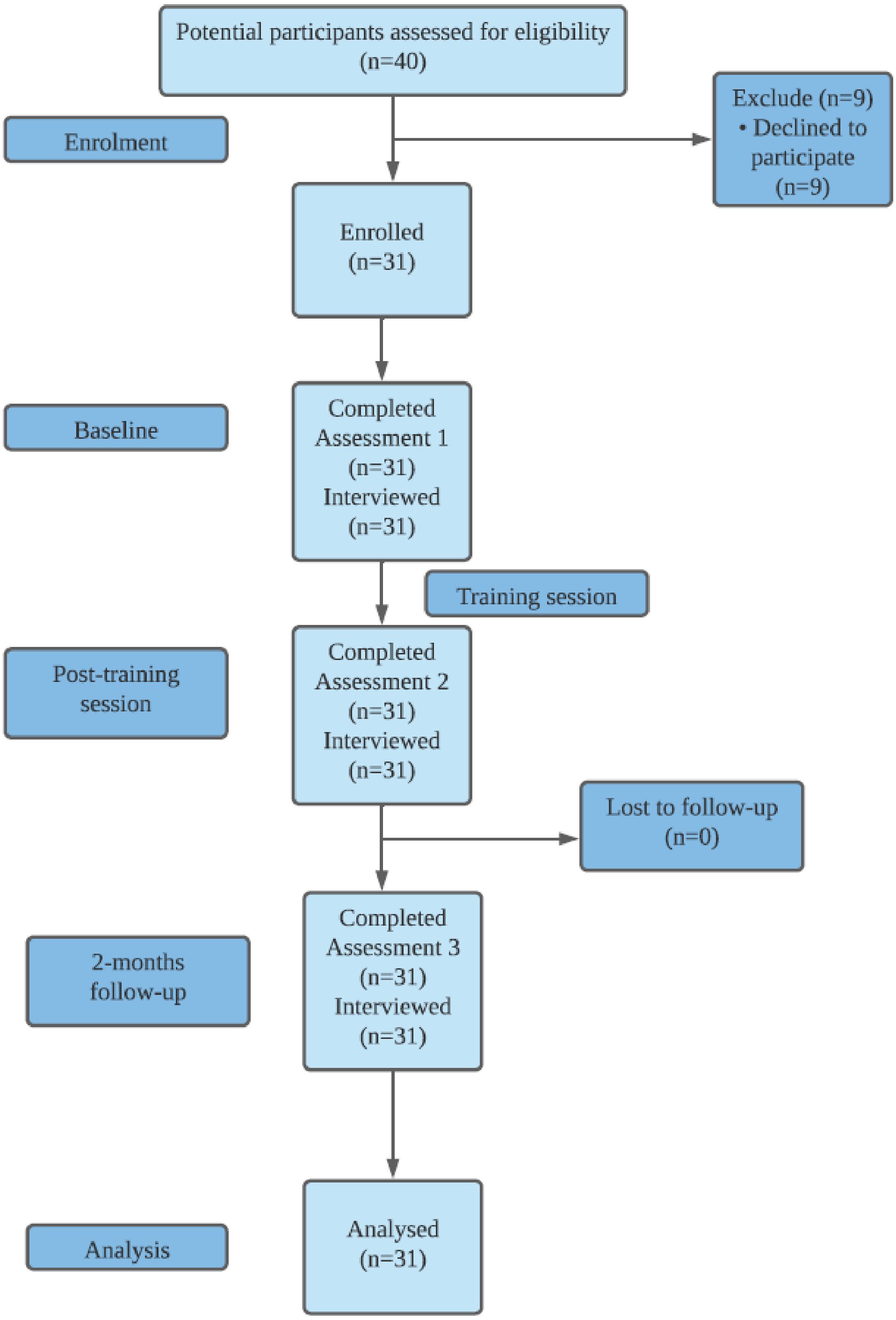

Figure 6.7 Participation flow diagram of CONSORT recommendations (Schulz et al. 2010)

6.3.1.2 Demographic characteristics

Majority of participants were female respiratory physiotherapists (n=28) and only three male respiratory physiotherapists took part in the study. The participants' age ranges from 25 to 35 with mean age was 28.23 (SD = 3.05) years old. Their number of years of qualified as physiotherapist range from 2 to 10 (M = 4.90, SD = 2.62) years since graduated from undergraduate physiotherapy programme. Participants' working experience in respiratory physiotherapy were ranging from 2 to 8 years with mean years of experience was (M = 4.32, SD = 2.23).

Table 6.11 shows characteristics of participants who took part in this study. Most participants were junior respiratory physiotherapists who have experience between 2 to 4 years in respiratory physiotherapy practice and 12 of them were senior respiratory physiotherapists. There was a small percentage of proportion among participants who have had experience in treating patients with IPF condition (29%), however majority of them did not have any experience with IPF. In addition, all of them have never received any training in detecting Velcro crackles in patients with IPF. There were 13 days of annual leave taken by the seven participants (M = 1.86, SD = 1.46) within two months following the post-training assessment. Overall, three cases of patients who were detected for Velcro crackles have been referred for further investigation of IPF by two participants (M =1.5, SD = 0.71) within two months after the post-training assessment.

Table 6.11 Characteristics of participants (*N*=31)

Variable	Total number	Frequency	Percentage
Respiratory Physiotherapist			
5 years and above (senior)		*N* = 12	39%
2 years to 4 years (junior)		*N* = 19	61%
Experience with IPF patient			
Yes		*N* = 9	29%
No		*N* = 22	71%
Heard about Velcro crackle			
Yes		0	0
No		*N* = 31	100%
Training for detecting Velcro crackles			
Yes		0	0%
No		*N* = 31	100%
Total number of leave taken by participants	13 days	*N* = 7	21%
Total number of referrals for IPF	3 cases	*N* = 2	6%

6.3.1.3 Inter-observer reliability

Table 6.12 shows findings from the Fleiss Kappa analysis of inter-observer reliability of respiratory physiotherapists in detecting Velcro crackles from pre-recorded lung sounds of patients with IPF over time, which were during the pre-training, post-training and two-month follow-up assessments. During the pre-training assessment, the Kappa value indicated poor agreement of inter-observer reliability according to Landis and Koch (1977) (Figure 6.8). However, the reliability score for post-training assessment increased to 0.36 point higher than pre-training, which represented moderate agreement among participants (Table 6.14) (Figure 6.8).

The z statistic revealed that there was a statistically significant improvement in inter-observer reliability from the pre-training to post-training assessments with $z = -16.09$, $p < 0.001$. In addition, a statistically significant difference was also found between the pre-training and at two-month follow-up assessments, in which the reliability score at the two-month follow-up assessment was 0.30 point higher than the pre-training assessment ($z = -13.64$, $p < 0.001$). Over time, at the two-month follow-up assessment reliability was reduced to 0.06 point compared to post-training yet represented moderate agreement (Table 6.12) (Figure 6.8). The z statistic indicated that there was a statistically significant difference between reliability scores at the post-training and two-month follow-up assessments ($z = 2.12$, $p = 0.03$).

Overall, the standard errors represented small effect size for all three assessments. The findings show that training session has improved the inter-observer reliability of respiratory physiotherapists from poor agreement at the pre-training assessment to moderate agreement at the post-training assessment. This might be due to improvement of their skill in detecting Velcro crackles from the lung sound recordings. Nevertheless, after prolonged duration of two-month follow-up assessment, the reliability was slightly reduced compared to post-training assessment, which might be because their skill retention have reduced after prolonged time.

Table 6.12 Kappa values for inter-observer reliability of respiratory physiotherapists during pre-training, post-training and two-month follow-up assessments

Assessment	Kappa (***k***)	Standard Error (***SE***)
Pre-training	0.20	0.01
Post-training	0.56	0.02
At two-month follow-up	0.50	0.02

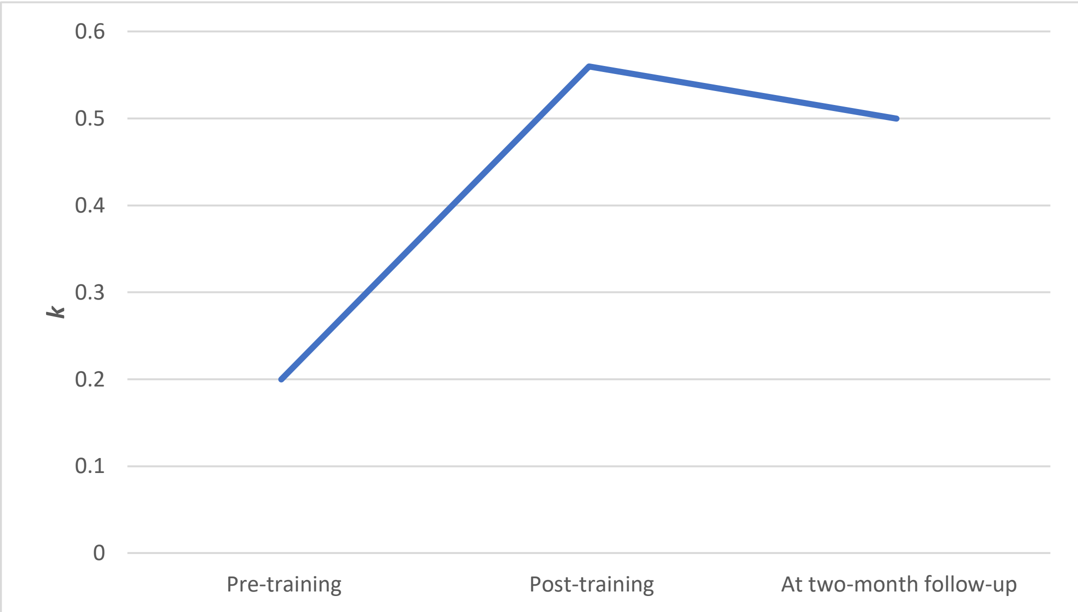

Figure 6.8 Kappa values for inter-observer reliability of respiratory physiotherapists during pre-training, post-training and two-month follow-up

Table 6.13 demonstrates inter-observer reliability of participants based on detailed category of lung sounds which include recognition of crackles (distinguishing abnormal from normal lung sounds), categorisation of crackles (classifying the crackles into fine, coarse or both) and nature of crackles (identifying Velcro or non-Velcro crackles) at the pre-training, post-training, and two-month follow-up assessments. Reliability was relatively low for all categories, which indicated slight to moderate agreement among participants at the pre-training assessment (Figure 6.9). Nevertheless, reliability was improved after the training session which the values reflected moderate to substantial agreement for all categories at the post-training and two-month follow-up assessments (Table 6.13) (Figure 6.9).

The z statistic revealed that there were statistically significant differences of kappa values for all the three categories between the pre-training and post-training assessments (recognition of crackles with $z = -6.59$, $p < 0.001$, categorisation of crackles with $z = -16.09$, $p < 0.001$ and nature of crackle sounds with $z = -11.07$, $p < 0.001$), and also between the pre-training and at two-month follow-up assessments (recognition of crackles with $z = -6.36$, $p < 0.001$, categorisation of crackles with $z = -13.42$, $p < 0.001$ and nature of crackle sounds with $z = -14.76$, $p < 0.001$). However, during the two-month follow-up assessment, the kappa values for recognition of crackles, categorisation of crackles and nature of crackles were slightly reduced to 0.01point, 0.06 point, and 0.02 point respectively from the post-training assessment scores (Table 6.13). The z statistic indicated that there was a statistically significant difference of inter-observer reliability for categorisation of crackles between post-training and two-month follow-up assessments ($z = 2.12$, $p = 0.03$). Nevertheless, no statistically significant differences were found for recognition and nature of crackles between post-training and two-month follow-up ($z = 0.24$, $p = 0.81$, $z = 0.55$, $p = 0.58$ respectively).

The inter-observer reliability for recognition of crackles was found to be higher agreement than categorisation and nature of crackle sounds for all assessments (Table 6.13). The z statistic revealed that there were statistically significant differences of inter-observer reliability between recognition and categorisation of crackles at the pre-training, post-training, and two-month follow-up assessments ($z = 6.66$, $p < 0.001$, $z = 3.33$, $p < 0.001$, $z = 4.72$, $p < 0.001$ respectively). In addition, there were also statistically significant differences of inter-observer reliability between recognition and nature of crackle sounds at the pre-training, post-training, and two-month follow-up assessments ($z = 6.66$, $p < 0.001$, $z = 3.33$, $p < 0.001$, $z = 4.72$, $p < 0.001$ respectively).

The kappa values for recognition of crackles represented moderate agreement at the pre-training assessment and substantial agreement for both the post-training and two-month follow-up assessments (Table 6.13). In contrast, categorisation of crackles and nature of crackles reflected slight agreement at the pre-training assessment and moderate agreement at both the post-training and two-month follow-up assessments (Table 6.13). Nevertheless, no statistically significant differences of inter-observer reliability were found between categorisation and nature of crackle sounds for all the three assessments.

Table 6.13 Kappa values for reliability in detecting Velcro crackles on a category during pre-training, post-training and two-month follow-up assessments

	Category					
	Recognition of crackle sounds		Categorisation of crackle sounds		Nature of crackle sounds	
Assessment	***k***	***SE***	***k***	***SE***	***k***	***SE***
Pre-training	0.40	0.03	0.20	0.01	0.19	0.01
Post-training	0.68	0.03	0.56	0.02	0.54	0.03
At two-month follow-up	0.67	0.03	0.50	0.02	0.52	0.02

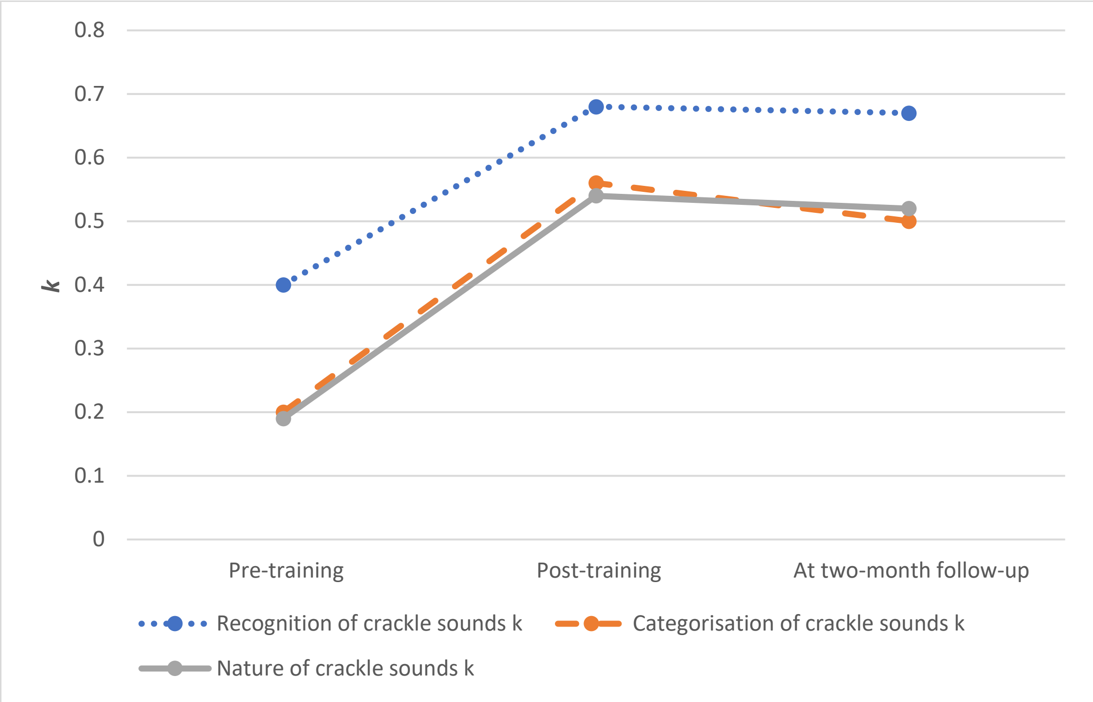

Figure 6.9 Kappa values for reliability in detecting Velcro crackles on a category during pre-training, post-training and two-month follow-up assessments

6.3.1.4 Accuracy, sensitivity and specificity of Velcro crackles detection over time

Figure 6.10 shows the trend of accuracy scores of Velcro crackles detection by participants over time during the pre-training, post-training, and two-month follow-up assessments. There was an improvement in mean accuracy from pre-training (58.06%) towards post-training (86.84%) assessments. However, the mean accuracy decreased to 82.97% at the two-month follow-up assessment.

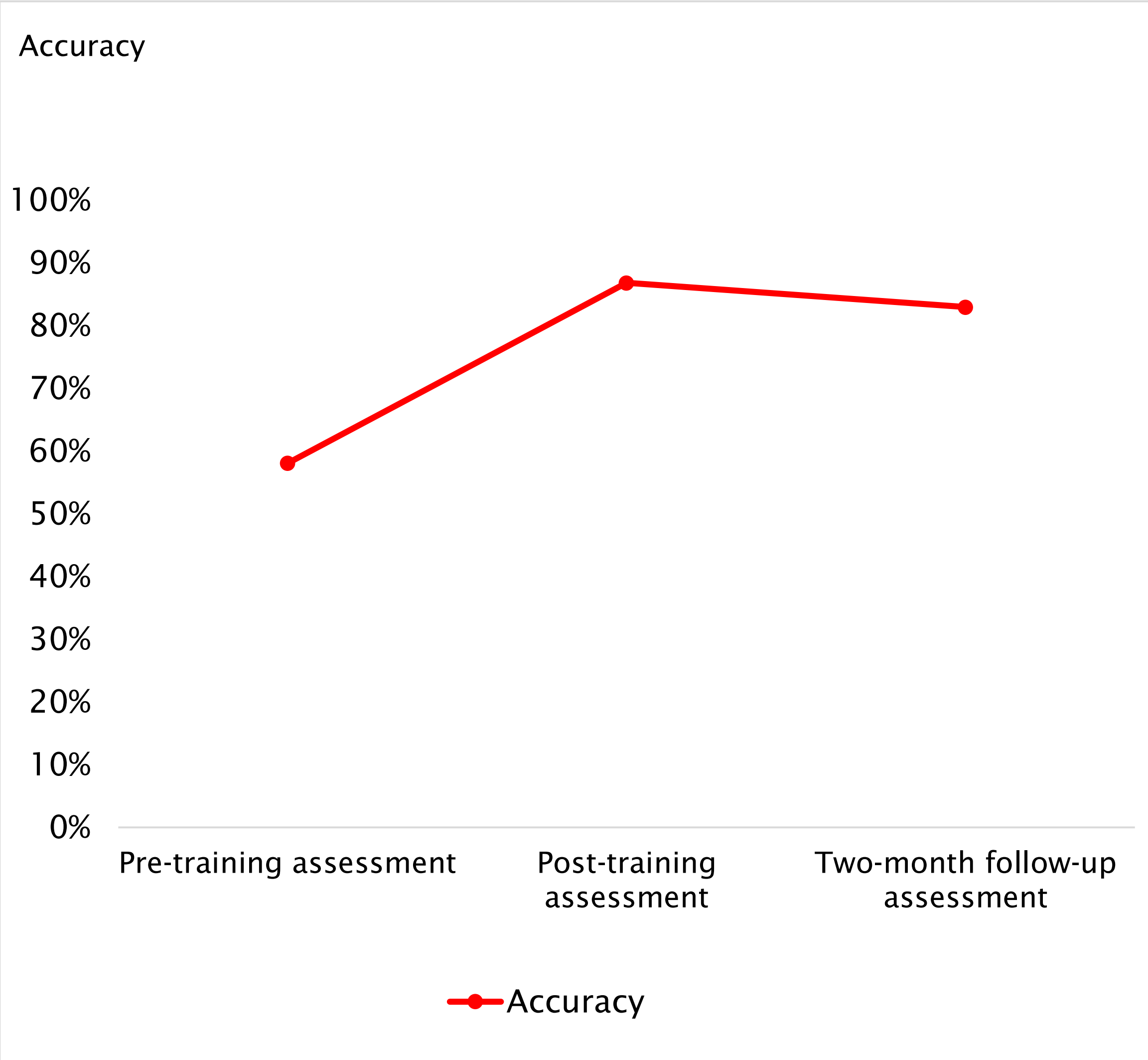

Figure 6.10 Accuracy scores of Velcro crackles detection at the pre-training, post-training and two-month follow-up assessments

Figure 6.11 illustrates the trend of sensitivity scores of Velcro crackles detection by participants over time during the pre-training, post-training and two-month follow-up assessments. The mean sensitivity increased from 43.49% at the pre-training assessment to 85.48% at the post-training assessment. However, the mean sensitivity dropped to 80.21% at the two-month follow-up assessment.

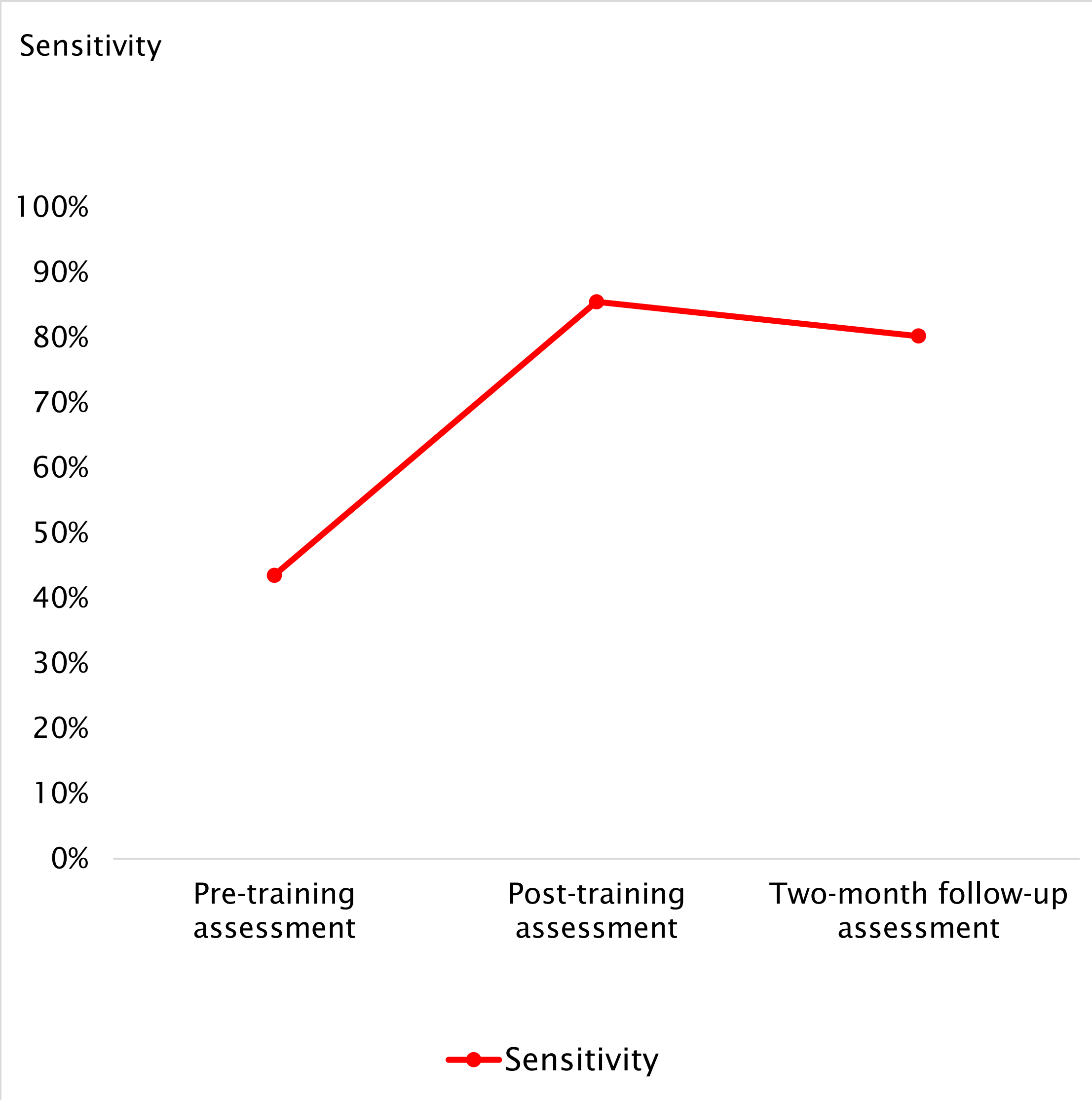

Figure 6.11 Sensitivity scores of Velcro crackles detection at the pre-training, post-training and two-month follow-up assessments

Figure 6.12 illustrates the trend of specificity scores of Velcro crackles detection by participants over time which at the pre-training, post-training, and two-month follow-up assessments. The mean specificity increased from 84.54% at the pre-training assessment to 91.32% at the post-training assessment. However, it decreased to 88.84% at the two-month follow-up assessment.

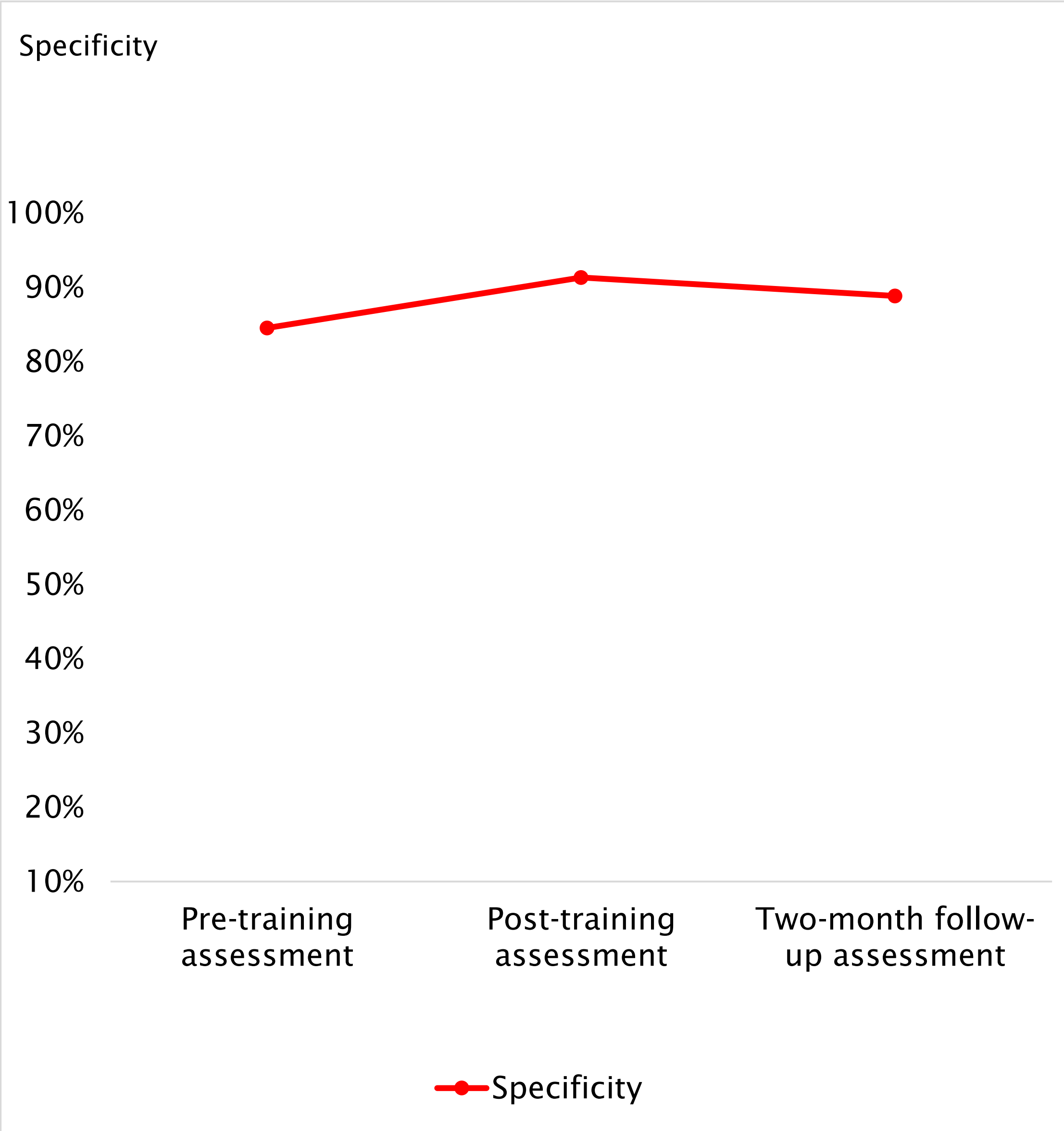

Figure 6.12 Specificity scores of Velcro crackles detection at the pre-training, post-training and two-month follow-up assessments

Table 6.14 shows the overall scores for accuracy, sensitivity, and specificity of Velcro crackles detection by respiratory physiotherapists during pre-training, post-training, and two-month follow-up assessments. A Friedman test was used to investigate the impact of training session on the assessments of Velcro crackles detection scores among respiratory physiotherapists with time points, which at the pre-training, post-training, and two-month follow-up assessments. Participants were asked to detect Velcro crackles from 25 pre-recorded lung sounds for each assessment. The repeated measures Friedman test indicated that participants' scores of accuracy and sensitivity during the three level of assessments did change statistically significant over time, $p < 0.05$ (Table 6.14). However, there was no statistically significant difference between specificity scores measured before training, after training, and at two-month follow-up, $p > 0.05$ (Table 6.14).

Post-hoc test using a series of pairwise comparisons with the Wilcoxon Signed Rank test and a Bonferroni adjusted alpha level of 0.17 was used to determine whether there were any statistically significant differences in accuracy, sensitivity, and specificity between the pre-training, post-training, and two-month follow-up assessments scores of Velcro crackle detection (Table 6.15).

A Wilcoxon Signed Rank test revealed that there was a statistically significant difference between the scores of accuracy of Velcro crackles detection at pre-training and post-training, $p < 0.001$ (Table 6.15). Accuracy was significantly increased from median score of 56% at the pre-training assessment to median score of 88% at the post-training assessment $p < 0.001$. In addition, accuracy at the two-month follow-up assessment (*Mdn* = 80%) was significantly higher than accuracy at the pre-training assessment (*Mdn* = 56%), $p < 0.001$. The effect sizes of these two pairwise can be described as large, $r = 0.86$. However, accuracy at the two-month follow-up assessment (*Mdn* = 80%) was significantly lower than accuracy at the post-training assessment (*Mdn* = 88%), $p < 0.05$. This effect size can be described as medium, $r = 0.43$.

Likewise, a Wilcoxon Signed Rank test indicated that there were statistically significant differences of pairwise comparisons between sensitivity scores at the pre-training, post-training, and two-month follow-up assessments, $p < 0.05$ (Table 6.15). Sensitivity of Velcro crackles detection by participants at the post-training assessment (*Mdn* = 87.50%) was significantly higher than sensitivity at the pre-training assessment (*Mdn* = 43.75%), $p < 0.001$. Besides, sensitivity at the two-month follow-up assessment (*Mdn* = 81.25%) was significantly higher than accuracy at the pre-training assessment (*Mdn* = 43.79%), $p < 0.001$. The effect sizes of these two pairwise can be described as large, $r = 0.87$ and $r = 0.85$ respectively. However, sensitivity at the two-month follow-up assessment (*Mdn* = 81.25%) was significantly lower than sensitivity at the post-training assessment (*Mdn* = 87.50%), $p < 0.05$. This effect size can be described as medium, $r = 0.39$

Specificity at the post-training assessment (*Mdn* = 100.00%) was higher than specificity at the pre-training assessment (*Mdn* = 88.89%) (Table 6.15). However, a Wilcoxon Signed Rank test indicated that there was no statistically significant difference between specificity scores of Velcro crackles detection at the pre-training and post-training assessment, $p > 0.05$. This effect size can be described as medium, $r = 0.35$. Meanwhile, specificity was found to be constant at the two-month follow-up assessment (*Mdn* = 88.89%) and at pre-training assessment, which was clearly no statistically significant difference, $p > 0.05$. This effect size can be described as small, $r = 0.19$. Specificity at the two-month follow-up assessment (*Mdn* = 88.89%) was lower than specificity at the post-training assessment (*Mdn* = 100.00%), but no significant difference was found, $p > 0.05$. This effect size can be described as small, $r = 0.16$.

Table 6.14 Accuracy, sensitivity and specificity during the pre-training, post-training and two-month follow-up assessments

	Assessment								
	Pre-training		Post-training		Two-month follow-up		χ^2	*df*	*p*
	% Mean (*SD*)	% *Mdn* (*IQR*)	% Mean (*SD*)	% *Mdn* (*IQR*)	% Mean (*SD*)	% *Mdn* (*IQR*)			
Accuracy	58.06 (13.42)	56.00 (52.00, 68.00)	86.84 (5.58)	88.00 (80.00, 92.00)	82.97 (7.00)	80.00 (80.00, 88.00)	47.44	2	0.000*
Sensitivity	43.49 (19.37)	43.75 (31.25, 56.25)	85.48 (8.74)	87.50 (81.25, 93.75)	80.21 (9.66)	81.25 (75.00, 87.50)	44.81	2	0.000*
Specificity	84.54 (19.38)	88.89 (77.78, 100.00)	91.32 (11.19)	100.00 (88.89, 100.00)	88.84 (11.83)	88.89 (77.78, 100.00)	3.610	2	0.164

*statistically significant differences, $p < 0.05$

Table 6.15 Pairwise comparisons with the Wilcoxon Signed Rank test of Velcro crackle detection scores at pre-training, post-training and two-month follow-up assessments

	Assessment											
Score	Pre-training and Post-training				Pre-training and Two-month follow-up				Post-training and Two-month follow-up			
	T	*z*	*r*	*p*	*T*	*z*	*r*	*p*	*T*	*z*	*r*	*p*
Accuracy	0.00	-4.79	0.86	0.000*	3.50	-4.80	0.86	0.000*	75.00	-2.38	0.43	0.02*
Sensitivity	1.50	-4.84	0.87	0.000*	6.00	-4.75	0.85	0.000*	82.50	-2.18	0.39	0.03*
Specificity	36.00	-1.94	0.35	0.052	95.00	-1.04	0.19	0.30	75.50	-0.90	0.16	0.37

*statistically significant differences, $p < 0.05$

6.3.1.5 Accuracy, sensitivity and specificity of Velcro crackles detection according to the levels of clinical experience

Even though the median scores of accuracy for Velcro crackles detection appeared higher in senior group of respiratory physiotherapists than junior group at the pre-training (junior = 56% and senior = 58%), post-training (junior = 88% and senior = 90%), and two-month follow-up assessments (junior = 80% and senior = 82%) (Table 6.16), the Mann-Whitney U test did not find any statistical significance in differences for all the three assessments, $p > 0.05$ (Table 6.17).

Table 6.16 shows the median score of sensitivity was higher in junior group (43.75%) than senior (40.63%) at the pre-training assessment. At the post-training assessment, senior group has higher median score (87.50%) than junior (81.25%). However, both groups have similar median scores of sensitivity at the two-month follow-up assessment (81.25%). A Mann-Whitney U test indicated that there were no statistically significant differences in sensitivity of Velcro crackles detection between junior and senior respiratory physiotherapists for all the three assessments, $p > 0.05$ (Table 6.17).

In addition, median scores of specificity were similar in junior and senior groups at the pre-training assessment (88.89%) (Table 6.16). However, senior group scored higher median sensitivity than junior which were 100% and 88.89% respectively at both post-training and two-month follow-up assessments. A Mann-Whitney U test revealed that there were no statistically significant differences in specificity of Velcro crackles detection between junior and senior respiratory physiotherapists for all the three assessments, $p > 0.05$ (Table 6.17).

Table 6.16 Median scores of accuracy, sensitivity and specificity for Velcro crackle detection according to the levels of clinical experience at the pre-training, post-training and two-month follow-up assessments

	Assessment					
	Pre- training		Post-training		Two-month follow-up	
	Junior	Senior	Junior	Senior	Junior	Senior
	% Mdn (IQR)	*% Mdn (IQR)*	*% Mdn (IQR)*	*% Mdn (IQR)*	*% Mdn (IQR)*	*% Mdn (IQR)*
Accuracy	56.00 (52.00, 68.00)	58.00 (48.00, 68.00)	88.00 (80.00, 88.00)	90.00 (84.00, 92.00)	80.00 (76.00, 88.00)	82.00 (80.00, 91.00)
Sensitivity	43.75 (31.25, 56.25)	40.63 (29.87, 60.94)	81.25 (81.25, 93.75)	87.50 (76.56, 87.50)	81.25 (68.75, 87.50)	81.25 (76.56, 87.50)
Specificity	88.89 (77.78, 100.00)	88.89 (80.21, 100.00)	88.89 (77.78, 100.00)	100.00 (88.89, 100.00)	88.89 (77.78, 100.00)	100.00 (80.21, 100.00)

Table 6.17 Mann-Whitney U test outcomes for accuracy, sensitivity and specificity according to the levels of clinical experience at the pre-training, post-training and two-month follow-up assessments

	Assessment								
	Pre- training			Post-training			Two-month follow-up		
	U	*z*	*p*	*U*	*z*	*p*	*U*	*z*	*p*
Accuracy	111.00	-0.12	0.92	90.50	-0.98	0.35	96.50	0.47	0.48
Sensitivity	110.00	-0.16	0.89	112.50	-0.06	0.95	90.00	-0.99	0.35
Specificity	113.00	-0.04	0.98	74.00	-1.77	0.11	94.50	-0.83	0.44

6.3.1.6 Relationship between accuracy, sensitivity and specificity of Velcro crackles detection with participants' days of leave within two months

A Spearman's rho analysis was used to measure the correlation between participants' accuracy, sensitivity, and specificity of Velcro crackles detection at the two-month follow-up assessment with their days of leave taken within two months following the training session. A Spearman's rho revealed that there were statistically significant correlations with strong negative correlation coefficients between days of leave with the accuracy (rs = -0.85, p = 0.02), and sensitivity (rs = -0.84, p = 0.02) at the two-month follow-up assessment.

However, no statistically significant correlation was found between days of leave and specificity (rs = -0.47, p = 0.29) of Velcro crackles detection score at the two-month follow-up assessment, with correlation showed negative moderate correlation coefficient.

6.3.1.7 Relationship between accuracy, sensitivity and specificity of Velcro crackles detection and participants' years of clinical experience in respiratory physiotherapy

A Spearman's rho analysis was calculated to measure the correlation between participants' accuracy, sensitivity and specificity of Velcro crackles detection with their years of clinical experience in respiratory physiotherapy. Table 6.18 shows that there were no statistically significant correlations between years of clinical experience and accuracy, sensitivity and specificity of Velcro crackles detection scores at the pre-training, post-training, and two-month follow-up assessments generally, $p > 0.05$.

Table 6.18 shows that there was a weak positive correlation coefficient between accuracy and years of clinical experience at the pre-training assessment, whereas no correlations were found at the post-training and two-month follow-up assessments (Table 6.18). Besides, weak positive and negative correlation coefficients were found between sensitivity and years of clinical experience at the pre-training and two-month follow-up assessments respectively, whereas no correlation was found at the post-training assessment (Table 6.18). No correlation was found between specificity and years of clinical experience at the pre-training and two-month follow-up assessments, whereas a weak positive correlation coefficient was found at the post-training assessment (Table 6.18).

Table 6.18 Correlations between Velcro crackle detection scores and participants' years of experience working in respiratory physiotherapy at the pre-training, post-training and two-month follow-up assessments

	Assessment					
	Pre- training		Post-training		Two-month follow-up	
	rs	*p*	*rs*	*p*	*rs*	*p*
Accuracy	0.11	0.57	0.01	0.96	-0.02	0.90
Sensitivity	0.21	0.27	-0.06	0.75	-0.16	0.39
Specificity	-0.05	0.78	0.17	0.36	-0.08	0.66

6.3.1.8 Summary of quantitative component

According to the quantitative data analysis of study two, inter-observer reliability of participants in detecting Velcro crackles was significantly increased from poor agreement at the pre-training assessment to moderate agreement at the post-training assessment. However, reliability was significantly reduced at the two-month follow-up assessment from the post-training assessment, yet still indicates moderate agreement. Accuracy and sensitivity during pre-training, post-training, and two-month follow-up assessments did change significantly over time. Specificity remained constant over time. Accuracy and sensitivity were significantly increased at the post-training assessment from the pre-training assessment. However, there were significant decay in accuracy and sensitivity from the post-training to the two-month follow-up assessments.

There were significant negative correlations between days of leave with the accuracy and sensitivity at the two-month follow-up assessment. No correlation was found between participants' days of leave and specificity. Besides, no correlations between participants' years of clinical experiences with accuracy, sensitivity, and specificity in detecting Velcro crackles were observed for all the three assessments. There were no significant differences found in accuracy, sensitivity, and specificity between junior and senior participants.

The next section will highlight the findings from complementary qualitative component in study two.

6.3.2 Results from the qualitative component of semi-structured interview

6.3.2.1 Introduction

Since the results from the assessment forms to detect Velcro crackles over time alone may not provide enough detail and depth into participants' experiences and perceptions in order to further explore their perception towards Velcro-crackles, the training session and transfer of skill, therefore data from qualitative component was embedded into this mixed methods design. This approach was used to gather rich data regarding participants' experiences and perceptions towards Velcro crackles detection overtime. All 31 participants were interviewed by the researcher at the end of each assessment, at pre-training assessment, post-training assessment and two-month follow-up assessment. This section discusses the qualitative data relating to findings from the interviews.

6.3.2.2 Experiences of Velcro crackles detection at pre-training session

There were two main questions and three secondary questions within the interviews that were related to the topic of participants' experiences of Velcro crackles detection at pre-training session.

i. How do you find the crackle sounds in these recordings?
   a. How did you decide the sound is Velcro crackles?
   b. How would you describe the Velcro crackles that you heard in the recording?

ii. What are the difficulties in detecting Velcro crackles in these recordings?
   a. How easy was it to detect the Velcro crackles in the recording?

These questions were aimed to further explore in depth of participants' view regarding this topic. Table 6.19 shows the responses of the participants whom revealed three main themes and three sub-themes constructed to reflect their responses relating to their experiences of Velcro crackles detection at pre-training session.

Table 6.19 Summary of themes and subtheme derived from interview regarding the topic of clinical experience of Velcro crackles detection during pre-training session.

Themes	Sub-themes	Categories
Ability to recognise lung sounds	Determined	
	Difficulty	Repetition of listening
		Unusual clinical practice
	Uncertainty	
Unfamiliar with Velcro crackles		
Distraction		

6.3.2.2.1 Theme 1: Ability to recognise lung sounds

Ability to recognise lung sounds was an important theme as it spoke to the interpretation of the lung sounds that participants heard from the pre-recordings. Recognition enable participants to differentiate the presence of normal or abnormal lung sounds, classify detailed categories of crackle sounds into fine or coarse, and decide whether the crackles are Velcro or non-Velcro during the assessment. This recognition of lung sounds was influenced by three subthemes which were raised by interviewees as determined, difficulty, and uncertainty during completing the pre-training assessment.

Determined

The first question in the assessment form was to evaluate the ability of participants to detect the presence of normal or abnormal lung sounds. Most interviewees (*N* = 25) were able to recognise lung sounds between normal and abnormal sounds when answering the first question during pre-training assessment session. They were able to differentiate the characteristics of normal lung sounds and abnormal lung sounds such as crackles and wheeze while listening to the pre-recording files. For instance, one interviewee said:

'Yes… I was able to detect the crackle sounds in those recording to answer the first question. I could clearly hear the quite normal breath sounds and abnormal sounds, like wheeze and crackles from the recording.'

(Participant P02)

This response represents participants were determined that they were able to interpret the nature of lung sounds between normal and abnormal lung sounds. This was echoed in other response by other participants who also stated that it was easy to detect the presence of abnormal lung sounds due to frequent listening to lung sounds in daily clinical practice. For example, one interviewee mentioned:

'It was easy for me to detect them because I frequently hear of these during daily clinical practice on chest assessment. Thus, I am able to detect whether there is presence of crackles sound or not.'

(Participant P14)

In addition, there were also a few participants who were able to determine the types of crackles such as fine or coarse crackles from the recording when answering the second question. This second part of question was to assess participants' ability to categorise the crackle sounds that they heard into fine or coarse crackles types. One interviewee said:

'I can tell there were fine crackles and coarse crackles when listening to those recording sounds.'

(Participant P07)

Difficulty

On the contrary, most interviewees (*N* = 21) have difficulty to categorise the type of crackles into detailed categories of fine or coarse crackles. There were two categories within subtheme of difficulty which were repetition of listening and unusual clinical practice. Interviewees explained it was hard to differentiate the characteristic of fine and coarse crackles because they found these crackle sounds were quite similar. Thus, to overcome this difficulty some of them did a repetition of listening to those pre-recorded lung sounds. For instance, one interviewee mentioned:

'*Urmm.. In some of the files I found it hard to detect whether those crackles that I heard are coarse or fine. Because those sounds were quite similar for me. Mmm..so I have to replay again and again some of those recording sounds to detect the type of crackles.'*

(Participant P12)

Another interviewee responded that by listening repeatedly to those recordings could help her to know which phase of respiration that the crackles present during breathing cycle. As she stated:

'It was difficult to decide fine or coarse crackles, they were similar for me. I have to hear them a few times and carefully listen whether the crackles were present at early, mid, or end of inspiration phase. And also, whether they were heard during expiration phase.'

(Participant P19)

Surprisingly, there was one interviewee claimed that she found very difficult to recognise the differences between fine and coarse crackles due to unfamiliar with these sounds. She expressed that she seldom practices auscultation on her patients during chest assessment since working in the respiratory area due to the time consuming process of auscultation. This situation indicated that she applied unusual standard clinical practice from others respiratory physiotherapists when assessing patient with respiratory diseases.

'I am having difficulty to categorise those crackles into fine or coarse. I am not familiar with the crackles because I rarely do auscultation in my clinical practice. You know, I just don't like to do it (auscultation) on my patients, because it will take your time like 5 to 7 minutes. I just treated them based on their complaints. Yes…if they complain of having phlegm, I will clear their lungs without bothering with doing auscultation assessment.'

(Participant P15)

Uncertainty

All interviewees (N = 31) raised the uncertainty to describe the characteristics of Velcro crackles sounds and to detect them from recordings. As a results, they tried to assume the nature of Velcro crackle sounds when answering the last question. This question was used to assess their ability to identify the crackles that they heard were Velcro or non-Velcro in nature. Some interviewees assumed that Velcro crackle is a fine type of crackle. For instance, interviewee P22 stated:

'I just guess that fine type of crackles with high pitch are Velcro crackles when answering the form.'

(Participant P22)

On the other hand, other interviewees guessed that Velcro crackle was actually a coarse crackle. One interviewee, P30 said:

‘I was completely not sure about these Velcro crackles. Mmm…I assume coarse crackles are the Velcro crackles sounds, but then I’m guessing my answer to complete the question.’

(Participant P30)

Meanwhile, interviewee P25 tried to predict Velcro crackle sounds based on its name the ‘Velcro’, which produces similar sound of tearing apart of Velcro tape.

‘Seriously I am not sure how the Velcro crackles sounds are…Maybe the sounds are like when you pulling the Velcro tape. But then, I don’t know the exact sound of Velcro crackles.’

(Participant P25)

In general, it is clear from interviewees’ responses that they were not able to recognise the characteristics of Velcro crackle sounds during pre-training assessment. Many of them lacked of skill to interpret and detect between fine or coarse crackles which they found very hard to categorise those types of crackles. Nonetheless, they were able to recognise the presence of normal lung sounds and abnormal lung sounds during the assessment.

6.3.2.2.2 Theme 2: Unfamiliar with Velcro crackle sounds

It appeared that all participants (*N* = 31) raised an issue that they neither have any experience of Velcro crackle sounds in clinical practice nor during previous pre-qualifying undergraduate study. For instance, one interviewee said:

'Seriously, I really have no idea about it. This is the first time I heard the terminology of Velcro crackles.'

(Participant P02)

She later added that:

'Oh no…I couldn't confirm my answer because I'm assuming fine crackles are Velcro crackles.'

(Participant P02)

It was clear from her response (participant P02) that she was not able to recognise exactly the nature of Velcro crackle sounds.

Similar issue was mentioned by another interviewee when he said:

'I have never been exposed to this kind of crackles before. I only know about fine and coarse crackles, but not this one (Velcro crackle).'

(Participant P13)

In addition, another interviewee asserted that:

'Well, I am not familiar with the crackle (Velcro crackle). I never learned about it before in lecture or during clinical practice.'

(Participant P25)

Some interviewees (*N* = 5) highlighted that without having acquired knowledge and skills on how to detect Velcro crackle sounds, it is impossible for them to recognise these crackle sounds during pre-training assessment. This was apparent from one of them who said:

'Overall, it is difficult to detect the Velcro crackles without you having any knowledge and skills of what the Velcro crackles about.'

(Participant P08)

Apparently, all the interviewees shared the same experience where they had never been exposed to the Velcro crackle sounds during previous undergraduate study and clinical practice as physiotherapists. Therefore, they have no knowledge about the characteristics of Velcro crackles that they heard from pre-recorded lung sounds. All of them were uncertain about their answers during pre-training assessment.

6.3.2.2.3 Theme 3: Distraction

Another point that was raised by participants was the quality of the lung sounds that they heard during pre-training assessment. Most of them ($N = 18$) mentioned that they could hear an extraneous noise which could distract their focus during detecting the lung sounds. For example, one interviewee explained:

'*Sometimes, in the certain recordings I heard an annoying noise like a person trying to adjust the stethoscope head, which interrupt the clear sound of those recordings'*

(Participant P07)

However, participant P07 later added that she still could manage to hear the lung sounds and could tell whether there was presence of crackles or not in those recordings.

Another interviewee added similar response regarding this which she asserted:

'Occasionally, I could hear rubbing sounds from stethoscope in some of those files. Somehow, I was distracted and yes, I need to carefully listen to them. But most of the time I could differentiate between the crackle sounds and rubbing sounds.'

(Participant P20)

Although extraneous sounds produced by incorrect technique of handling the stethoscope during recording chest auscultation might cause distraction to participants, some of them felt that they could still detect the lung sounds from those recording files. It can be suggested that, with the knowledge and skill regarding lung sounds' characteristics recognition that they have had, participants were able to distinguish those external sounds (rubbing noises from stethoscope) from the lung sounds during assessment.

6.3.2.3 Impact of training on participants' perceptions towards of Velcro crackles detection during post-training assessment.

There were five main questions within the interviews that were related to the topics of impact of training and participants' perceptions towards Velcro crackles detection after the training session.

i. What do you think about this training?

ii. What do you think of your ability to detect Velcro crackles after the training session?

iii. How did you decide the sound is Velcro crackle?

iv. What do you think is the best way to improve the training?

v. Who else do you think that could benefit from this training package of Velcro crackle detection?

These questions were aimed to explore in depth of participants' views and opinions regarding this topic further. Table 6.20 shows five main themes and nine subthemes that were constructed to reflect their responses relating to the impact of training and participants' perceptions towards Velcro crackles detection at pre-training session.

Table 6.20 Summary of themes and subthemes derived from interview regarding the topics of impact of training session and participants' perceptions towards Velcro crackles detection after the training session

Themes	Sub-theme
Perceived benefits	Helpful
	Increased awareness
Comprehension	Acquisition of new knowledge and skill
Recognition of Velcro crackles	Attentive
	Confident
Learning methods	Online training
	Workshop training
Early exposure of the training	Healthcare professionals
	Undergraduate students of healthcare professionals

6.3.2.3.1 Theme 1: Perceived benefits

The training session of Velcro crackles detection was viewed as beneficial by participants. This spoke to its acceptability amongst participants in this study. There were two subthemes within this theme ('helpful' and 'increased awareness') which explained in more detail how participants perceived the training of Velcro crackles detection as beneficial.

Helpful

All participants (*N*=31) valued the training session. They found that the training was really helpful in assisting them to detect Velcro crackles easily and complete the lung sounds evaluation during the post-training assessment. For instance, one interviewee explained:

'For me, I found the training (Velcro crackle detection) was very useful. Yes, it really helps me to detect the crackles (Velcro crackles). I could easily answer this second assessment compared to the first one before.'

(Participant P06)

Furthermore, some participants (*N*=8) mentioned that the training slides were very useful as there were concise information relating to IPF disease and Velcro crackles. Therefore, participants found that the training had provided them with better understanding about IPF disease and how to recognise Velcro crackles. For example, one interviewee stated:

'Frankly, I like this training very much. The slides have such simple information that you should know about IPF condition and Velcro crackles. And..they were easy to understand too.'

(Participant P17)

And she later added that:

'…yes, the training helps me to detect Velcro crackles just now. Previously (during pre-training assessment), I found it was difficult to complete the assessment without the training.'

(Participant P28)

This was echoed in another response by an interviewee who also stated that the information provided in the training have assisted her in recognising the Velcro crackles during post-training assessment.

'The training slides were very informative. This training has assisted me to detect the Velcro crackles during assessment.'

(Participant P19)

Meanwhile, participants also appreciated the pre-recording of Velcro crackle sounds that were embedded in the training slides. This helped them to distinguish Velcro crackles from other lung sounds. As one of the interviewees mentioned:

'The slides that you could listen to lung sounds were very useful. Because, I could listen to the sounds of Velcro crackles, and at the same time I could try to differentiate them with course crackles, wheezing and normal breath sounds. This is a good practice!'

(Participant P10)

Increased awareness

Another benefit that was mentioned by participants (*N*=26) was about increased their awareness level towards IPF disease and Velcro crackles detection. This awareness illustrates participants' perceptions regarding IPF that they had gained from the training session. Participant P15 talked about his experience of IPF before and after receiving the training. He responded in a way that highlighted his awareness about IPF is a fatal lung disease, stating:

'Previously, I don't think that IPF would be a serious respiratory condition. But now, after the training session, I'm more aware about IPF. IPF is a progressive lung disease and can lead to mortality. And we as physiotherapists should be

more alert with the sign and symptom of IPF patients especially when they presented Velcro crackles during auscultation assessment.'

(Participant P15)

Another interviewee also shared that the training has increased her awareness after her wrong perceptions towards IPF disease. She emphasised that this training session should be delivered to other respiratory physiotherapists so that it could enhance their awareness towards IPF disease. Therefore, increase in awareness will lead to an appropriate and timely medical management to be given to the patients. She expressed:

'This training made me aware that IPF is an incurable condition. Before this, I thought that it could be cured, you know, like bronchitis. Please let other respiratory physiotherapists out there know about this training too. So that everyone could be aware too… That actually, IPF is a life-threatening condition. They could refer the patients to respiratory physicians soon as possible if they found Velcro crackles during chest assessment.'

(Participant P24)

In addition, some participants (*N*=9) appreciated that they had gained awareness towards IPF condition, especially about the association between IPF and Velcro crackles. They particularly realised that the presentation of Velcro crackle sounds in patients with IPF was relating to the scarring of lung tissues and, not due to secretion retention which they had thought previously. For example, one of the interviewees stated:

'*Oh dear, I really believed the crackles (Velcro crackles) was due to secretion retention in patients with IPF. I did give them chest clearance technique during treatment session before this. Supposedly this is not an appropriate intervention though! I am really grateful, that now I am more aware about this disease and have realised the crackles are due to fibrosis process of the lung tissues.'*

(Participant P01)

In addition, another interviewee asserted that:

'I'm very thankful that I am more aware about the importance of detecting the Velcro crackles in patients after the training session. Velcro crackles is generated because of scarring of alveoli tissues and not because of sputum retention.'

(Participant P17)

And she later added that:

'…I think we should focus the treatment more on pulmonary rehabilitation and endurance training to help patients with IPF. So that these could delay the progression of the disease'

(Participant P17)

From these findings, it is apparent that interviewees had gained awareness about the importance to understand IPF condition and Velcro crackles in patients with IPF. The training has made them aware that IPF should be diagnosed as early as possible so that an appropriate intervention could be delivered to patients. This will help to delay the progression of the disease and promote exercise endurance amongst patients.

6.3.2.3.2 Theme 2: Comprehension

It appeared that all participants (*N*=31) were able to grasp the purpose of the training on Velcro crackles detection. Participants responded that they had gained better understanding about IPF condition and Velcro crackles. They also could see the importance to learn and acquire the skill on how to detect Velcro crackle sounds in patients.

The theme of comprehension was strengthened by one subtheme which was constructed from interviewees' responses as acquisition of knowledge and skill regarding IPF and Velcro crackles detection. Participants believed that the knowledge and skill that they gained from the training session have helped them to distinguish Velcro crackles from other lung sounds. Furthermore, this skill helped them to detect Velcro crackles in pre-recording lung sounds when completing post-training assessment.

Acquisition of knowledge and skill

It was apparent from the participants' responses during post-training interview that there was an overwhelming positive feedback towards the training on Velcro crackles detection. They explicitly mentioned that they had acquired better knowledge regarding IPF such as its definition, its incidence and prevalence, risk factors for IPF, its signs and symptoms, Velcro crackle sounds and medical management for patients with IPF. As one interviewee stated:

'I found that it (training) has increased my knowledge a lot about IPF. You know, today I had gained better understanding regarding the disease of IPF, who are at the risk of IPF and the common signs and symptoms that patients may have. Definitely, patients will have Velcro crackles sounds in their lungs. These are the crackle sounds that we should look for during chest auscultation.'

(Participant P29)

Similarly, another interviewee also expressed that the training session has improved her understanding about IPF which she claimed that IPF is an alarming condition.

'I could see that its incidence and prevalence was increasing year by year. And patients have poor prognosis too. It's because IPF is a progressive disease. I could say IPF is an alarming condition that we should detect earlier and help them (patients) with proper medical care to delay the progression of IPF disease.'

(Participant P22)

Moreover, she also gained understanding about the appropriate treatment for patients with IPF. And she later added that:

'Yes, patients may become breathless as the disease progresses due to drop in oxygen saturation, so oxygen therapy and pulmonary rehabilitation should be delivered to them.'

(Participant P22)

In addition, participants also highlighted that they have learned the characteristics of Velcro crackles and acquired the new skill on how to detect Velcro crackles sounds through auscultation assessment after the training session. For instance, one interviewee said:

'From this training, I have learned about Velcro crackles sounds that are present in patients with IPF. I mean the features of crackle sounds. Previously I don't have an idea on how to recognise Velcro crackles. Well, today I gained a new skill on how to detect these crackles from the patients. I could detect Velcro crackles during assessment today.'

(Participant P20)

Similarly, another interviewee expressed that this was the first training that she has had and gained a new skill from the training session. She mentioned that after the training session she could differentiate between Velcro crackles and other lung sounds when completed the post-training assessment. She stated:

'For me, this was a new skill that I have learned today. I had never done anything like this training before. It's interesting when you could acquire new skill which help you to detect Velcro crackles in the post-training assessment. Now, I am able to distinguish between Velcro crackles and other lung sounds.'

(Participant P13)

From these responses, it can be suggested that the training session on Velcro crackles detection in patients with IPF has given a positive impact on participants' knowledge and skill regarding IPF as well as Velcro crackles detection respectively. These further highlights that participants have acquired better understanding and knowledge about IPF condition and gained new skill on how to detect Velcro crackles. Besides that, they also valued the importance of early Velcro crackles detection in patients with IPF which lead to appropriate physiotherapy intervention.

6.3.2.3.3 Theme 3: Recognition of Velcro crackles

The theme recognition of Velcro crackle sounds did appear from the participants' responses during interview session at post-training assessment. After the training, majority of participants (*N*=28) responded that they were able to distinguish Velcro crackles sound from other lung sounds in those pre-recoded files. Two subthemes include 'attentive' and 'confident' were constructed from responses which related on how participants recognise the Velcro crackle sounds when completing the post-training assessment.

Attentive

During post-training interview majority of participants (*N*=28) explicitly mentioned that they were more attentive towards the Velcro crackle sounds following the training session. In addition, participants mentioned that they were able to detect the characteristics of Velcro crackles sounds which are fine type of crackles, high pitch sounds and present throughout the inspiratory phase during listening to those pre-recorded sounds. For example, one interviewee declared:

'Absolutely yes! I could answer this assessment better compared to the first one before. I can easily recognise normal and abnormal lung sounds, then be able to detect fine or coarse crackle from abnormal lung sound. The Velcro crackle is fine, high pitch…and can be heard during inspiration phase.'

(Participant P08)

In another example of being more attentive towards Velcro crackles after the training session, participant P27 explained on how she detected the sounds.

'…..when you listen carefully, you can hear them (Velcro crackles) during inspiration. Yes, only during inspiration phase. They are high pitch sounds. And their sounds are similar as tearing a Velcro strap. And yes, I could answer the second assessment better.'

(Participant P27)

Another interviewee added:

'Yes, I found it easier to complete the post-training assessment. This time I am more alert when listening to the lung sounds. Firstly, when I heard inspiration phases, I tried to listen for any crackles sounds from early to end of inspiration phase. And..they (velcro crackles) should be high pitch sounds of course.'

(Participant P18)

From these findings, it is apparent that interviewees were able to describe the features of Velcro crackles and how they detected these crackles clearly compared to pre-training assessment. Generally, it can be suggested that the training session of Velcro crackles detection had given positive impact on attentiveness of participants to recognise the Velcro crackles during post-training assessment.

Confident

It was clear that most participants (*N*=28) found value in the training as a means of improving their confidence to recognise Velcro crackles during post-training assessment. For instance, P03 respiratory physiotherapist said that the training session had 'increased her confidence', that she could recognise the Velcro crackle sounds in the second assessment compared to first assessment which she was unsure about them (Velcro crackles) previously.

Similarly, another interviewee (Participant P16) emphasised that she had more confidence to detect Velcro crackles this time (post-training assessment) as she had gained the knowledge and skills on how to detect them (Velcro crackles), hence she could distinguish the features between Velcro crackles and other abnormal lung sounds. Interviewee P05 also spoke of her self-confidence when answering post-training assessment:

'Well, I feel more confident in being able to detect Velcro crackles and complete the assessment just now, and…I am very sure that I could differentiate between fine and coarse crackles. Before this, I was uncertain about my answers (pre-training assessment) because I don't even know how Velcro crackles sounds were. Should they be fine or coarse type of crackles? You know, mmm... I just predicted them as coarse crackles.'

(Participant P05)

Overall, from these responses, it can be suggested that the training of Velcro crackles detection had proved to be beneficial in building confidence amongst respiratory physiotherapists as they had acquired the knowledge and skill on how to recognise Velcro crackle sounds.

6.3.2.3.4 Theme 4: Continuous learning

Another theme mentioned by interviewees was the continuous learning of the Velcro crackle detection. They believed that continuous learning throughout clinical practice would enhance their ability to grasp and retain this skill over long-term duration. This continuous learning might be influenced by the training approach. Two subthemes of the training methods were pointed up by interviewees, which included 'online training' and 'workshop training'.

Online training

There was an overwhelming response from interviewees in support of continuous learning on how to detect Velcro crackles through online training. Majority of them (*N*=21) stated that online training would be a positive idea that benefits all learners especially respiratory physiotherapists in various ways. For example, one participant expressed her support for online training explaining:

'I think it would be good to have this learning session through online training. Well, it is practical way for us to get easy access for it whenever we need it at any time. This is so convenient too, mmm…because we don't have to travel far and pay for extra expenses to get this training done. It can be done at your free time during clinical or at home if you want.'

(Participant P06)

And she later added that:

'….this online training could encourage more physiotherapists to take part in the training and consequently, everyone will be aware about the Velcro crackles and IPF disease.'

(Participant P06)

Additionally, another respiratory physiotherapist stated her agreements by saying:

'I would prefer the training to be online. As I am busy during clinical working hours, I could spend my free time to do this self-learning. And..I will give full support if it is available online. It will be an excellent opportunity for all physiotherapists especially those who are working in respiratory field. Anyone can get access through it, hence could help them to recognise Velcro crackles in clinical.'

(Participant P11)

One interviewee expressed her opinion regarding other benefits of online training in which she could repeat the training whenever she feels necessarily. She asserted that:

'By doing online, participants are able to get back to the training again and again as they want to, or if they think they still need it, or just in case to recall back their knowledge and skill.'

(Participant P01)

For another interviewee, online learning session is more preferred as it could be easily accessible anytime whenever he needed and keep up with the latest information faster than workshop training. He explained that:

'I think continuous learning is an important aspect, as it will keep up with the latest knowledge and skill about IPF disease in clinical practice. For me, once you had acquired the knowledge and skill from the training workshop, you just can continuously update them through online learning courses regarding IPF whenever you need to. It is much faster this way. This could also help you to retain your skill on Velcro crackles detection.'

(Participant P23)

These responses appear to highlight that self-study via online training allows participants to study at their own pace and at any time that is convenient to them. Furthermore, participants could arrange their own training schedule that meets their individual needs, which does not interfere with their clinical work commitments. The fact that online training is cheaper and more convenient when compared to other learning methods is enough to encourage more participants to consider it.

Workshop training

Although generally online training was the more preferable learning methods, some participants (*N*=10) did suggest that the learning of Velcro crackles detection to be delivered via workshop training. The interviewees stated that a workshop training may provide a better understanding of the knowledge and skill as there will be an interactive course. This may also be a good way of two-way interaction between participants and the trainer during the session. For instance, one interviewee expressed:

'I would rather learn this (Velcro crackles detection) through a workshop. Maybe a one-day workshop training should be OK. Yes…Of course during the session you will have lots of questions or doubts, then you may just want to clarify them with the trainer at that time. For me, this is the best way to learn about IPF and Velcro crackles. And…also to practise on how to detect Velcro crackle sounds.'

(Participant P04)

Another participant mentioned that an interactive training through workshop might allow them to be corrected by the trainer immediately if they had done any mistakes during practical session. As she mentioned:

'The ideal way to deliver this training is, it should be done via workshop training. There… instantly the trainer will be able to correct you if you make any mistakes during detection of lung sounds. I think two-way interaction course is more effective than learning by yourself.'

(Participant P27)

Similarly, one participant also expressed their support for workshop training session, explaining:

'I am sure a workshop training would be an excellent experience! I would strongly support this learning method (training via workshop). You know, participants will be more focused during the session as they will be concentrating on the trainer. And the trainer also will give direct attention to you if he or she found that you are a bit slow to catch up the skill (recognition of Velcro crackles) during the session.'

(Participant P28)

For another interviewee, participating several training workshops which have invited patients with IPF disease during the sessions would drive her to get the most out of the training sessions. She asserted that:

‘By attending several series of workshop regarding IPF would be great for me. Maybe a yearly workshop. If the organiser could invite some patients with IPF during the sessions would give the best opportunity for participants to really engage with the patients and give them the live experience on Velcro crackles recognition. Participants also can apply hands on technique which could promote their skill acquisition and retention. Practice makes perfect.’

(Participant P31)

In general, from these responses it can be suggested that training through an interactive workshop session might also benefit the learners as well. They can have more time for discussion about activities and more time to practise the skills. As this kind of approach involve an active engagement and interaction between trainer and participants, thus this will ensure the effectiveness of training session.

In addition, it is clear from participants’ responses that they see continuous learning regarding IPF and Velcro crackles as vital to enhance their long-term skill retention. Regardless the training sessions through workshops or online courses, both were viewed as important to keep their knowledge and skill updated.

6.3.2.3.5 Theme 5: Early exposure of the training

An early exposure towards the training of Velcro crackle sounds is crucial. This might prepare respiratory physiotherapists and other health professionals with the knowledge and clinical skill on how to detect Velcro crackles amongst patients with IPF at the very early stage during their clinical working. The theme early exposure of the training was constructed from the participants’ responses which consists of two subthemes in regard to the population of targeted learners including healthcare professionals and pre-qualifying students.

Healthcare professionals

Overall, all interviewees (*N*=31) raised that an early training of Velcro crackles detection should be delivered to healthcare professionals including respiratory physiotherapists, respiratory physicians, general physicians and nurses at the earliest year of their clinical practice. Participants believed that an early exposure to the training will enhance better understanding of the knowledge and ability to recognise Velcro crackles in patients. Therefore, an early detection of Velcro crackles amongst patients could be made in clinical settings. This would lead to a timely and appropriate medical intervention for patients with IPF. As one of the interviewees explained that:

'Well, it's good to expose health practitioners with this training at their earliest clinical practice. So that, they will have better knowledge and skill on how to detect Velcro crackles. They could practise this skill in their daily clinical work. And…this will help them to be able to recognise the Velcro crackles in patients at early stage of IPF disease.'

(Participant P21)

Another interviewee also stated that:

'I think this kind of training should be delivered to general physicians and respiratory physicians as well, not only to respiratory physiotherapists. You know, patients will always consult their physicians when they have any respiratory problems. If physicians are well-trained, they could be able to detect the Velcro crackles in patients at early stage and make further management for them.'

(Participant P09)

In addition, there was one interviewee who mentioned that an early exposure of this training to healthcare professionals could help them update their knowledge and skill about Velcro crackles if they had learned it previously during undergraduate study. She expressed that:

'……it is would be nice to get this training earlier. Yes, everyone (healthcare professionals) could get the latest information about IPF and how to detect Velcro crackles which might update the knowledge and skill that they had gained in university.'

(Participant P24)

In general, from these responses it can be suggested that an early exposure towards Velcro crackles detection amongst healthcare professionals and pre-qualifying students would promote better knowledge and skill acquisition in their clinical practice and clinical placement respectively. Therefore, these will increase the rate of early detection of patients with IPF and further medical intervention could be proceeded as soon as possible.

Undergraduate students of healthcare professionals

Other than introducing this training to healthcare professionals, many participants (*N*=17) stressed concern that this training should be provided earlier to undergraduate students too including physiotherapy, nursing and medical students during their clinical placement in final year.

An early exposure to Velcro crackles detection training helps to integrate students' knowledge regarding IPF condition and skill on how to detect Velcro crackles with clinical experiences. As a result, this integration promotes better understanding and skill acquisition towards recognition of Velcro crackles in patients during their clinical placement. For example, one interviewee explained:

'I think this training should be exposed to those final year physiotherapy and medical students at universities. You know, it should be as soon as they are in their clinical placement. So,.. this training will facilitate them with the theory and skill on how to detect Velcro crackles during clinical year. Students will appreciate this skill better, because they could practice it during clinical placement.'

(Participant P15)

Another interviewee emphasised that an early exposure to the Velcro crackles detection training will enhance students' practical ability during clinical placement and prepare them to be capable physiotherapists in their future clinical practice. He asserted that:

'It would be better if you could give this training to those final year students. Yes, they could gain new skill from the training. This would be great opportunity for them to practice it in their clinical year and ensure they would be an efficient physiotherapist in near future.'

(Participant P08)

In addition, one participant also highlighted that the appropriate timing to deliver this training should be when the students are in their clinical placement. This will help students to develop the basic knowledge and skill on how to recognise Velcro crackles. They also will be able to apply and integrate their knowledge and skill effectively before they become future healthcare professionals. She stated that:

'Yeah, this training should be given to physiotherapy and medical students at the right time. I mean during their clinical placement. They will have strong knowledge about IPF and skill to detect Velcro crackle before working in clinical setting later. Yes, they will have time to practise the skill that they had learned effectively during their clinical placement.'

(Participant P27)

6.3.2.4 Participants' experiences of skill retention and skill transfer at two-month follow-up

There were three main questions within the interviews that related to the topic of participants' experiences of skill retention and skill transfer after two months following the training session of Velcro crackles detection. These questions were aimed to explore in depth of participants' views and opinions regarding this topic further. The questions were:

i. How is your ability to detect Velcro crackles over the last two months?

ii. How important is this skill for you as a respiratory physiotherapist in clinical setting?

iii. What are the barriers to apply the skill of Velcro crackles detection in your clinical practice?

Table 6.21 shows four main themes and seven subthemes which were revealed from the participants' experiences of skill retention and skill transfer at two-month follow-up.

Table 6.21 Summary of themes and subtheme derived from interview regarding the topic of participants' experiences of skill retention and skill transfer at two-month follow-up

Themes	Subthemes
Skill retention	Declined
	Retained
	Repetitive skill practice in clinical
Learning skill transfer	Changes on referral rate
	Sharing new skills with others
Time constraint	
Acknowledge the importance of skill in clinical practice	Accurate assessment
	Monitoring progression of the disease

6.3.2.4.1 Theme 1: Skill retention

The theme skill retention was constructed from participants' responses during two-month follow-up interview session. This theme related to their long-term skill retention on Velcro crackles detection which was after two months following the training session that they had previously.

There were three subthemes within skill retention which include declined, remained and repetitive skill practice in clinical did appear following the interview session.

Declined

Most of the participants (*N*=19) expressed that the skill retention of Velcro crackles detection declined at the two-month follow-up assessment. However, after making an attempt to recall the characteristics of Velcro crackles and listening to pre-recorded lung sounds repeatedly during assessment, they thought that more or less they could detect the Velcro crackles from the recordings. As one of the interviewees mentioned:

'At first, I was lost over a long period, but after I had reviewed those pre-recorded lung sounds, then I think that I was able to detect the Velcro crackles in the assessment (two-month follow-up assessment).'

(Participant P19)

Others interviewees also added similar responses on their ability to recognise Velcro crackles over long-term duration. As one interviewee stated:

'Actually, I had somewhat forgotten the nature of the sounds (Velcro crackles). Then, after listening back those few recording of lung sounds in assessment files and recall back the features of Velcro crackles, I think I still have the skill to detect them. Yeah, I think I was able to detect those Velcro crackles.'

(Participant P22)

'I had to recall the sounds (Velcro crackles) by listening to those lung sound files for a few times in order for me to answer the assessment.'

(Participant P07)

Retained

In contrast, some of the participants (*N*=12) mentioned that they still have the ability to detect Velcro crackles at two-month follow-up assessment, which indicated that their acquired skill retained over the long term. They also claimed that they could still remember the information about IPF and Velcro crackle sounds that they had gained over last two months. For example, one interviewee explicitly talked about her ability to recognise Velcro crackles after long-term period, saying that:

'Over a long period of time, I could say, I still have the skill and knowledge that I have learned from the training session before. I can remember characteristics of Velcro crackles and their sounds as well. And yes, I can detect which pre-recording files that got Velcro crackles during this follow-up assessment.'

(Participant P31)

Another interviewee also asserted that she was able to retain the knowledge and skill over long-term duration, hence she was able to detect Velcro crackle sounds during the two-month follow-up assessment. She stated:

'Yes, I was able to distinguish Velcro crackles from others lung sounds. And I could detect them (Velcro crackles) during assessment just now. I'm happy to let you know that I still remember the information about IPF and Velcro crackles from the last training session.'

(Participant P21)

Likewise, one interviewee claimed her long-term skill retention towards Velcro crackles detection, stating that:

'I can retain the skill that I'd learned since last two months after the training. Yes, I was able to detect Velcro crackle sounds when completing the assessment (two-month follow-up assessment).'

(Participant P04)

From these responses, it is apparent that most interviewees mentioned that they have forgotten the skill of Velcro crackles detection and needed to recall their memory by listening to those pre-recorded lung sounds before they could answer the assessment form. On the contrary, some of them explicitly responded that they still have the skill and able to recognise these crackle sounds during the two-month follow-up assessment. These findings may indicate that most interviewees could at least in part retain their skill, and some of them were able to retain this skill completely over long-term duration. This implies that the knowledge and skill they had acquired in the training session two months ago are still accessible in their long-term memory.

Repetitive skill practice in clinical

There was a response regarding repetitive skill practice on Velcro crackles detection in clinical setting from the interviewees during the two-month follow-up interview session. Some of them (*N*=8) were aware that the skill acquired during the training session need to be repeatedly practiced in their daily clinical work, so that it will retain over prolonged period.

In addition, they also acknowledged that by doing repetitive skill practice in clinical would enhance their performance on Velcro crackles detection amongst patients effectively. For instance, one interviewee shared her experience on repeated skill practice saying that:

'Well, I always practise the skill that I'd acquired to detect Velcro crackles during respiratory assessment in clinic. As respiratory physiotherapists, pulmonary auscultation is a must for us to assess respiratory patients. And I always try to detect for Velcro crackles if my patients may present with. I really believe by repeatedly practising the skill this will help me to recognise the crackles better.'

(Participant P12)

In this regard, another interviewee also mentioned that she routinely practiced the skill on Velcro crackles detection to help her to detect these crackles effectively:

'I don't have any restriction to practise this in my practice. I always auscultate every respiratory patient that I see in clinical setting. Whenever I do auscultation assessment, I routinely apply this skill and try to listen for Velcro crackle sounds in my patients.'

(Participant P03)

And she later added that:

'After sometime, I realised that I could perform the skill (recognition of Velcro crackles) effectively during auscultation assessment.'

(Participant P03)

Likewise, one interviewee also stated that her repetitive practice of the skill during clinical work had enabled her to retain the skill over long-term period and detect the Velcro crackles during the two-month follow-up assessment. She said:

'Yes, I do practise it (skill on Velcro crackles detection) on my patients daily in clinical work. Because of that, I think I was able to retain it for a long period of time. And I was able to detect Velcro crackles in the follow-up assessment just now.'

(Participant P09)

From these findings, it appeared that participants appreciated the skill on how to detect Velcro crackle sounds which they had acquired during the last training session two months ago. This is because, some of them repetitively practise it in their clinical work especially during auscultation assessment on their patients.

6.3.2.4.2 Theme 2: Skill transfer

Skill transfer was an important theme as it reflected to the effectiveness of the training session, in which participants were able to transfer the acquired skill of Velcro crackles detection into clinical practice successfully. There were two subthemes within this theme which were changes on referral number and sharing new skill with others. These two subthemes were described in more detail how skill transfer occurred following two months period after the training session.

Changes on referral number

Subtheme changes on referral number appeared from participants' responses during the interview session. A few participants (*N*=2) mentioned that they have detected a few patients with Velcro crackle sounds during auscultation assessment. Subsequently, they have referred them to pulmonary physician for further medical investigation to diagnose for IPF. However, they reported that the diagnosis of these patients was still under further investigation at the time of interview session occurred. For example, one interviewee reported that:

'I have detected two cases of my patients having Velcro crackle sounds during auscultation assessment. Then, I asked them to come back and see me on the next appointment after one-week period. Again, during auscultation the crackle sounds were still there at the same area, the basal of their lungs. I found the

sounds characteristics were the same as Velcro crackles! I quickly talked to the doctor and referred those patients to him for further investigation. I never did any referral like this previously.'

(Participant P31)

Another interviewee expressed her gratitude for being trained to detect Velcro crackle sounds. She mentioned that this skill enabled her to refer patient for further management which previously she never did. She also shared her experience when she found out one of her patients presented with Velcro crackles at his lower lobe of the lung:

'I really appreciated this skill that I had. Before this, I didn't know about Velcro crackles and how to detect them. And..I've made no referral to physician before this. But now, I could detect one of my patients presented with Velcro crackles. These crackles wouldn't disappear after deep breathing exercise and coughs. They were still there, at the lower lobes of patient's lung. I suspected he might have IPF, but you know further investigation should be done by medical team. Yes…., I did refer him to pulmonary physician. Till now I am still waiting for the full investigation results whether his diagnosis is IPF or not.'

(Participant P12)

From these responses, even though only a few participants have detected Velcro crackle sounds in their patients, it still appeared that they were able to transfer their newly acquired skill into clinical practice. A few numbers of patients' referrals have been made to the physician for further investigation, which participants never did previously before the training session. This indicated that there had been changes on referral number from zero referral to a few number of referrals on patients' cases to physician after they acquired the skill from the training session.

Sharing new skill with others

Another subtheme that was mentioned by some of the participants (*N*=6) on how they used to transfer the new skill acquired in clinical setting was by sharing this skill with others, especially their respiratory physiotherapy colleagues and physiotherapy students who were doing clinical placement under their supervision. As one interviewee expressed his willingness to share the skill on Velcro crackles detection with his other respiratory physiotherapist colleagues so that they could be able to detect Velcro crackles at the earliest stage of patient condition. He stated that:

'For me, this was a great opportunity to share this new skill with my other friends in respiratory physiotherapy. Yes, I did share the information about IPF and skill on Velcro crackles detection with them at my department. So that, everybody could be aware about IPF and be able to detect the Velcro crackles as early as possible in patients.'

(Participant P09)

Similarly, another interviewee viewed that the skill she had acquired from the previous training session as priceless and she was able to disseminate it amongst her other colleagues. This sharing session has enhanced her skill acquisition and retention on Velcro crackle sounds detection. She said that:

'I did share this IPF and the skill on Velcro crackles detection with my friends too. I think this skill is worth to learn by every respiratory physiotherapy, because it will help you to recognise Velcro crackles in your patients. Meanwhile, I also gained better skill acquisition and able to retain it.'

(Participant P04)

In addition, some interviewees said that they did transfer their skill to physiotherapy students whom they supervised during clinical placement. For instance, one interviewee shared that:

‘I do have some physiotherapy students to supervise for their clinical training. I did share with them the knowledge about IPF and Velcro crackles. And.. I also trained them the skill on how to recognise Velcro crackle sounds during auscultation assessment in patients. Yeah, they seemed to had acquired this skill as well.’

(Participant P03)

In general, from these findings, it can be suggested that there was a skill transfer within two months after the training session of Velcro crackle sounds detection amongst participants. Some of the participants were able to translate this particular skill in their clinical practice and also to their respiratory physiotherapy colleagues and students.

6.3.2.4.3 Theme 3: Time constraint

Another theme constructed from participants’ responses was the time constraint that may hinder them from practising their newly acquired skill in clinical practice.

The factor that was raised by most of the participants (*N*=17) which they could not apply this skill on their patients was due to the time constraint during clinical practice. This factor has somewhat influenced the ability of their long-term memory to effectively retain the skill acquired over long-term period. As one of the interviewees shared on her daily busy outpatient clinic:

"For outpatient situation, there is a limitation of time to practise this skill. Yes, there are high number of patients coming in per day. I couldn’t auscultate them

thoroughly to look for Velcro crackles. I feel that I am quite lost with it (skill to detect Velcro crackles).'

(Participant P07)

Similarly, some of them were unable to apply this skill effectively because they have to do extra workload of patients' cases any time their colleagues were on leave or on sick leave. For example, one interviewee mentioned:

'Sometimes, there was a few weeks that I needed to cover extra cases of respiratory patients. Especially when my friends had to take a leave. So, it is hard for me to practise this skill on patients as I have not got enough time to do so.'

(Participant P17)

Despite the extra workload on the number of patients, some of interviewees also shared that they had to deal with administrative works as well during clinical time. For this reason, this situation has impeded them from practising the new skill acquired. As one interviewee stated:

'Actually, I got no time to practise it. For me I have to spare some hours of my clinical practice to do some works relating to management, which needed me to prepare a lot of documentation especially for audit purposes.'

(Participant P18)

6.3.2.4.4 Theme 4: Acknowledged the importance of skill in clinical practice

It appeared that all participants' responses (*N*=31) overwhelmingly acknowledged the importance of the newly acquired skill in clinical practice in order for them to detect Velcro crackles in their patients during interview session at two-month the follow-up assessment.

This theme also reflected that participants really understood the purpose of the training session, why they should retain the skill they had acquired and transfer the skill into clinical practice over the long-term period. Within this theme, there were two subthemes which were constructed from participants' feedback which include 'delivering accurate assessment and treatment' and 'monitoring progression of the disease'.

Delivering accurate assessment and treatment

Participants highly valued the skill on Velcro crackles detection in clinical practice. All of them mentioned that this skill can help them to deliver accurate assessment and treatment for patients with IPF condition during their practice.

For example, one interviewee explained that an accurate assessment could be done because respiratory physiotherapists are able to distinguish either the crackle sounds generated due to secretion retention or lung fibroses. She said that:

'It is very important for us to have this skill because it helps us to detect Velcro crackles precisely during auscultation assessment on our patients. Moreover, this skill helps us to distinguish the type of crackles presented in patients whether they are due to secretion retention or fibrosis of the lung tissues.'

(Participant P15)

Likewise, other interviewees also asserted that the skill on Velcro crackles detection can help to make correct assessment in detecting Velcro crackles as well as deliver appropriate treatment for patients with IPF. As one interviewee asserted that:

'This skill helps physiotherapists to be accurate in detecting Velcro crackles during auscultation assessment. These Velcro crackles might tell you that the patients may have lungs fibrosis condition. Therefore, you could deliver an

appropriate physiotherapy treatment such as pulmonary rehabilitation for patients.'

(Participant P26)

In this regard, another interviewee also mentioned that:

'I think, this acquired skill has assisted me to do correct auscultation assessment particularly to detect Velcro crackles in patents. Subsequently, I could deliver an accurate treatment to patients. And…surely I can provide an effective treatment for them.'

(Participant P03)

For another interviewee, she believed that this skill would prevent her from giving inappropriate treatment that would not bring any benefit to the patients with IPF. This is because an accurate detection of Velcro crackle sounds during auscultation assessment will subsequently help her to deliver appropriate physiotherapy treatment for IPF patients. She explained that:

'This skill helps me to make an accurate assessment regarding the type of crackles presented during auscultation, especially the Velcro crackle sounds. Then you will be able to decide a suitable treatment plan for the patients. For sure, you won't waste your time by doing chest clearance which is likely won't help patients with IPF. Because they do not have any sputum retention. The appropriate physiotherapy treatment for them is to train their respiratory muscles and exercise endurance. These help to improve their pulmonary function.'

(Participant P10)

Monitoring the progression of the disease

Some participants (*N*=11) raised that this skill would help them to monitor the progression of the IPF disease. This is because, Velcro crackle sounds tend to progress from lower lobes to middle and superior lobes of the lungs as the disease progress over time. Therefore, it is important for physiotherapists to retain the skill in order for them to keep monitoring the Velcro crackles in their patients over long-term period. In addition, they could prepare for the next phase of physiotherapy intervention as the condition progress to help the patients. For instance, one interviewee said that:

'Apparently, this skill will allow us (physiotherapists) to monitor progression of the disease in patients with IPF. As what I've learned from the last training session, the Velcro crackle sounds tend to progress from basal towards middle lobe of the lungs over time. So, as we know the progression stage of the disease then we could plan the next phase of exercises for them.

(Participant P14)

Likewise, another interviewee also acknowledged the importance of this skill in clinical practice. As the condition progresses, physiotherapists might hear these Velcro crackle sounds in middle zone of the lungs as well. Therefore, they could monitor closely the progression of IPF condition in their patients. As one interviewee mentioned that:

'For me, this skill is so important because I could monitor the progression of patient condition frequently. You know, this skill enables us to detect the Velcro crackle sounds whether they have progresses towards middle zone of the lungs.'

(Participant P29)

And later she added that closely monitoring of the Velcro crackle sounds will help her to know the progression of the IPF condition in her patients. Hence, suitable intervention could be delivered according to the stage of her patients' condition. She explained that:

'Yes, especially in pulmonary rehabilitation program we could design the exercise accordingly to the progression of patients' condition if you are closely monitoring them in clinical. For example, patients who are at the later stage of their IPF condition might struggle with breathlessness. So, we should emphasise on how to cope with it by giving them oxygen support and encourage them to do breathing control exercise during their daily activities.'

(Participant P20)

In general, from these responses, it can be suggested that the last training session on skill of Velcro crackle sounds detection which was done two months prior to the post-training interview has given a positive impact on participants' knowledge in IPF disease. Participants highly valued the skill that they had acquired and acknowledged the importance of this skill in clinical practice. They have emphasised that this skill has empowered them to make an accurate assessment to detect Velcro crackle sounds in patients and consequently, appropriate treatment could be delivered to patients with IPF. In addition, they also highlighted that this skill enables them to monitor closely the progression of IPF condition in their patients.

6.3.2.4.5 Summary of qualitative component

The qualitative findings found that all participants who expressed uncertainty about characteristics of Velcro crackle sounds and unfamiliarity with these sounds at pre-training interview have reported that the training session was beneficial and helpful for them to detect Velcro crackles at post-training assessment during post-training interview. All of them highlighted that they were able to comprehend the training session and acquire new knowledge and skill following the training session at post-training interview. Unfortunately, majority of them mentioned that their skill retention of Velcro crackles detection declined at the two-month follow-up interview because of inability to practise the skill due to time constraint. Only some of them expressed their ability to retain the skill over time and were able to detect Velcro crackles at the two-month follow-up assessment.

A few participants did report about their skill transfer in clinical practice at two-month follow-up interview session, and they were the same people who reported increased confidence and attentiveness in detecting Velcro crackles at post-training interview. Both participants (P31 and P12) who expressed confidence in detecting Velcro crackles at post-training interview were the same people who made referrals within two months following the training session. Participant (P19) who reported of having difficulty to detect Velcro crackles due to infrequent practise on auscultation at pre-training interview has expressed that she was more attentive towards the Velcro crackles detection at post-training interview. However, she (P19) claimed loss of skill over time at two-month follow-up interview due to time constraint in applying the skill in clinical practice. Although majority of participants expressed loss of skill over time, all participants' responses noted that they highly acknowledged the importance of this skill in clinical practice during two-month follow-up interview.

In addition, participants have suggested that this training should be a continuous learning programme which can be delivered via online and interactive training workshop. They mentioned that an early exposure of this training should be delivered to healthcare professionals at their earliest year of clinical practice and also to students at their final year clinical placement.

The next chapter will discuss the findings from the study one and study two, with reference to the existing literature.

Chapter 7: Discussion

7.1 Introduction

This chapter discusses the findings from study one and study two, with reference to the existing literature. Limitations of each study and suggestions for future research will be highlighted.

7.2 Study One:

A preliminary study of the impact of training on reliability of respiratory physiotherapists' detection of Velcro crackles in IPF patients.

7.2.1 Introduction

The aim of this preliminary study was to explore the impact of training on the ability of respiratory physiotherapists to detect Velcro crackles in IPF patients using recorded lung sounds files. In this chapter the findings from the study will be discussed in the context of current literature and research. Finally, limitations of this study and some suggestions for future research will be highlighted.

7.2.2 Demographic findings

Almost all participants in study one and two were female respiratory physiotherapists. Similarly, this was also found in other studies which have indicated that female participants were the highest proportion of gender in their studies (Allingame et al. 1995; Morrow et al. 2010). This reflects the fact that the majority of health care professional workforce especially in physiotherapy profession is predominantly female physiotherapists. In general, participants involved in this study were considered young physiotherapists aged below 40-year old with the majority of them were junior physiotherapists in respiratory physiotherapy practice. Likewise, findings from those previous studies also found that their participants were young physiotherapists considered as junior physiotherapists in respiratory clinical practice (Aweida and Kelsey 1990; Brooks et al. 1993; Jailani and Wong 1998; Morrow et al. 2010).

There was a low percentage of participants who have had experience with IPF patients. In addition, most of them never heard about the term Velcro crackles in IPF condition and none of them think that they were be able to recognise this type of crackles. This is not surprising because IPF is a rare lung disease, with overall incidence rate less than 5 per 100,000 person-years (ATS 2002; Gribbin et al. 2006; King Jr et al. 2011; Navaratnam et al. 2011).

7.2.3 Intra-observer reliability

There were two data sets of 20 lung sounds recording files which were presented twice for Group A and B, on each Assessment 1 and 2 to assess intra-observer reliability. Intra-observer reliability was assessed within the same participants for Group A (trained) and Group B (untrained) during Assessment 1 in study one. The findings were found to be higher for most participants in Group A, indicating moderate to perfect agreement than untrained participants in Group B who only scored from fair to moderate agreement during Assessment 1.

In addition, intra-observer reliability within the same participants in Group B, before and after training was assessed using two data sets of the same recording files during Assessment 1 and another two data sets of the same recording files during Assessment 2. The result shows intra-observer reliability has improved for all participants in Group B, which ranged from moderate to perfect agreement following the training session during Assessment 2.

During Assessment 2, intra-observer reliability for all participants in Group A were found to be moderate to perfect agreement, which indicate the same findings as in Assessment 1. The majority of participants from Group A (67%), were found to have high kappa values that indicate substantial to perfect agreement (k=0.62 to

0.81) during Assessment 2. However, 50% of the participants from Group B were found to have high kappa values that reflect substantial to perfect agreement (k=0.71 to 0.9) during Assessment 2. High percentages of participants who scored substantial to perfect agreement in Group A might be due to the repeated tests (4 tests) which they have completed at Assessment 1 and 2 following the training session given during Assessment 1. Unlike the participants in Group B, they have only received the training session during Assessment 2, which indicated less tests (2 tests) completed by them after the training session. This might suggest that, repeated practices in detection of Velcro crackles after appropriate training session could improve intra-observer reliability of participants in this study.

There was variability of kappa values within participants in Group A and Group B during Assessment 1 and Assessment 2. The varied intra-observer reliability scores among all participants in the present study can be claimed to be due to the reason of different clinical years of experience among the physiotherapists as well as the experience they had with their patients with IPF. These findings were consistent with the results found by Morrow et al. (2010) and Pasterkamp et al. (1987), who discovered that there was a wide variability of agreement within the observers ranging from poor to moderate agreement (k=-0.01 to 0.60). This may indicate that the interpretation of lung sounds for every participant was rather fluctuate and inconsistent.

7.2.4 Inter-observer reliability

In study one, Group A physiotherapists who have received their training prior to Assessment 1 were able to appreciate definite sound of Velcro crackles with moderate inter-observer reliability than untrained Group B, which found to have poor agreement of reliability. However, inter-observer reliability has improved from poor agreement to moderate agreement for Group B during Assessment 2 after the training session received by all participants prior to the assessment. These findings suggest that appropriate training sessions prior to assessment has resulted in improvement of inter-observer reliability of assessment. Proper training session in this study involved auditory and visual presentation through audacity software has improved participants interpretation of Velcro crackles, hence the reliability increased (Sim and Wright 2005; Murphy 2008).

Findings from study one suggests that participants in Group A are able to acquire the skill and retain the knowledge of detecting Velcro crackles following the short-term period between learning session and assessments. After 30 minutes of training session, participants were immediately given two sets of lung sounds files to be assessed at their convenient time. They were given one week to complete the tests for Assessment 1 and again another week to complete the tests for Assessment 2. The result of inter-observer reliability for Group A indicates moderate agreement during both Assessment 1 and 2 following the training session. Hence, this might be reflected that participants from Group A are able to acquire and retain the skills of recognition of Velcro crackles through short-term period between training session and assessments.

On the other hand, this was not the case for Group B. The participants in Group B do not have training session in Assessment 1, but they were given a 30 minutes training session prior to the tests in Assessment 2. This training session was similar as the one given to Group A. The period between the training and assessment for Group B was only one-week. Since the participants in both groups were assessed within a short period of time following the training session (approximately within one to two weeks during the tests of this study) therefore, it is difficult to estimate whether the participants are competent enough to practise their skills acquisition or if the practise would have an effect on the reliability of detection for Velcro crackles during assessments. Therefore, further study was done which is study two to assess short-term and long-term learning effect (following two months of training of Velcro crackles detection) on participants’ skills retention.

In study two, inter-observer reliability of all participants in detecting Velcro crackles has also improved from poor agreement to moderate agreement following 30 minutes of training session. This indicated that participants were able to acquire the skill of Velcro crackles detection and also be able to retain this skill within a short-term period after the training session.

Assessment of inter-observer reliability before and after training sessions has been reported by other authors in detecting abnormal lung sounds (Brooks and Thomas 1995; Morrow et al. 2010). The findings of this study are in agreement with those of Brooks and Thomas (1995) who reported improvement in inter-observer reliability among respiratory physiotherapists after the education session. They found that inter-observer reliability of detecting abnormal lung sounds using auscultation to be poor to fair agreement before the education session, however after the education session the reliability improved from fair to almost perfect agreement among trained physiotherapists.

Furthermore, it was discovered that participants who received the training on particular task will agree more often than those without training which indicated better reliability (Workum et al. 1986). The previous study done by Brooks and Thomas (1995) compared and assessed normal and abnormal lung sounds from patients with respiratory conditions and patients without respiratory conditions. Brooks and Thomas in their study did not appear to give any specific diagnosis about respiratory conditions of their patients. As a result, it is difficult to predict which abnormal lung sounds investigated in their study and in fact, it is uncertain whether those abnormal lung sounds were from patients who had common or rare respiratory conditions. So, to claim that their results are specific enough is simplistic and arguable. For instance, the improvement of reliability scores for abnormal lung sounds can be argued because there is a potential that the abnormal lung sounds came from a common condition of patient who had asthma, pneumonia and bronchitis rather than IPF.

On that note, this present study took the initiative to evaluate abnormal lung sounds from patients who were specifically diagnosed of having fibrotic and non-fibrotic lungs diseases using the HRCT. This fibrotic lung disease of IPF is a rare respiratory condition and was associated with Velcro crackles. The majority of participants in this study never had any experience of listening to Velcro crackles before in their clinical practices. Nevertheless, from the findings it shows that there has been an improvement of inter-observer reliability to detect these Velcro crackles from this rare IPF disease after the training session. This study suggests that, given an appropriate training to clinician to recognise these Velcro crackles of this rare disease might improve their ability to detect them. Hopefully, this will help in early detection of Velcro crackles in IPF patients and thus will promote better prognosis due to the early referral to pulmonologist specialist.

On the other hand, Morrow et al. (2010) found that inter-observer reliability of physiotherapists and paediatricians in detecting adventitious lung sounds was fair before the education sessions and remained constant after the education session. The education session did not improve the inter-observer reliability in detecting bronchial breathing, which may be due to the quantity and/or quality of the training given towards observers which did not help them much to interpret of bronchial breathing sounds correctly (Morrow et al. 2010). Furthermore, the authors have not highlighted the duration of educational intervention given to their participants, which might be difficult to compare with the present study. In the present study, participants were given approximately 30 minutes of training regarding Velcro crackles in IPF and pre-recorded examples of these crackles were played using audio-visual software for participants to listen to until they were confident enough to do the test.

Inter-observer reliability for Group A (trained physiotherapists) between assessment one and assessment two was affected over time. The finding showed that kappa value was found to be slightly reduced from 0.59 in assessment one to 0.58 in assessment two. However, their reliability still indicates moderate agreement based on recommendation by Landis and Koch (1977). Perhaps, this might be because the participants tend to be less attentive or fail to recall of what they have learnt prior to assessment one regarding Velcro crackle's sounds one week prior completing assessment two. Inter-observer reliability was relatively high for Group B than Group A during assessment two. The reason might be that Group B has just received the training session prior to assessment two and participants were more attentive and aware of how the Velcro crackles sounds were (Morrow et al. 2010). Meanwhile, participants from Group A might fail to recall the Velcro sounds over time when completing their assessment two. Indeed, achievement of competence and expertise in clinical skill required continuously educational training throughout the profession (Benner 2001). Nonetheless, reliability for both Group A and B during assessment two still represent moderate agreement among participants.

In general, inter-observer reliability in detecting Velcro crackles in patients with IPF for all trained Group A and B represent moderate agreement among participants during assessment one and assessment two (k= 0.58 to 0.59). This finding is contrasting to the results of Baughman et al. (1991) who reported kappa value =0.46 in detecting crackles in IPF patients via auscultation. The difference in results between the study of Baughman et al. (1991) with the present study might be due to difference in technique of listening used during assessment of lung sounds. This might be because participants in the present study were asked to listen to the recorded lung sounds files using both audio and visual feedback software, which is the audacity software to detect Velcro crackles.

Meanwhile, Baughman et al. (1991) asked their participants to examine in vivo reliability of auscultation among IPF patients using conventional stethoscope, which relied on participants hearing alone to detect Velcro crackles. Hence, there were advantages for participants in the present study to listen to the recorded lung sound files repeatedly while having a visual feedback of lung sound waveforms during listening until they were satisfied and ready to answer the question. Availability of auditory as well as visual identification of waveforms significantly helped to improve in detection of adventitious lung sounds (Kiyokawa et al. 2001; Murphy 2008). This takes advantage of the fact that many people are predominantly visual rather than auditory learners (Murphy 2008). Similarly, inter-observer reliability finding in the present study is higher than those studies done by other authors in detecting abnormal lung sounds who only depended on hearing acuity to interpret the lung sounds (Spiteria et al. 1988; Aweida and Kelsey 1990; Brooks et al. 1993; Allingame et al. 1995; Jailani and Wong 1998; Elphick et al. 2004; Morrow et al. 2010).

Moreover, variables or categories of adventitious lung sounds including presence or absence of crackles, type of crackles such as fine, coarse or both and presence or absence of Velcro crackles affected the agreement among participants in this study. Inter-observer reliability was higher for all variables for trained Group A which reflect moderate to substantial agreement than untrained Group B (fair to moderate agreement) during assessment one. Nonetheless, after the training session, reliability for all variables for Group B improved during assessment two which represent moderate to substantial agreement. Brooks and Thomas (1995), also noted that improvement in inter-observer reliability for all specific variables for all groups of physiotherapists occurred following educational session. They found that inter-observer reliability indicates from poor to moderate agreement before the education session towards fair to almost perfect agreement after the education session. Improvement in reliability following training session is probably due to the enhancement of participants' current knowledge of nomenclature of adventitious lung sounds especially in Velcro crackles and their receptiveness to change (Brooks and Thomas 1995; Morrow et al. 2010).

Similarly, this study findings of reliability for recognition of adventitious lung sounds (presence or absence of Velcro crackles) for all Group A and Group B following training sessions are consistent with the findings by those published studies in detecting lung sounds, which represents substantial agreement among participants (k=0.61 to 0.75) (Workum et al. 1986 ; Kiyokawa et al. 2001; Prodhan et al. 2008). This might be because inter-observer agreement is better when there is only one category such as the presence or absence of adventitious sounds (Piirilä and Sovijärvi 1995). Yet, reliability was relatively low for variable that has more categories such as fine, coarse or both that reflects moderate agreement among participants for both Group A and B during assessment one and assessment two.

Previous studies have also found that the agreement become poorer when there are more characteristics to consider during assessment (Workum et al. 1986 ; Piirilä and Sovijärvi 1995; Sim and Wright 2005). Overall, the findings of standard error for kappa (SE) of agreement for all groups as well as all variables yielded from 0.05 to 0.06. The majority of participants in this study have preferred to agree towards the absence of crackles rather than its presence which have also reflected in their higher percentages scores of specificity than sensitivity for both Group A and B. These findings have consensus with the work done by Workum et al. (1986) who discovered that agreement on normality where absence of crackles was greater than agreement on abnormality among observers in detecting crackles during auscultation. This may suggest that normal lung sounds are easier to identify than abnormal lung sounds among participants.

7.2.5 Accuracy, sensitivity and specificity

Accuracy refers to the ability of observers who were correctly diagnosed with the presence or absence of disease (Aweida and Kelsey 1990; Brooks et al. 1993). It is a proportion of the true positives and true negatives upon the total number of cases (Metz 1978). Group A that received training session was found to be more accurate (88%) than Group B (53%) in detecting Velcro crackles during assessment one. However, there was improvement in percentages (approximately 30% to 50% increments) of accuracy responses rate for Group B after the training session during assessment two. Generally, both Group A and B were found to have similar percentages scores of accuracy (approximately 88%) during assessment two. These indicate that the training session provided prior to assessment has resulted in improvement of participants' skill to accurately identify Velcro crackles.

The percentage of accuracy response rate for Group B before the training session is consistent with the results of previous studies particularly in regard to the accuracy of physiotherapists in interpreting lung sounds (Aweida and Kelsey 1990; Brooks et al. 1993; Allingame et al. 1995; Jailani and Wong 1998). Aweida and Kelsey (1990), found that overall accuracy rate was 47%, Brooks et al. (1993) found that 50% of accuracy responses rate, Allingame et al. (1995) found only 39% of accuracy in physiotherapists group and Jailani and Wong (1998) found that an overall accurate responses was 60% in physiotherapists who interpreted lung sounds auscultation. All participants from those previous studies were not given specific training session prior to assessment. As a result, it may suggest that an appropriate training and educational sessions will be effective in improving accuracy of lung sounds interpretation (Jailani and Wong 1998).

Sensitivity refers to the proportion of lung sounds which were correctly identified as Velcro crackles by the observers (Pallant 2010). Sensitivity of the test was high for all tests in Group A participants (80% to 85%) who have received the training session compared to untrained Group B participants which was poor (22% to 26%) during assessment one. However, sensitivity increased for both tests in Group B (80% to 85%) following the training session during assessment two. During assessment two, both trained groups A and B yielded high sensitivity scores for all tests (80% to 85%). This may suggest that there was improvement in participants' ability to distinguish Velcro crackles in IPF patients in relation to the gold standard following educational intervention. There were high proportion of true positive and low proportion of false positive for Group A and B which received the training session during assessment one and two than untrained Group B during assessment one. The finding in this study is constant with Morrow et al. (2010), who also found that sensitivity improved after education intervention (from 58% to 78%). Nevertheless, the study finding is contradict with the result found by Prodhan et al. (2008) which sensitivity was at 41% in detecting adventitious lung sounds in children. This may be because educational intervention given to participants that helps to improve sensitivity scores in the present study.

Likewise, specificity was also found to be higher for both tests in Group A (trained) (91% to 95%) than Group B (untrained) (77% to 76%) during assessment one. After the training session, specificity improved for all tests in Group B during assessment two (above 90%). Specificity was high for all trained Group A and B during assessment two, which are above 90% for all tests. Specificity relates to the proportion of lung sounds which were correctly identified without having Velcro crackles by the observers (Pallant 2010). There were high proportion of true negative and low proportion of false negative for Group A and B which received the training session during assessment one and two compared to untrained Group B during assessment one.

This also indicates that there was improvement in participants' ability to correctly detect lung sounds without Velcro crackles in IPF patients after educational intervention. High specificity scores in detecting abnormal lung sounds has been reported in the reliability study of healthcare professionals conducted by Prodhan et al. (2008). In this study, participants were required to detect wheeze sounds among children in clinical setting. Unlike the present study, participants from Prodhan's study were not given any educational intervention regarding abnormal lung sounds prior to the assessment. Therefore, it is difficult to make comparison between the two studies with the present study due to the different study protocol.

In addition to that, the finding for specificity from the present study is also inconsistent with the finding from Morrow et al. (2010). Morrow et al. (2010) in their research found that specificity remained constant throughout the study and was not affected by educational intervention, which might be due to the insufficient quality or quantity of training given to participants. In the present study, participants were allocated approximately 30 minutes of training session in a group and they were allowed to play the sample of Velcro crackles repeatedly until they confident enough to do the test. However, this was not be the case in study done by Morrow et al. (2010) where participants were given a group training session before the assessment. In addition, the authors have not appeared to mention specifically of the duration of training session in their study procedure. Again, it is difficult to make comparison between this study with the present study due to the different study procedures and no information regarding the duration of training session.

7.2.6 Limitations and clinical implications

Potential limitations of this present study should be considered when interpreting the study findings. The present study was using pre-recorded lung sounds files during assessment instead of in-vivo auscultation. Therefore, some sound quality might be lost during recording, storing and playback of lung sounds (Morrow et al. 2010). In other words, the adventitious lung sounds came from recorded files may be compromised from the true quality sound that is normally heard during direct chest auscultation, which may be more challenging in detecting abnormal lung sounds (Aweida and Kelsey 1990; Brooks et al. 1993). This factor explains moderate agreement among observers compared to those previous studies using in-vivo auscultation, which yielded good agreement of reliability (Workum et al. 1986 ; Levy et al. 2004; Prodhan et al. 2008).

In addition, participants were asked to listen to the recorded lung sounds files at their own convenient environment (at home or office) using overhead headphones provided. This environment was different from a typical clinical setting which is noisy such as in a busy ward or clinic. Participants might find themselves to be more attentive and focused during assessment one and two at their own convenient environment. These factors might result for quite consistent reliability findings over time for trained Group A.

Another limitation of this study is that there was no baseline measurement for Group A before the training to provide data base. Therefore, it is not possible to assess and monitor any changes of reliability scores before and after the implementation of training session for this group. This limitation was acknowledged by the researcher, and further improvements and development of the study design have been made in the study two.

Furthermore, participants in this study were only being assessed on their interpretation of lung sounds from recordings files so other skills involved in auscultation such as placement of the stethoscope on the chest, how they ask patients to breathe and patients' positioning during auscultation were not assessed in this study. Although these skills are basic yet they are important to be practised correctly by clinician during auscultation in order to be able to listen to the lung sounds precisely. Moreover, these skills were taught during their undergraduate year and they could be easily revised again by referring to respiratory assessment textbook whenever necessary. Finally, all participants involved in this study were all respiratory physiotherapists from the same institution, UKMMC. Therefore, it should be cautioned when comparing the findings to the general population.

In general, the findings of inter-observer and intra-observer reliability show that the presence and absence of Velcro crackles interpreted during listening to the recorded lung sounds files is a reproducible sign when they are being listened by trained observers. However, the reliability of overall findings in the present study indicate only moderate agreement among trained observers for Group A and B. There is, at least this study suggests that training and education intervention help to improved reliability. It is important for respiratory physiotherapists to be able to interpret the lung sounds correctly as well as having similar agreement with one other in providing consistent clinical decisions (Jailani and Wong 1998) .

To the researcher's knowledge, there is no other study that examine the impact of training among respiratory physiotherapists in detecting Velcro crackles from patients with IPF. The clinical implications from these findings suggest for a potential role of education and training sessions in detecting Velcro crackles to be implemented in clinical setting for respiratory physiotherapists. The training session on Velcro crackles has the potential to improve inter and intra-observer reliability, accuracy, sensitivity and specificity of Velcro crackles detection among respiratory physiotherapists. The incidence of IPF is increasing worldwide and currently, therapy for this disease has become challenging because of its complex and unresolved pathogenic process (Cottin and Cordier 2012). Therefore, healthcare professionals including respiratory physiotherapists should be trained to recognise Velcro crackles during auscultation so that early detection of these crackles in patients will facilitate early referral to pulmonologist for prompt diagnosis of IPF.

Besides, clinician could monitor the progression of this disease by listening to these Velcro crackles during auscultation. Initially, Velcro crackles appeared in the basal areas of the lung at the early stage of the disease, and later as the disease progress these crackles could be heard to the upper zones of the lung. As a result, early detection and monitoring of Velcro crackles will provide better clinical decisions in treating patients (Brooks and Thomas 1995; Jailani and Wong 1998). Appropriate clinical decisions such as pharmacological treatments, pulmonary rehabilitation, oxygen therapy and lung transplantation in treating IPF patients could be offered earlier to patients for long-term prognosis of this dreadful disease.

7.2.7 Summary

This section has discussed the main findings of the study one in relation to current literature. Limitations of this study and clinical implications from the findings have been presented to continue and improve lung sounds auscultation among respiratory physiotherapists. The next section will discuss the main findings of the study two.

7.3 Study Two:

The impact of training on respiratory physiotherapists' competency to detect Velcro crackles in patients with idiopathic pulmonary fibrosis: A longitudinal mixed method study.

7.3.1 Introduction

The aim of this study was to explore the impact of training session on Malaysian respiratory physiotherapists' ability to detect Velcro crackles in pre-recorded lung sounds of patients with idiopathic pulmonary fibrosis over time. Besides, it also aimed to explore participants' experiences of Velcro crackles detection, their perceptions towards the training sessions and their ability to detect Velcro crackles over prolonged periods of time. Data were collected using quantitative and qualitative approaches in a mixed methods concurrent nested study design. The typology approach in this study design involved quantitative component as the primary, while the secondary qualitative component was embedded to reinforce and enhance the results of the primary component in the study.

The primary quantitative component included assessment of the impact of training on the inter-observer reliability and scores of Velcro crackles detection amongst participants which were analysed over time. Besides, the effects of participants' years of experience and category of employers on their scores of Velcro crackles detection over time were also examined. In addition, the secondary qualitative component was nested in this study to provide support for the dataset of primary component. This secondary component was used to gather qualitative data from the interviews which explored more in-depth detail regarding participants' experiences of Velcro crackles detection, their perceptions towards the training sessions and their ability to detect Velcro crackles over time.

This section discusses and integrates the findings from the quantitative (assessment forms of lung sounds) and qualitative components (interviews), with reference to the existing literature. Finally, discussion related to limitations of the study and suggestion for future study will be emphasised.

7.3.2 Impact of training on inter-observer reliability, accuracy, sensitivity and specificity of Malaysian respiratory physiotherapists in detecting Velcro crackles from pre-recorded lung sounds over short term, as well as their experiences of Velcro crackles detection and perceptions towards the training

Early identification of Velcro crackles during lung auscultation assessment of the patients has been proposed as a key element of early diagnosis in IPF disease (Cottin and Cordier 2012; Cordier and Cottin 2013; Cottin and Recheldi 2014). Sellarés et al. (2016) revealed that Velcro crackles were found in all of the patients who have a final diagnosis of IPF during lung auscultation in their study. They also observed that there was an association between Velcro crackles at auscultation and the presence of honeycombing in HRCT, which was related with IPF disease (Sellarés et al. 2016). Thus, auscultation of Velcro crackles appears to be more practical for clinicians to use in clinical setting, and this might give an early warning of the presence of fibrosing lung for an early diagnosis of IPF in primary care. Moreover, Cottin and Cordier (2012) have urged pulmonologists to train their students and general physicians to identify the features of Velcro crackles during lung auscultation in patients for an earlier diagnosis of IPF.

In addition to general physicians, respiratory physiotherapists are also providing care towards patients with respiratory conditions. It is also essential for respiratory physiotherapists to be able to detect Velcro crackles in their patients which could help to facilitate an early diagnosis of IPF. Therefore, this current study aimed to explore the impact of Velcro crackles detection training on Malaysian respiratory physiotherapists' ability and experience in detecting Velcro crackles from pre-recorded lung sounds of patients with IPF over time.

The specific objectives for primary quantitative component of this study were to evaluate the short-term effect of training session on inter-observer reliability amongst Malaysian respiratory physiotherapists and their accuracy, sensitivity and specificity in detecting Velcro crackles. In addition, the specific objectives for secondary qualitative component of this study were to explore respiratory physiotherapists' clinical experiences of Velcro crackles detection before and after the training, and also to explore their perceptions towards the training session.

The finding from this present study (study two) found that there is a positive impact of Velcro crackles detection training on Malaysian respiratory physiotherapists' reliability to detect Velcro crackles from pre-recorded lung sounds over short term. Initially, before the training, inter-observer reliability of respiratory physiotherapists in detecting Velcro crackles was 0.20, indicating slight agreement among participants at the pre-training assessment. Nevertheless, the training session yielded significant improvement in the reliability of Velcro crackles detection (k=0.56) by respiratory physiotherapists at the post-training assessment. Participants showed moderate agreement of reliability on Velcro crackles detection at the post-training assessment.

The result of poor reliability is consistent with the findings of the previous studies that have investigated the reliability of auscultation among clinicians (Aweida and Kelsey 1990; Brooks et al. 1993; Brooks and Thomas 1995; Jailani and Wong 1998; Morrow et al. 2010). Aweida and Kelsey (1990) identified fair inter-observer reliability (kappa value of 0.22) among non-specialised physiotherapists in detecting lung sounds via auscultation using five tape-recorded. Brooks et al. (1993) in their follow-up study had investigated inter-observer reliability in auscultating the same five tape-recorded lung sounds as Aweida and Kelsey (1990), also reported similar kappa value of 0.26 which reflected fair agreement among specialised physiotherapists in cardiorespiratory care. Similarly, Jailani and Wong (1998) who used stethoscope to auscultate 10 tape-recorded lung sounds, found slight agreement for overall inter-observer reliability among 16 physiotherapists. Up to now, very few studies have investigated the effect of education on reliability of auscultation of lung sounds among clinicians. Previous studies of Brooks and Thomas (1995) and Morrow et al. (2010) have evaluated the effect of training on inter-observer reliability of lung sounds, and they reported fair agreement of inter-observer reliability among physiotherapists before the training session.

In accordance with the present finding, a previous study done by Brooks and Thomas (1995) have revealed that education intervention resulted in improvement in reliability of lung sounds detection via in vivo auscultation among physiotherapists. They reported a significant improvement in inter-observer reliability from fair agreement at baseline to almost perfect agreement among physiotherapists following one and a half hour of education session. However, the finding in the present study is contrary to that of Morrow et al. (2010) who found there was no improvement in inter-observer reliability among physiotherapists and paediatricians in detecting bronchial breathing from pre-recorded breath sounds following educational intervention. Their participants' inter-observer reliability remained constant as fair agreement at both baseline test and post-education test. A possible explanation for this is might be due to poor quality of educational material used by Morrow et al. (2010), which only focused on description of the cause and characteristics of bronchial breathing sounds, and only compared the bronchial breathing sounds to normal breath sounds. Therefore, their educational intervention might not be sufficient to give impact on participants' knowledge and skill in identifying bronchial breathing in infants.

In contrast, the training material in the present study comprehensively addressed the key elements that related is to IPF condition in term of its prevalence, prognosis, signs and symptoms, medical management, underlying pathology of IPF that associated with the characteristics of Velcro crackles and also standardised nomenclature for abnormal lung sounds. All the information provided is in line with the current evidence. The correct technique of auscultation procedure was also included to refresh participants' skill in auscultation. Moreover, examples of pre-recorded Velcro crackles, normal lung sounds, wheezes, coarse crackles and fine crackles with their characteristics' descriptions were included in the training material for participants to compare and contrast the characteristics amongst these lung sounds.

The training material that encompassed description of respiratory conditions which are related to their specific abnormal lung sounds might facilitate learning and performance skill in identifying lung sounds (Meruvia-Pastor et al. 2015). Furthermore, Morrow et al. (2010) did not mention the duration of educational intervention given to their participants specifically in the study. This could be argued whether the session could provide an ample time for participants to learn and acquire the skill in identifying bronchial breathing in infants. Unlike the present study, 30 minutes of training session was delivered to participants with included questions and discussion to facilitate knowledge and skill acquisition regarding IPF and Velcro crackles detection. Thus, the training session that was delivered to the participants in the present study has improved participants' inter-observer reliability in identifying Velcro crackles from slight agreement at baseline assessment to moderate agreement at post-training assessment following the training session.

The inter-observer reliability for recognition of crackle sounds (distinguishing abnormal from normal lung sounds) were found significantly higher in the level of agreement than categorisation of crackles (classifying the crackles into fine, coarse or both) and nature of crackle sounds (identifying Velcro or non-Velcro crackles) at both pre-training assessment (fair agreement) and post-training assessment (substantial agreement). The qualitative finding corroborated these findings and provide additional explanation on how participants recognise the lung sounds during assessments. Qualitative finding revealed that the ability of participant to recognise lung sounds particularly in distinguishing abnormal from normal lung sounds was as determined by most participants. For example, most of them commented that they were able to differentiate the characteristics between normal breath sounds and abnormal lung sounds including crackle and wheeze easily when completing the assessments. In addition, other participants also mentioned that they were determined in detecting the presence of crackles from pre-recorded lung sounds due to the frequency of auscultating patient with respiratory conditions in clinical practice. However, only a few participants mentioned that they were able to detect fine and coarse crackles at pre-training assessment.

These findings are in agreement with the findings of Melbye et al. (2016), who found inter-observer reliability among 12 clinicians reached moderate agreement when the categories of crackles were combined, while fair agreement of reliability was obtained when they classified the crackles into detailed categories. In addition, the present findings also support the findings of Brook and Thomas (1995). Brook and Thomas (1995) reported high level of agreements in inter-observer reliability when groups of physiotherapists distinguished abnormal lung sounds from normal lung sounds (k=0.33-0.84 at pre-education assessment and k=0.37-0.99 post-education assessment), whereas low level of agreements were obtained when they classified abnormal lung sounds into detailed categories (k=0.13-0.59 at pre-education assessment and k=0.27-0.69 at post-education assessment) for both assessments before and after education session. This finding may have occurred because it is easier to recognise the presence of any abnormal lung sound such as crackle from a normal lung sound. However, it become more difficult to distinguish the crackles into detailed categories such as fine and coarse crackles by auscultation (Melbye et al. 2016).

Inter-observer reliability was found relatively low for all the detailed categories of crackles such as categorisation of crackle sounds (classifying the crackles into fine, coarse or both types) and identification nature of crackles (identifying Velcro or non-Velcro crackles) which were slight agreements at pre-training assessment. The qualitative findings corroborated this finding and provided further explanation on participants' experiences regarding Velcro crackles detection from pre-recorded lung sounds at pre-training assessment.

Qualitative findings revealed that the ability of participants to recognise lung sounds was influenced by difficulty and uncertainty during completing the pre-training assessment. Most participants mentioned that they have difficulty to categorise the type of crackles into detailed categories of fine or coarse crackles. For example, one participant expressed that those fine and coarse crackles that she listened from the pre-recorded lung sounds were quite similar for her. Therefore, to overcome this difficulty she repeatedly listened to those lung sounds in order for her to know the phase of respiration that the crackles present and distinguish the characteristics between fine and coarse crackles. In addition, one participant mentioned that she found it very difficult to categorise the crackles into detailed categories of fine and coarse due to lack of practice in auscultation during working hours. Therefore, her unusual standard of clinical practice in respiratory assessment has reduced her ability to classify the type of crackles due to lack of experience in listening to those fine and coarse crackles during her clinical practice.

Although all the participants mentioned that they were uncertain about the characteristics of Velcro crackles during the interview, they tried to answer the question by guessing the nature of Velcro crackles at the pre-training assessment. For example, some of them assumed Velcro crackles are fine crackles, while others assumed as coarse crackles. There was one participant who predicted Velcro crackles as having similar sound as tearing apart of Velcro tape, however she could not define whether these crackles are fine or coarse. These findings may suggest that Malaysian respiratory physiotherapists lacked the skill of interpreting fine and coarse crackles during auscultation due to lack of understanding about the characteristics of these crackles. Thus, they found it very difficult to classify the crackles into fine or coarse crackles. Clinicians should have knowledge and understanding regarding characteristics of the fine and coarse crackles in order to differentiate these two types of crackles. Coarse and fine crackles could be differentiated based on their intensity, frequency and duration of crackles which have been recommended by the American Thoracic Society (1977). Loud, low pitched and longer duration crackles may be interpreted as coarse crackles, while less loud, high pitched and short duration crackles may be interpreted as fine crackles (Piirilä and Sovijärvi 1995). Furthermore, all participants were uncertain about Velcro crackles detection at pre-training assessment may be because they have no knowledge about the characteristics of Velcro crackles.

The present finding of low inter-observer reliability that was observed when participants classified abnormal lung sounds into detailed categories before the training session is in agreement with the findings of previous studies on the reliability of lung sounds detection (Melbye et al. 2016; Aviles-Solis et al. 2017; Brooks and Thomas 1995; Jailani and Wong 1998). Melbye et al. (2016) who examined inter-observer reliability in classifying of 20 video recordings of lung sounds into detailed categories of adventitious sounds, reported poor to fair agreement for the detailed categories of crackles (*k*=0.12 to 0.33) and wheezes (*k*=0.07 to 0.40) among 12 paediatricians and doctors. Likewise, a recent study by Aviles-Solis et al. (2017) used the digital recordings of 120 lung sounds in evaluating inter-observer reliability among 28 observers from seven different countries across some European borders. They identified slight to fair agreement of inter-observer reliability among general practitioners from the Russian (k=0.20), students (k=0.40) and pulmonologists (k=0.37) when classifying lung sound files for the presence of crackles.

Besides, Brooks and Thomas (1995) also found low kappa values of inter-observer reliability which indicated slight to fair agreement among groups of physiotherapists when detecting specific abnormal lung sounds into breath sounds, crackle, wheeze and phase of respiration of crackles and wheeze before the education session. In addition, Jailani and Wong (1998) found low kappa values of inter-observer reliability for specific abnormal lung sounds which indicated slight (k=0.11) and fair agreement (k=0.21) for coarse crackles and fine crackles respectively, which are similar with the findings from present study.

However, the training session resulted in significant improvement in the inter-observer reliability for all the detailed categories of crackles among respiratory physiotherapists. Participants' inter-observer reliability for all detailed categories of crackles were significantly increased following the training session, which indicated moderate agreement for both categorisations of crackles and identification nature of crackle sounds during post-training assessment. The present findings corroborate the findings of Brooks and Thomas (1995). Brook and Thomas (1995) reported general improvement of inter-observer reliability for detecting abnormal lung sounds into specific categories following the education session, which reflected fair to substantial agreement among groups of physiotherapists.

This result may be explained by the fact that the training session has covered a topic of standardised nomenclature for the terminology of lungs sound and their details description of characteristics in the present study (Mikami et al. 1987; Pasterkamp et al. 2016). It has been suggested that training session regarding standardisation of the terminology of lung sounds should be implemented in the study in order to improve inter-observer reliability on lung auscultation findings among clinicians (Aviles-Solis et al. 2017). In the present study, the terms of standardised nomenclature of abnormal lung sound such as wheezes, crackles, fine and coarse crackles with their specific characteristics' description were included in the training session in order to gain similar understanding among participants. The education regarding standardised nomenclature might play an important role in improving reliability for all detailed categories of abnormal lung sounds among respiratory physiotherapists in this present study. This might explain that there was an improvement in understanding of lung sounds terminology among respiratory physiotherapists, which subsequently improved their agreement on lung sound findings following the training session.

In general, the present findings revealed that participants' scores of accuracy and sensitivity, did change statistically significant over time at the pre-training, post-training and two-month follow-up assessments. However, no statistically significant difference was found between specificity scores measured before training, after training and at two-month follow-up.

The initial finding of low accuracy (58.06%) of Velcro crackles detection in the present study indicating that just over half the proportion of lung sounds which truly were Velcro crackles and not Velcro crackles we so identified by the respiratory physiotherapists in relation to the reference standard of HRCT finding (Kohavi and Provost 1998). This finding is consistent with the findings of previous studies that have investigated the accuracy of physiotherapists in auscultating tape-recorded lung sounds (Aweida and Kelsey 1990; Brooks et al. 1993; Allingame et al. 1995). Aweida and Kelsey (1990) reported overall low accuracy rate of 47% among physiotherapists in detecting abnormal lung sounds. Their accuracy finding ranged from 33% for low pitched wheeze and stridor to 63% for pleural rub (Aweida and Kelsey 1990). Similarly, Brooks et al. (1993) also found overall low accuracy rate of 50% among specialised physiotherapists in cardiorespiratory field, which ranged from 35% for low pitched wheezes to 77% for bronchial breath sounds.

In addition, Allingame et al. (1995) who compared the accuracy of auscultation of lung sounds between new physiotherapy graduates and experienced cardiopulmonary physiotherapists found that the accuracy rate for new graduates group was 31.3%, whereas the experienced physiotherapists group was 39.3%. Therefore, the overall accuracy rate yielded 35.3% in this study (Allingame et al. 1995), which was lower than those reported by Aweida and Kelsey (1990), Brooks et al. (1993) and the present study. A possible explanation for this is might be due to the differences of participants' inclusion criteria used within the studies. The present study recruited participants who have at least two years of clinical experience in respiratory physiotherapy.

Likewise, Aweida and Kelsey (1990) as well as Brooks et al. (1993) also recruited participants who have at least one year of clinical experience. However, Allingame et al. (1995) included a group of new graduates who have at least one to three months experience in respiratory field in their study. They found that the new graduates have responses with high frequency of incorrect abnormal lung sounds especially the crackle sounds. Whereas, experienced cardiopulmonary physiotherapists were more precise than new graduates in detecting abnormal lung sounds (Allingame et al. 1995). This might suggest that physiotherapists who have at least one year to two years of clinical experience tended to have higher accuracy score than new physiotherapy graduates.

However, the present finding of low accuracy does not support those of Jailani and Wong (1998) and Morrow et al. (2010). Jailani and Wong (1998) found the overall average score of accuracy was 60% among physiotherapists in auscultating lung sounds, which was higher than the finding of the present study. A possible explanation for this might be influenced by the educational programme that participants had prior to the study. It was noted that participants of Jailani and Wong (1998) have received an in-service programme regarding assessment skills which was being delivered at their institution as part of continuous professional development during the study period. On the contrary, all participants in the present study reported no training being received regarding assessment skill on detection of Velcro crackles in patient with IPF prior to the study. Morrow et al. (2010) also reported high accuracy score of 72.5% in detecting bronchial breathing by auscultation among physiotherapists and paediatricians, which is contrary to the finding in the present study. This inconsistency may be due to the unfamiliar term of Velcro crackle that was used for assessment in the present study. All participants in the present study reported that they have never heard about the Velcro crackle prior to the study, whereas bronchial breathing sounds that were used in the study of Morrow et al. (2010) are familiar abnormal lung sounds among clinicians and commonly found in their children patients.

The present finding showed that there was a significant improvement (86.84%) in accuracy of Velcro crackles detection from the pre-training assessment to the post-training assessment following the training session. This may indicate that the training has resulted an improvement in participants' skill on Velcro crackles detection in this present study. However, this finding is contrary to that of Morrow et al. (2010) who reported no significant improvement was found in accuracy following education session. They found the accuracy scores remained constant at the baseline (72.5%) and post-education (72.5%) tests in detecting bronchial breath sounds (Morrow et al. 2010). To the researcher's knowledge, only Morrow et al. (2010) has evaluated the effect of education on accuracy, sensitivity and specificity of auscultation. A possible explanation for this may be that participants in the present study have received adequate training during the education session which resulted significant improvement in accuracy score, whereas Morrow et al. (2010) concluded that no significant improvement in accuracy score following educational session may be due to the lack of adequate educational intervention given to their participants.

Similarly, sensitivity of Velcro crackles detection via auscultation in the present study was low (43.49%) before the training session, at pre-training assessment. This finding indicates that less than half the proportion of actual Velcro crackles were detected by the respiratory physiotherapists from the overall lung sounds in relation to the reference standard of HRCT finding (Bowling 2014). However, sensitivity increased significantly to 85.48% at the post-training assessment from the pre-training assessment, indicating that the training session has resulted an improvement in respiratory physiotherapists' ability to recognise Velcro crackles correctly based on the reference standard of HRCT. The initial present finding of low sensitivity is in line with those of previous studies (Morrow et al. 2010;

Prodhan et al. 2008). However, the present study reported lower sensitivity than that was found by Morrow et al. (2010). Morrow et al. (2010) found poor sensitivity (58%) of bronchial breathing detection via auscultation among physiotherapists and paediatricians before the educational intervention. Prodhan et al. (2008) who examined wheeze detection in the paediatric intensive care unit among clinicians, have asked their participants to auscultate the patients and recorded their findings regarding the presence of wheeze at baseline and every hourly for six hours. They also reported poor sensitivity results of the physician, nurses and respiratory therapists which were 49%, 44% and 41% respectively (Prodhan et al. 2008).

Furthermore, the sensitivity increased significantly following the training session in the present study is consistent with Morrow et al. (2010). Similarly, they also reported a significant improvement in sensitivity which increased to 74% when their participants were identifying bronchial breathing via auscultation following educational intervention, at post-education test (Morrow et al. 2010). The initial present finding of lower sensitivity than that was found by Morrow et al. (2010) may have occurred because all participants in the present study were not familiar with the Velcro crackles before, compared to the bronchial breathing sounds which were common abnormal lung sounds to those participants of Morrow et al. (2010). In addition, it can thus be suggested that the training session that they had in the present study was able to improve their ability to detect Velcro crackles correctly from the pre-recorded lung sounds at post-training assessment.

Initially, the specificity of Velcro crackles detection among respiratory physiotherapists in the present study was 84.54% before the training session. This indicates that 84.54% of lung sounds which truly were not Velcro crackles were identified so by the respiratory physiotherapists (Pallant 2010). Specificity increased to 91.32% at post-training assessment following the training, but no significant difference was found between sensitivity scores at the pre-training and post-training assessments. This finding indicates that there was notable improvement of the participants’ ability to correctly identify non-Velcro crackle sounds from the pre-recorded lung sounds based on the reference standard of

HRCT finding following the training, however it did not reach statistically significant improvement in specificity. The initial finding of specificity is in agreement with those of Morrow et al. (2010) and Prodhan et al. (2008). Morrow et al. (2010) reported specificity of 77.3% in detecting bronchial breath sounds by clinicians. In addition, Prodhan et al. (2008) reported specificity of 76%, 80% and 89% in detecting wheezes by physician, nurses and respiratory therapists respectively.

The result of no significant improvement in specificity following the training session in the present study is in agreement with previous study of Morrow et al. (2010). Morrow et al. (2010) reported the specificity remained constant at baseline (77.35) and post-education (72%) tests. Thus, they suggested that the education session has no effect in clinicians' specificity (Morrow et al. 2010), which also may imply to the finding in the present study.

In general, the findings of poor inter-observer reliability and low score in accuracy, sensitivity and specificity of Velcro crackles detection from pre-recorded lung sounds before the training in the quantitative data were corroborated with the qualitative findings. The qualitative findings provided further explanation on participants' experiences and perceptions of Velcro crackles detection before the training session. Qualitative findings revealed that all participants were unfamiliar with Velcro crackle sounds at pre-training assessment. For example, all participants explicitly mentioned that they never heard about the Velcro crackle before and also have had no experience of it during clinical practice or previously during their undergraduate study at university. As one participant expressed that she was unfamiliar with Velcro crackle due to never having learned about it before. This may suggest that Malaysian respiratory physiotherapists have no knowledge about the Velcro crackle at pre-training assessment. Therefore, all of them were uncertain when detecting Velcro crackles from pre-recorded lung sounds at the pre-training assessment.

In addition, the theme distraction which was revealed from qualitative finding did support the findings of quantitative data. For example, most of them stated that their focus in detecting lung sounds were distracted with the external noises like rubbing sounds in certain recordings when completing the assessment. This situation might contribute to the findings of poor inter-observer reliability and low score in accuracy, sensitivity and specificity. Those external noises were produced by incorrect technique of handling the stethoscope during recording lung sounds via auscultation. One participant mentioned that those external sounds have distracted her attention during listening to the pre-recorded lung sounds, however she tried to listen carefully in order for her to distinguish the abnormal from normal lung sounds. Some participants felt that they could detect the presence crackles from the pre-recorded lung sounds. This may suggest that the knowledge and skill of auscultation that they already had enabled them to distinguish crackles from the external noises during the assessment.

Generally, the quantitative findings revealed that the training session resulted in significant improvement in inter-observer reliability, accuracy and sensitivity of Velcro crackles detection among respiratory physiotherapists from the pre-training assessment to the post-training assessment. The qualitative results corroborated these findings and provided further explanation on participants' experiences of Velcro crackles detection after the training and also their perceptions towards the training. Qualitative findings revealed that there were perceived benefits, comprehension as well as recognition of Velcro crackles by participants from the training session that they had during interview session which was after post-training assessment.

Perceived benefits refer to the positive perceptions that resulted from specific action (Leung 2013). For example, all participants in the present study viewed the training session of Velcro crackles detection that they had as beneficial in terms of detecting Velcro crackles as well as increased awareness towards IPF and Velcro crackles. These perceived benefits reflected acceptability of participants towards the training of Velcro crackles detection. All participants highly valued the training session as it was very helpful in helping them to detect Velcro crackles, thus they found it was easier to complete post-training assessment compared to pre-training assessment previously.

Some participants did express that the content of training materials relating to IPF and Velcro crackles were very concise and informative. For example, one participant mentioned that the information about IPF and how to recognise Velcro crackles were easy to understand, which subsequently helped her to detect Velcro crackles from pre-recorded lung sounds at post-training assessment. Moreover, they also appreciated the training slides which have embedded pre-recorded Velcro crackles and other lung sounds for participants to listen during the session. For instance, one participant explained that she could distinguish the characteristics of Velcro crackles by comparing them with other lung sounds, which she found that was such a good practice for her.

These qualitative findings are in line with the finding of Smythe et al. (2018), who reported the acceptability of the clubfoot training among their participants. They highlighted that the content of the training materials that deliver clear key information as well as feasible style of learning were found to be effective and valued by participants (Smythe et al. 2018). For example, one of their participants said:

'This was exactly the material that I needed to advance my knowledge at this stage'

(Participant, Advanced Course in Smythe et al. 2018)

Another benefit that was mentioned by participants was increase in their awareness level towards IPF disease and Velcro crackles detection, which subsequently will lead to an appropriate and timely medical management to be delivered to patients. For example, one participant explained that the training has increased his awareness about prognosis of IPF which is a progressive fatal condition. Thus, he should be alert with the Velcro crackles presentation during auscultation in patients, which could be an early diagnosis of IPF. In addition, some participants stated that they had gained awareness about the association between IPF and Velcro crackles, which indicating fibrosing of the lung tissues. Therefore, they realised the appropriate physiotherapy intervention that promoting exercise endurance such as pulmonary rehabilitation should be implemented to help patients with IPF.

Another theme from the qualitative findings that was corroborated with the significant improvement in quantitative findings following the training session was comprehension. All participants explicitly responded that they had gained better understanding about IPF condition and acquired such important skill on how to detect Velcro crackle sounds in patients after the training. These acquisition of knowledge and skill have helped them in detecting Velcro crackles from pre-recorded lung sounds at post-training assessment. For example, one participant expressed that this training has increased her knowledge and understanding about the incidence, signs and symptoms and appropriate treatment of IPF disease, and also the characteristics of Velcro crackles.

In addition, participants also highlighted that they have acquired the new skill on how to detect Velcro crackles sounds via auscultation from this training. For instance, one participant stated that the acquired skill has helped her to distinguish Velcro crackles from other lung sounds at the post-training assessment. These findings may suggest that the training has delivered positive impact on participants' knowledge and skill regarding IPF as well as Velcro crackles detection respectively.

The theme recognition of Velcro crackles from qualitative findings was also corroborated with the quantitative findings. Participants were attentive and confident when recognising the Velcro crackles at post-training assessment following the training session. Majority of participants stated that they were able to recognise Velcro crackles from other lung sounds at the post-training assessment. For examples, participants were more attentive towards the characteristics of Velcro crackles during listening to those pre-recorded lung sounds. They were able to detect Velcro crackles which are fine type of crackles, high pitch sounds and present throughout the inspiratory phase following the training session. Participants also commented it was easier to complete post-training assessment compared to pre-training assessment.

In addition, majority of participants mentioned that the training has increased their confidence in detecting Velcro crackles at post-training assessment compared to pre-training assessment. For example, one participant stated that she was confident to classify the nature of crackles that she heard as Velcro or non-Velcro crackles compared to pre-training assessment. Generally, these findings may suggest that the training has improved recognition of Velcro crackles detection among Malaysian respiratory physiotherapists who felt determined and confident about their ability to detect Velcro crackles at post-training assessment.

In general, the qualitative findings regarding Malaysian respiratory physiotherapists' experiences of Velcro crackles detection following the training and also their encouraging perceptions towards the training session were affirmed by the quantitative results at the post-training assessment.

7.3.3 Impact of training on inter-observer reliability, accuracy, sensitivity and specificity of Malaysian respiratory physiotherapists in detecting Velcro crackles from pre-recorded lung sounds at the two-month follow-up, as well as their experiences regarding Velcro crackles detection

The next specific objectives for primary quantitative component of this study were to evaluate the effect of training on inter-observer reliability amongst Malaysian respiratory physiotherapists and their accuracy, sensitivity and specificity in detecting Velcro crackles at the two-month follow-up. Besides that, the next specific objective for secondary qualitative component of this study was to explore participants' experiences of Velcro crackles detection in clinical after two months, following the training session.

The present finding showed that inter-observer reliability of Velcro crackles detection among respiratory physiotherapists was significantly lower at the two-month follow-up assessment (k = 0.50) than the post-training assessment (k = 0.56). This inter-observer reliability represented moderate agreement among participants at the two-month follow-up assessment. The result of decreased in inter-observer reliability at the two-month follow-up assessment from the post-training assessment is consistent with the finding of the previous study (Morrow et al. 2010). Up to now, only Morrow et al. (2010) has investigated the effect of education on reliability, accuracy, sensitivity and specificity of auscultation over time, which measured at the baseline test, post-education test and follow-up test. Morrow et al. (2010) found that the inter-rater reliability of bronchial breath sounds detection amongst clinicians has dropped from 0.30 at the post-education test to 0.29 at the eight-week follow-up test which indicated fair agreement. A possible explanation for the decay in inter-observer reliability of the present study, might be that the skill retention on Velcro crackles detection among respiratory physiotherapists reduced at the two months, following the training session.

However, this present finding revealed that moderate agreement of inter-observer reliability among participants at the two-month follow-up assessment was similar as their agreement level at the post-training assessment. This similar agreement at both post-training and two-month follow-up assessment was confirmed by the findings of reliability for the detailed category of lung sounds, which revealed that no statistically significant differences of inter-observer reliability for recognition of crackles and nature of crackle sounds between the post-training and two-month follow-up assessments. Only the inter-observer reliability for categorisation of crackles was found significantly reduced at the two-month follow-up assessment from the post-training assessment.

In addition, this moderate agreement for overall kappa in the present study was found higher than the agreement found in the study of Morrow et al. (2010) at their follow-up test. It can therefore be assumed that the knowledge and skill of Velcro crackles detection that the participants had acquired during the last training session is still accessible in their long-term memory at the two-month follow-up assessment. Furthermore, the qualitative findings of the present study corroborated this quantitative result and provided further explanation for how the participants' experiences of Velcro crackles detection after a prolonged duration.

Qualitative findings revealed that the skill retention of Velcro crackles detection was completely retained in some of the participants at the two-month follow-up interview. For example, participants stated that they were able to detect Velcro crackles at the two-month follow-up assessment due to the long-term memory regarding the information about Velcro crackles which they acquired during the training session. For instance, one of the participants claimed that she could still remember the characteristics of Velcro crackles and was able to detect them during the two-month follow-up assessment. In addition, some participants highly valued this skill and mentioned that they repeatedly practice it in clinical. For instance, one participant stated that she routinely practices the skill during auscultation assessment in clinical which has facilitated her skill retention over the long term. As a result, she was able to detect the Velcro crackles at the two-month follow-up assessment. This finding was also reported by Wijbenga et al. (2019) who found that repetition in clinical practice helped to increase practical experience and solidify the skill towards pattern recognition.

These qualitative findings affirmed the result of moderate agreement in inter-observer reliability among Malaysian respiratory physiotherapists at the two-month follow-up assessment.

There was a significant improvement in accuracy from the pre-training assessment compared to the two-month follow-up assessment. During the time between pre-training and two-month follow-up assessments, respiratory physiotherapists may have been more attentive towards the characteristics of Velcro crackles after the training session, thus improving their accuracy score. However, acuracy of Velcro crackles detection significantly decreased from the post-training assessment compared to the two-month follow-up assessment. This finding may suggest that the ability of participants to identify actual Velcro crackles and not Velcro crackles in relation to the reference standard have reduced at the two months, following the training session.

Furthermore, a statistically significant negative correlation was found to exist between accuracy and participants' days of leave at the two-month follow-up assessment. This indicates that the ability of participants to accurately detect the actual Velcro crackles and non-Velcro crackles appears to deteriorate with days of leave within the two months, thus this finding has affirmed the decay of accuracy at the two-month follow-up assessment. A possible explanation for this might be because the days of leave taken by participants have affected their skill practice in clinical. The finding of the present study does not support the previous study of Morrow et al. (2010). Morrow et al. (2010) found that the accuracy at the eight-week follow-up test was increased to 79.3% from 72.5% at the post-education test, yet no statistically significant difference was found between the two tests. This inconsistency may be due to the effect of 30% dropout rate of participants at the follow-up test in the study of Morrow et al. (2010), which may have introduced bias in their results.

Likewise, there was a significant improvement in sensitivity from the pre-training assessment to the two-month follow-up assessment. This indicates that participants may have been more aware towards the characteristics of Velcro crackles following two months of the training session, hence improving sensitivity in detecting Velcro crackles. However, sensitivity of Velcro crackles detection among participants significantly decreased from the post-training assessment compared to the two-month follow-up assessment. This result may indicate that the ability of participants to identify truly Velcro crackles from the pre-recorded lung sounds in relation to the reference standard have decreased at the two months, following the training session.

Moreover, a statistically significant negative correlation was found to exist between sensitivity and participants' days of leave at the two-month follow-up assessment. This indicates that the ability of participants to correctly detect the actual Velcro crackles seem to decline with days of leave within the two months, thus this finding has affirmed the decay of sensitivity at the two-month follow-up assessment. Again, a possible explanation for this might be because the days of leave taken by participants have affected their skill practice in clinical. The present finding is contrary to that of Morrow et al. (2010) who found that the sensitivity of bronchial breath sounds detection remained at 74% during the post-education and eight-week follow-up tests which was clearly not statistically significant. Again, this discrepancy could be attributed to the dropout rate of participants at the follow-up test in their study.

Specificity was found to be constant at the two-month follow-up assessment and at the pre-training assessment. This may suggest that the ability of participants to identify truly non-Velcro crackles was not affected by the training session. Besides, no statistical significance was found in specificity between the post-training and the two-month follow-up assessments. This finding may explain that the ability of participants to identify truly non-Velcro crackles from the pre-recorded lung sounds in relation to the reference standard remained at the two months, following the training session. Likewise, there was no statistically significant correlations between days of leave and specificity at the two-month follow-up assessment. This finding may suggest that there was no association between specificity and days of leave within two months. The finding of the present study is in agreement with that of Morrow et al. (2010), who found that the specificity at the eight-week follow-up test remained constant at baseline, post-education and follow-up tests. They concluded that specificity in detecting bronchial breathing sounds was not affected by the education session (Morrow et al. 2010).

Overall, the quantitative findings revealed that there were significant decline in inter-observer reliability, accuracy and sensitivity of Velcro crackles detection from the post-training to the two-month follow-up assessments. However, the reliability, accuracy and sensitivity scores at the two-month follow-up assessment were significantly higher than the scores at the pre-training assessment. The qualitative results in the present study corroborated these findings and provided further explanation on participants' experiences of Velcro crackles detection at two months, following the training session.

Qualitative findings revealed that most of the participants expressed their skill retention of Velcro crackles detection declined at the two-month follow-up assessment. For example, they affirmed that they have forgotten the characteristics of Velcro crackles. However, after making an attempt to recall the characteristics of Velcro crackles and listening to those pre-recorded lung sounds repeatedly during the assessment, majority of them claimed that they could roughly detect the Velcro crackles during the assessment. These findings thus indicated that most of the participants could at least in part retain their skill, demonstrating that the knowledge and skill they had acquired in the training session two months ago are still accessible in their long-term memory.

Qualitative findings also showed the obstacle that may hinder participants from practising this newly acquired skill in clinical was due to time constraint. Hence their skill decayed at the two-month follow-up, following the training session. This result is similar to that of Snodgrass and Odelli (2012), who reported loss of skills amongst their participants after one week without practice. Skill decay refers to the loss of trained skills after a period of non-use which is particularly problematic in situations where individuals receive initial training on knowledge and skills that they may not practise for extended periods of time (Arthur et al. 1998).

For example, most of the participants in the current study mentioned that they could not practise this skill in clinical due to lack of time. They mainly spend their working hours dealing with high number of caseload every day, extra workload of patient cases to be covered in the circumstances that their colleagues are on leaves and other administrative responsibilities. Malaysia is facing a shortage of physiotherapy workforce and most physiotherapy departments in public and private hospitals are understaffed, such that a constant excessive workload is unavoidable (Nordin et al. 2011). This high workload forces physiotherapists to treat an average of 15 to 20 patients per day for 8 working hours (Nordin et al. 2011), thus participants may have no time to apply the acquired skill from previous training session in their clinical practice. Moreover, other factors such as increased patient-to–therapist ratios and limited therapist-patient contact time in physiotherapy care (Nordin et al. 2011) might also hinder participants to practise the Velcro crackles detection properly during pulmonary auscultation because of time constraint. In general, all these factors may contribute to the loss of knowledge and skill over time due to the lack of opportunity to apply the knowledge and practise the skill they have learned in training session. Therefore, this finding further affirmed the decay upon of quantitative findings in this study.

Knowles with his andragogy theory identified that adult learners value self-directed learning, have experiences from their own personal learning resource, seek problem solving through learning, ready to learn about topics relevant to their own realities and they need internal motivation (Knowles, 1990). Experiential learning is one of the adult learning theories that suggests on the ideas that adults are comprehending well when they are directly involved with hands on experience and reflective learning of professionals' skills in real life context, instead of reading and memorising from books. Thus, this experiential learning theory is adopted to underpin the training programme of Velcro crackles detection for respiratory physiotherapists in this current study. Kolb (1984) believed that knowledge is constructed through the transformation of experience and described the learning cycle as having four phases: concrete experience, reflective observation, abstract conceptualisation, and active experimentation. Ideally, concrete experience happens when the learner is actively engaged in the experience or activity, for instance participants in this study were directly involved in listening to the lung sounds including Velcro crackles using audio video software face-to-face training session. Then, reflective observation occurs when participants use analytical skills to review and reflect on their experience of listening to the different of lung sounds. The next stage is abstract conceptualisation where participants acquire skill from their experience and distinguish Velcro crackles during immediate post-training assessment. Active experimentation occurs when participants had their hands-on tasks in clinical practice and apply the new skill to detect Velcro crackles in patients, using their decision making and problem-solving skills. Active experimentation then leads to concrete experiences, and the cycle of experiential learning continues.

However, this experiential learning cycle is impaired at certain extent when most participants in this study stated they had no opportunity to practise the acquired skill in clinical setting between acquisition and retention periods, that leads to loss of skill over time at two-month follow-up assessment. Decline in skill retention over time must be overcome with an intensive and continuous training strategy (Stefanidis et al. 2006; Castellvi et al. 2009). Repetitive training between acquisition and retention phases has been shown to be a more efficient training strategy in the retention of skills amongst healthcare professionals (Castellvi et al. 2009). This continuous training strategy could be implemented using an online educational experience with a foundation on the adult learning theory to develop clinical competency for physiotherapy practice over time. An example would be online IPF training package to be given to participants following their face-to-face training session to enhance the quality of learning.

This online training package should be developed with the reference of the adult learning principles to further facilitate learning process amongst participants (Knowles, 1990). An interactive online training that is embedded with quizzes and is task oriented pertinent to IPF condition and Velcro crackles is preferable, as adult learners prefer to be actively participating in their learning experience. Online training may allow participants to learn repeatedly whenever they need to, at their own pace and convenient time and using practical learning devices such as mobile phone, tablet, laptop or computer. Besides, adult learners are self-directed and goal oriented, as they prefer to learn the course that benefit their work most. The continuous online training helps to keep participants' updated with the latest information of IPF and retains their acquired skill over time, regardless if they lack hands on practice in clinical setting. Hence, this continuous online learning strategy may promote a better skill retention over time during follow-up assessment. In contrast, if participants only rely on face-to-face training from the previous session, they may experience loss of skill over time if lack of skill usage in clinical practice. Further recommendations of the online training that is required to enhance physiotherapists competency and skill retention will be discussed in detail in section 8.4.

7.3.4 Effect of training on accuracy, sensitivity and specificity of Malaysian respiratory physiotherapists according to the levels and years of clinical experience over time

The present findings of the study found that there were no statistically significant differences between the levels of clinical experience (junior and senior groups) and accuracy, sensitivity and specificity of Velcro crackles detection value over time. In addition, no correlations were found between years of clinical experience and accuracy, sensitivity and specificity of Velcro crackles detection value over time. These findings may suggest that levels and years of clinical experience were not affected or associated with the training intervention, indicating both junior and senior groups of respiratory physiotherapists have similar acceptance of new information and skill on Velcro crackles detection that resulted similar scores in accuracy, sensitivity and specificity over time following the training, regardless their years of clinical experience.

These findings seem to be consistent with those obtained by Brooks et al. 1993. Brooks et al. (1993) found no difference between the accuracy of the specialised physiotherapists and the non-specialised physiotherapists in the auscultation of tape-recorded lung sounds. However, the findings of the present study do not support those previous research (Allingame et al.1995; Morrow et al. 2010). Allingame et al. (1995) who investigated accuracy and intra-rater reliability of auscultation, found that more experienced cardiorespiratory physiotherapists were more accurate than new graduates in auscultating lung sounds from the tape-record. Morrow et al. (2010) found a negative correlation between test scores of auscultation and years of clinical experience, reaching significance for the post-education test. They found that more experienced clinicians who are qualified for over five years deteriorated in test scores following education, while clinicians who have less than five years of clinical experience improved their test scores in detecting bronchial breath sounds following educational session.

7.3.5 Skill transfer in the clinical practice

Another specific objective for secondary qualitative component of this study was to explore participants' experiences of skill transfer in clinical during two months, following the training session.

Quantitative findings showed that there were three cases of patients who were detected for Velcro crackles during clinical practice have been referred for further investigation of IPF by two participants within two months, after the post-training assessment. These cases were recorded by participants in the two-month calendar diary that was given to them at the post-training assessment. The qualitative finding corroborated these findings and provided further explanation for how participants' experiences of their skill transfer, following two months after the training session.

Qualitative findings revealed that the skill transfer occurred in the clinical practice among participants, which related to the changes on referrals number for further investigation of IPF and sharing the new skill with others. Some of the participants have mentioned that they have applied the newly acquired skill of Velcro crackles detection during clinical practice. For example, there were responses from two participants during the interview session that they have detected Velcro crackles at the lower lobes of their patients' lungs during auscultation assessment. Subsequently, they have referred these patients to the physician for further investigation of IPF, in which participants have never donepreviously before the training session. This may indicate that the training session has improved participants' competency to detect Velcro crackles in their patients and influenced the changes on referrals number of the patients with Velcro crackles from zero to three cases within two months. Only three patients have been identified to have Velcro crackles within the two months, this small number may relate to that IPF is a rare disease condition, which its incidence is estimated as 6.8 to16.3 people per 100,000 population, per year (Nalysnyk et al. 2012).

In addition, some participants mentioned that they did share this newly acquired skill and information regarding IPF and Velcro crackles detection with other respiratory physiotherapy colleagues and students during clinical practice. For example, one participant stated that she has shared this skill to the physiotherapy students whom she supervised during clinical placement. This finding may also suggest that some participants were able to translate the skill that they had learned and shared with others during clinical practice within two months, following the training session.

7.3.6 The importance of skill in detecting Velcro crackles in clinical practice

It was not possible from the quantitative component to assess the importance of skill on Velcro crackles detection for respiratory physiotherapist in clinical. Hence, it was considered important to conduct interviews in order to gain a deeper insight regarding participants' perceptions towards the importance of this skill in their clinical practice.

The qualitative finding revealed that all participants appeared to acknowledge the importance of this newly acquired skill in clinical practice to detect Velcro crackles in their patients during interview session at the two-month follow-up. There were two subthemes that were constructed from their responses that this skill was acknowledged as important in delivering accurate assessment and treatment as well as monitoring progression of the disease. All participants mentioned that this skill could help them to make an accurate assessment during auscultation because they could distinguish precisely either the crackle sounds generated at the chest wall are due to secretion retention or lung fibroses. Subsequently, they could deliver an appropriate treatment that is effective for patients with IPF. For example, some participants have mentioned that the suitable physiotherapy treatment for patient with IPF is the pulmonary rehabilitation programme. Pulmonary rehabilitation provides a circuit training that can increase respiratory muscles and exercise endurance, which could help improve the pulmonary functions in patients with IPF (Holland et al. 2012). In addition, this programme will also train patients on how to control their breathing during breathlessness attack (Oldham and Noth 2014).

Another point that was raised by some of the participants regarding the importance of this skill in clinical practice was about allowing monitoring of the progression of the IPF disease in their patients. For examples, one participant explained that this skill will help her to keep monitoring the progression of Velcro crackles from the lower zone towards the middle zone of the lungs in her patients. Therefore, she could plan for the next phase of physiotherapy intervention as the condition progresses to help the patients. Besides, another participant did mention that closely monitoring the progression of the Velcro crackles in patients might allow her to design the intervention accordingly to the condition stage. For instance, she could provide more emphasis on how to cope with breathlessness during daily activities if the patient is at the later stage of IPF.

This qualitative finding regarding acknowledgement of the importance of acquiring the skill in detecting Velcro crackles may reflect that participants really understand the purpose of the training that they received, why they should have this skill, why they should retain the skill and transfer it into clinical practice. Despite the demands to acquire knowledge and skill, there is a need towards a process of developing in healthcare professionals (Taylor and Hamdy 2013). This qualitative finding links with the assertions within andragogy of adult learning theory that was proposed by Knowles (1988) which promotes individual development. Knowles et al. (2015) described that adults learner tend to be more-self-directed, internally motivated, ready to learn, need to know, learners' experiences and oriented to learn. These criteria may facilitate the growth of continual learning process towards IPF and Velcro crackles detection among participants over the long term in clinical practice.

7.3.7 Suggestions for improvement of the training

The qualitative findings suggest that there should be a continuous learning regarding the training of Velcro crackles detection throughout the clinical practice. Participants believe that this practice would enhance their ability to grasp and retain this skill over long-term duration, as well as to keep up their knowledge and skill updated. Two preferable learning methods raised by participants were online training and workshop training.

Majority of participants support the training of Velcro crackle detection via online, which they believed this method of training would benefit all the learners in various ways. For example, participants highlighted that this self-study via online training allows them to learn at their own pace that meets their individual needs and at any time that is convenient for them. In addition, participants find that online training is cheaper and more feasible than other methods which could encourage more people to learn. Online training of Velcro crackles detection could be viewed as a self-directive learning, which relates to the principles in andragogy of the adult learning theory (Knowles et al. 2015). In this learning setting, learners have set the agenda for their learning and they do receive less supervision from trainers in an online environment.

Meanwhile, some participants preferred the learning of Velcro crackles detection to be delivered via workshop training. Participants mentioned that they could gain better understanding of the knowledge and skill through workshop training because of the two-way interaction between learners and the trainer during the session. For example, one participant stated that via an interactive workshop, she could have an ample time for discussion and practical session. Another participant did mention that workshop training that invite patient with IPF would be beneficial, as learners would have an opportunity to engage with the patient and get to recognise Velcro crackles during direct auscultation assessment. Similarly, workshop training which actively engage the learners during the learning session via discussion and practical sessions, does apply the principle of self-directive learning in andragogy of adult learning theory (Knowles et al. 2015).

The qualitative findings revealed that an early exposure towards the training of Velcro crackles detection might equip health professionals with the knowledge and clinical skill on how to detect Velcro crackles amongst patients with IPF at the very early stage during their clinical working. Cottin and Cordier (2012) have urged pulmonologists to train their students and general physicians to identify the features of Velcro crackles during lung auscultation in patients for an earlier diagnosis of IPF. All participants raised that an early training should be delivered to healthcare professionals including respiratory physiotherapists, respiratory physicians, general physicians and nurses at the earliest year of their clinical practice, hence early identification of Velcro crackles during lung auscultation could be made in clinical settings. This early identification of Velcro crackles in patient has been proposed as a key element of early diagnosis in IPF disease (Cottin and Cordier 2012; Cordier and Cottin 2013; Cottin and Recheldi 2014). Subsequently, this would lead to a timely and appropriate medical intervention for patients with IPF.

Many participants stressed concern that this training should be provided earlier to undergraduates including physiotherapy, nursing and medical students during their clinical placement in final year. For example, one participant stated that this will help students to integrate the knowledge regarding IPF condition and skill on how to detect Velcro crackles with their clinical experiences during clinical placement. Therefore, students will have better understanding and skill acquisition towards recognition of Velcro crackles in patients during their clinical placement. Besides that, another participant mentioned that this will enhance students' practical ability during clinical placement and prepare them to be capable physiotherapist in their future clinical practice. This finding is supported in a qualitative study by Wijbenga et al. (2019), who explored how undergraduate physiotherapy students learn clinical reasoning skills during clinical placements. They found that students learnt most when they could apply their skills on patients in real-life during clinical practice due to the dynamic process of their clinical reasoning.

In sum, the findings revealed that participants appeared to support the training of Velcro crackles detection in clinical practice with several suggestions made for training improvement, including a development of continuous learning approach via online training and workshop training, as well as early exposure of the training towards the targeted learners including healthcare professionals and healthcare students.

7.3.8 Evaluation of the training program using the Kirkpatrick model

Training is regarded as a valuable investment and as one of the most important factors for healthcare professional development (Heydari et al. 2019). Training for healthcare professional workforce is provided routinely to update on skill practice and innovations ultimately aiming to improve patient care (Jones et al. 2018). Staff satisfaction, intended outcomes, and economical efficiency can gradually be improved as a result from the training productivity (AlYahya and Norsiah 2013). In contrast, if the efficacy of training in terms of its practical outcomes is not established, the behaviour of staff may be considered intractable, and resources may be wasted (Smidt et al. 2009). Although participants may claim that the training is beneficial, there is no guarantee it will impact their knowledge levels or behaviour (Ziarnik and Bernstein 1984). Thus, evaluating the efficacy of a training program according to an appropriate standard is stipulated as an essential component of the training process.

The Kirkpatrick model - developed by Kirkpatrick (1996) is widely used as one of the technique for appraisal of evidence for any reported training program in health-related studies (Smidt et al. 2009; Heydari et al. 2019; Dubrowski and Morin 2011; Lee et al. 2013; Nestel et al. 2011; Sinclair et al. 2015; Jones et al. 2018). This model may be used as an effective framework to evaluate the impact of the training program, whether it is expected to meet the needs of both organiser and the participants particularly in the healthcare setting (Smidt et al. 2009). Thus, the Kirkpatrick model of evaluation is adopted in this current study to appraise the training program of Velcro crackles detection amongst Malaysian respiratory physiotherapists. Besides, this model facilitates the use of both quantitative and qualitative data collections within a single study, which is ideally suited to this mixed methods study design. The Kirkpatrick model consists of four levels of evaluation: (1) reaction; (2) learning; (3) behaviour; and (4) results, and each level progressively informs the responsible organisation how successful the training program has been (Kirkpatrick 1996).

The first level of reaction was evaluated by exploring participants' attitudes towards the training to which extent they found the Velcro crackles detection training is favourable, engaging and relevant to their clinical work through qualitative method using a semi-structured interview. Qualitative results revealed that all participants perceived the training program as beneficial in helping them to acquire a new skill in detecting Velcro crackles and increasing their awareness towards the IPF condition. Moreover, they also acknowledged the importance of this skill and knowledge to be applied in their clinical practice. In the second level of the Kirkpatrick evaluation model, the effect of the training was evaluated on participants' learning outcomes in terms of both knowledge and skill acquisition via quantitative method of data collection (La Duke 2017). Pre- and post-training assessments were given to participants before and after the training program respectively. Evaluation of the learning level of Kirkpatrick's model showed that the training has significantly improved in inter-observer reliability, accuracy and sensitivity of participants in detecting Velcro crackles from the pre-training to the post-training assessments. These indicate that the training is effective in enhancing the participants' skill and knowledge.

The third level is evaluation of behaviour or performance that involves exploring participants' ability to apply their newly acquired knowledge and skill of Velcro crackles detection into practice in the clinical workplace. Kirkpatrick and Kayser (2016) suggest this third level is probably the most significant level of evaluation. Consequently, in this study, an evaluation of the training from the participants' perspective that relates to the change in their behaviour has been explored via qualitative approach, using a semi-structured interview. Qualitative findings revealed that the skill transfer was observed within some participants in this study. Some of them reported that they did apply the skill into practice and shared with others during clinical practice. Besides, two participants claimed that they did identify three patients who had Velcro crackles through auscultation, and have referred them to physician for further investigation of IPF. These reflect that the training program has influenced the changing behaviour in some of participants within this study.

The fourth level defined as results, is an evaluation of the conclusive impact that the training has had (Smidt et al. 2009), this might include improvement in physiotherapy practice towards IPF patients. Therefore, to further evaluate the results of the training program, subsequent follow-up for the three patients who were referred with a suspected diagnosis of IPF by the two participants (based on result of the third level) were made at 12-month after the last data collection (during 2-month follow-up assessment). Participants were contacted again via phone to confirm the outcome of their referrals, and both of them reported that their patients were diagnosed with IPF after further medical investigation. The evaluation of results level indicates that the training program has significant impact on healthcare practice in terms of improved skill competency of some Malaysian respiratory physiotherapists and, subsequently improved the patient outcomes.

Generally, this training program have successfully implemented all levels of the Kirkpatrick model in this study. Therefore, this training program of Velcro crackles detection provides the most comprehensive evaluations and lead to more robust conclusions and recommendations for the training (Jones et al. 2018; Bylund et al. 2011). It is highly suggested that the Kirkpatrick model to be used as an outcome measure for a physiotherapy training program to determine the success of the training and its impact on clinical practice.

7.3.9 Limitations

A number of potential limitations to this present study should be considered in order to appropriately interpret these findings.

The first limitation was that pre-recorded lung sounds files were used during the assessment instead of in-vivo auscultation. Some sound quality may be lost during recording through digital stethoscope, storing and playback of lung sounds. Furthermore, the abnormal sounds heard from pre-recorded files may be compromised by the true quality which is normally heard during in-vivo chest auscultation but, may be more challenging for participants to distinguish between external noises and crackles. This may impact the assessment findings.

The second limitation was that the interviewer was the same person who conducted the training session and assessments to the participants. Throughout the training session and assessments, there would have been a connection developed between the interviewer and participants, hence the study was exposed to reporting bias. This may impact the information received from participants during the interview sessions. It would be worthwhile in future study for the person conducting the interviews not to be involved in conducting the training or assessment. Therefore, this may reduce bias of the interviewer in the study.

7.3.10 Summary

The longitudinal mixed methods study found that initially, Malaysian respiratory physiotherapists were unable to detect the Velcro crackles from pre-recorded lung sounds due to unfamiliarity towards the characteristics of Velcro crackles. This study suggests that training is important for respiratory physiotherapists, and it has potential benefits to improve their ability in detecting Velcro crackles in the short term. However, participants' ability to detect the Velcro crackles decay at the two-month follow-up, indicating their skill retention declined over time because of time constraint to practice the skill in clinical. Although their skill retention declined, participants still acknowledged the importance of Velcro crackles detection in clinical practice. There is a skill transfer achieved by some participants at the two-month follow-up, indicating changes of referrals number of patients who have been detected for Velcro crackles and sharing the skill with others in clinical practice. In addition, there are a few suggestions for improvement of the training: 1) the training of Velcro crackles detection should be a continuous learning in clinical setting; 2) training should be delivered via online and interactive workshop; and 3) there should be an early exposure of the training to the health care professionals and students.

The next chapter, Chapter 8, provides a final conclusion of all the studies encompassed in this thesis.

Chapter 8: Conclusions

8.1 Introduction

This chapter highlights the overall key findings of all the studies (study one and two) encompassed in this thesis. It also highlights the findings in relation to implication for practice and directions for future study.

In general, this thesis aimed to explore the impact of training on Malaysian respiratory physiotherapists' ability in detecting Velcro crackles from pre-recorded lung sounds of patients with idiopathic pulmonary fibrosis. Two studies were conducted to address this aim.

The first study (study one) was a preliminary study to evaluate intra- and inter-observer reliability between trained and untrained groups of respiratory physiotherapists in detecting Velcro crackles from pre-recorded lung sounds. The specific aims of study one were:

i. To evaluate intra- and inter-observer reliability of the Velcro crackles in IPF patients for the trained Group A and untrained Group B.

ii. To determine intra- and inter-observer reliability of Velcro crackles before and after training sessions for Group B.

The second study (study two) explored the impact of training on respiratory physiotherapists' ability in detecting Velcro crackles from pre-recorded lung sounds of IPF patients over time. This study involved a longitudinal mixed methods design in which to address the specific aims of quantitative and qualitative components. The specific aims for primary quantitative component were:

i. To evaluate the short-term effect of the training session on inter-observer reliability, accuracy, sensitivity and specificity of Malaysian respiratory physiotherapists in detecting Velcro crackles from patients with IPF.

ii. To examine the long-term effect of the training session on inter-observer reliability, accuracy, sensitivity and specificity of Malaysian respiratory physiotherapists in detecting Velcro crackles from patients with IPF.

In addition, the aims for secondary qualitative component were:

i. To explore Malaysian respiratory physiotherapists' clinical experiences of Velcro crackles detection at baseline and after the training session.
ii. To explore Malaysian respiratory physiotherapists' perceptions of the training session for Velcro crackles detection.
iii. To explore participants' experiences of skill transfer into clinical practice.

8.2 Key findings of the study one (preliminary study) and study two (longitudinal mixed methods study)

The study one (preliminary study) has found that intra and inter-observer reliability of respiratory physiotherapists in detecting Velcro crackles were lower in the untrained Group B (slight to moderate agreement and slight agreement respectively) than the trained Group A (substantial to almost perfect agreement and moderate agreement respectively) at the Assessment 1. However, following the training session, intra and inter-observer reliability improved for Group B (substantial to almost perfect agreement and moderate agreement respectively) at the Assessment 2. Meanwhile, intra and inter-observer reliability for Group A remained constant at the Assessment 2 (substantial to almost perfect agreement and moderate agreement respectively). Similarly, the findings of accuracy, sensitivity and specificity in the untrained Group B were lower than the trained Group A at the Assessment 1. However, after the training session the accuracy, sensitivity and specificity improved from low to high scores in Group B at the Assessment 2. Meanwhile, the accuracy, sensitivity and specificity remained constant in Group A at the Assessment 2 (high scores > 80%). The findings may suggest that the trained participants are believed to be more reliable, accurate, sensitive and specific than untrained participants. This may suggest that the training session has improved respiratory physiotherapists' ability in detecting Velcro crackles from pre-recorded lung sounds of patients with IPF.

To date, no other studies have used a longitudinal mixed methods approach to examine the impact of training on clinicians' ability to detect lung sounds. In addition, this study is the first to evaluate Malaysian respiratory physiotherapists' ability to detect Velcro crackles from pre-recorded lung sounds of patients with IPF over time. The study two (longitudinal mixed methods study) has found that Malaysian respiratory physiotherapists' ability in detecting Velcro crackles from pre-recorded lung sounds did change significantly over time, following the training session. The training session has significantly improved the inter-observer reliability of Malaysian respiratory physiotherapists in detecting Velcro crackles from the pre-training assessment (slight agreement) to the post-training assessment (moderate agreement), over short-term duration. Similarly, their accuracy and sensitivity were significantly improved from the pre-training assessment to the post-training assessment. The qualitative findings corroborated these quantitative findings, suggesting that the training was perceived as beneficial by participants. In addition, participants were able to comprehend and acquired the knowledge and skill from the training, thus improving their attentiveness and confidence in recognising Velcro crackles.

However, the inter-observer reliability, accuracy and sensitivity declined from the post-training to the two-month follow-up assessment, following the two months training session. Specificity in detecting Velcro crackles from pre-recorded lung sounds remained constant over time. Besides, there were significant negative correlations between participants' days of leave at the two-month follow-up assessment with the accuracy and sensitivity. The qualitative findings corroborated these quantitative findings suggesting that participants' skill retention declined over time, due to time constraint to practise the skill in clinical. No significant differences between the levels of clinical experience (junior and senior groups) and accuracy, sensitivity and specificity of Velcro crackles detection over time. In addition, no correlations were found between years of clinical experience and participants' accuracy, sensitivity and specificity in detecting Velcro crackles over time. These findings may suggest that respiratory physiotherapists have similar acceptance of new information and skill on Velcro crackles detection during the training regardless their levels and years of clinical experience.

Besides, this longitudinal mixed methods study found that a skill transfer achieved by some participants at the two-month follow-up, indicating changes of referrals number of patients who have been detected for Velcro crackles and sharing the skill with others in clinical practice. In addition, qualitative findings suggest some improvement for the training: 1) the training of Velcro crackles detection should be a continuous learning in clinical setting; 2) training should be delivered via online and interactive workshop; and 3) there should be an early exposure of the training to the health care professionals and students.

Overall, the findings from these two studies suggest that the training session has on positive impact on Malaysian respiratory physiotherapists' ability in detecting Velcro crackles from pre-recorded lung sounds in the short term. However, the findings from the longitudinal mixed methods study found that respiratory physiotherapists' ability to detect Velcro crackles decay following two months, due to their skill retention declining over time. This may suggest that a continuous training programme could promote their long-term skill retention in detecting Velcro crackles.

8.3 Research implications for practice

Based on this thesis findings, there is a number of important implications for future practice which are:

i. The measurement tool of Velcro crackles detection using pre-recorded lung sounds files could be used in clinical setting to assess the ability of health care professionals in detecting Velcro crackles, since it is reliable with the consistent test-retest scores.

ii. The training session of Velcro crackles detection is recommended to be implemented in clinical practice to train health care professionals (respiratory physiotherapists, physicians and nurses) and undergraduate students (physiotherapy, medical and nursing students) in improving their auscultation interpretation towards the characteristics of Velcro crackles and detecting Velcro crackles among patients. Findings from this study may impact the undergraduate curriculum development, so that there will be better integration between theoretical knowledge and skill practice. In order to enhance students' skill competency and performance in clinical practice, the clinical placements should be integrated earlier within curriculum, particularly at the second year in undergraduate physiotherapy course.

iii. An early training exposure is recommended to the health care professionals at their earliest year of clinical practice and students at their final years of clinical placement. This will enhance their ability to detect the Velcro crackles as early as possible during clinical practice in primary care where sophisticated diagnostic technology like HRCT is not always available. Therefore, early diagnosis of patients with IPF could be made through auscultation.

iii. The training of Velcro crackles detection should be developed as a continuous training programme in clinical setting, which should be delivered through online and interactive workshop. This will promote acquisition and retention of the knowledge and skill regarding Velcro crackles detection over long-term.

iv. The impact of this research will enhance the acquisition of respiratory physiotherapists' skill and knowledge to detect Velcro crackle sounds during auscultation in clinical. This will promote earlier detection of patients with IPF and earlier referral of patients to pulmonologists to make definite diagnosis of IPF for better long-term outcome for patients. In addition, this skill of detection of Velcro crackles will help physiotherapists to inform optimum clinical decisions for therapeutic interventions that are appropriate for patients with IPF. The department of physiotherapy could participate in designing a pulmonary rehabilitation program particularly for the patients whom require breathing techniques, breathing retraining and suitable physical activity which has potential to promote quality of life among patients with IPF (Oldham and Noth 2014). Inclusive pulmonary rehabilitation program involves multidisciplinary intervention for patients with chronic respiratory disease including strength and endurance training, aerobic exercise and respiratory muscle training, supplemental oxygen, nutritional support and self-management (Spruit et al. 2013). A comprehensive systematic review and meta-analysis by Cheng et al. (2018)

was done to investigate the efficacy of pulmonary rehabilitation in patients with IPF, which involved the largest numbers of patients (142 participants) from four randomized controlled trials (RCTs) (Dowman et al. 2017; Vainshelboim et al. 2017; Gaunaurd et al. 2014; Nishiyama et al. 2008). Generally, these four RCTs included outpatient exercise training, home exercise, supplemental oxygen, education and medical care and varied in duration between 9 and 12 weeks of their pulmonary rehabilitation programs (Cheng et al. 2018). Findings from this meta-analysis indicated that the pulmonary rehabilitation significantly improved exercise capacity and health-related quality of life which significantly enhanced 6-minute walk distance and reduced in St. George's Respiratory Questionnaire (SGRQ)/IPF-specific respectively in patients with IPF at the end of the intervention program (Cheng et al. 2018). In addition, other studies also reported that pulmonary rehabilitation have significantly improve in functional exercise capacity (Swigris et al. 2011; Gomez et al. 2013), fatigue (Swigris et al. 2011), dyspnea level (Gomez et al. 2013; Lanza et al. 2020), anxiety and depression (Swigris et al. 2011) and health-related quality of life (Gomez et al. 2013) in patient with IPF.

Exercise training session that combine aerobic and resistance trainings in pulmonary rehabilitation increases in tidal volume and respiratory rate lead to increase in pulmonary ventilation and oxygen saturation (Louvaris and Vogiatzis 2015; Burton et al. 2004). Moreover, it improves cardiac conditioning as it increases cardiac output to meet oxygen demands of the working skeletal muscles during exercise training through systemic circulation of oxygenated blood (Burton et al. 2004). These enhance the efficiency of oxygen uptake by the skeletal muscle function at the cellular and molecular levels, subsequently improves fatigue resistant for the muscles including quadriceps, gluteus maximus and gasctrocnemius (Mador et al. 2001) as well as improve muscles performance (Louvaris and Vogiatzis 2015). Moreover, calories burned during exercise leads to increase fat-free body mass (Bernard et al. 1999). These effects translate to significant improvement in exercise capacity, dyspnea and quality of life (Nici et al. 2006). In general, pulmonary rehabilitation is recommended as a valid intervention program for patients with IPF as it has beneficial effect on physiological functions, quality of life and mental health.

8.4 Recommendations for future research

To date, no other studies have used a longitudinal mixed methods approach to examine the impact of training on clinicians' ability to detect lung sounds. In addition, this study is the first to evaluate Malaysian respiratory physiotherapists' ability to detect Velcro crackles from pre-recorded lung sounds of patients with IPF over time.

This research has highlighted many questions in need of further investigation. Future research should include participants from various health care professionals including physicians and nurses, and also from across regions in Malaysia to obtain more representative and generalisation findings. In addition, it should be considered to conduct this study amongst undergraduate health care students particularly physiotherapy students at their final year of study programme. Since there is an existence gap between theoretical and practice within undergraduate physiotherapy curriculum in Malaysia as discussed in section 1.2.3, this future study may explore the skill competency and performance of final year students regarding Velcro crackles detection in IPF patients before they are ready for entry-level physiotherapists in workplace practice. Findings from this future study may further shed light on the undergraduate curriculum development, so that there will be better integration between theoretical knowledge and skill practice. In order to achieve better outcome of students' skill competency and performance in clinical practice, the clinical placements should be timely integrated within curriculum, particularly at the earliest semester of the second year in the undergraduate physiotherapy course.

Further improvement on the development of the training package is required to achieve greater outcomes for future study. The development of online training package for future research is preferable than face-to-face training when considering loss of skill retention over time amongst participants in this study. This online training package should be developed with the reference of the adult learning principles to further facilitate the learning process amongst participants (Knowles, 1990). Online training program is particularly relevant for health professionals such as physiotherapists who commonly experience time constraint due to excessive workload during working hours and it is accessible to a larger percentage of the workforce including those in regional and remote areas to overcome logistical barriers (Lam-Antoniades et al. 2009). An interactive online training that is embedded with quizzes (lung sounds detection, characteristics of lung sounds and IPF condition), case study scenarios, audio-visual of lung sounds and is task oriented pertinent to IPF condition and Velcro crackles is preferable, as adult learners prefer to be actively participating in their learning experience and also use their experiences to gain a better understanding of the subject (Knowles, 1990). A navigation button should be included to allow interactive training, in which learners can navigation throughout the context of the training packages. Besides, a navigation button should allow learners to view the correct answers and their scores for the quizzes.

Besides, adult learners are self-directed and goal oriented, as they prefer to learn the course that benefit them most and help them in work-related decision making (Knowles, 1990). Adult learners are practical (Knowles, 1990) and online training is suitable for them. Online training may allow engagement of participants to access the training content repeatedly whenever they need to, at their own pace and schedule, and using practical learning devices such as mobile phone, tablet, laptop or computer. Such continuous online training helps to engage participants with the latest and updated information of IPF and retain their acquired skill over time, regardless if they lack of hands on practice in clinical setting. Development of online training for future research should consider its efficacy of intervention delivered to participants by evaluating the training outcomes using all four levels evaluation of the Kirkpatrick model comprehensively. For example, the first level Kirkpatrick evaluation model might be done by assessing participants' attitudes regarding the effect of training on their clinical practice via online questionnaire.

Evaluation of participants' competency might be done by embedding a task of Velcro crackles detection before and after online training session. This evaluation refers to the second level Kirkpatrick evaluation model which is to assess participants' learning outcomes in knowledge and skill acquisition. Next, assessment of skill retention amongst participants might be proposed by conducting a clinical audit to document any increase in the number of referrals with suspected diagnosis of IPF. This assessment is referring to the third level

Kirkpatrick evaluation model which is to assess skill transfer in the workplace. The fourth level Kirkpatrick evaluation model might be done by follow-up the referrals in order to confirm whether the patients are diagnosed with IPF condition. Therefore, a lengthened time frame for longitudinal study should be considered to allow for follow-up assessment up to 12 months of data collection in future research. This will allow for a more comprehensive evaluation of the training program using the level 4 (results) evaluation of the Kirkpatrick model to identify and document the outcome of referral patients who are suspected for diagnosis of IPF. Robust evaluation of the level 4 might reflect that the training program has successful in bringing an impact to healthcare practice particularly in physiotherapy (Kirkpatrick 1996).

8.5 Reflexivity

Reflexivity is a continuous process of reflection by researchers on their values (Parahoo 2006) and of recognising, examining, and understanding how their "social background, location, and assumptions affect their research practice" (Hesse-Biber 2007). It relates to sensitivity of the ways in which the researchers and the research process may shape the data collected. Reflexivity is a critical element as I might bring my own identity and biases during interaction with the participants and also during the interpretation of the data. In the introduction (section 1.2) I have specified that I had approached the research through the lens of a physiotherapist educator. Therefore, I took several steps to minimise any potential bias during the data collection and analysis phases including the role of prior assumption and experience. However, being a physiotherapist educator was also an advantage in helping me to design and develop the content of the training package as well as assessment form for participants in this study.

At the time of data collection and analysis, I was a 35-year-old Malay woman who was born in Malaysia and have experience both as a physiotherapist and as an academician in physiotherapy education. Thus, I shared some of the culture, values and norms with the participants in this study. These might be advantageous in terms of sharing and understanding the participants' views.

There are several limitations of the qualitative component which should be acknowledged in this study in order to interpret the study findings. Reflecting back on my experience during the data collection process in this study, I was the only person who conducted all of the training session, lung sound assessments, and conducted the interviews with the participants. Therefore, there may have been the potential for developing a connection between the researcher and the participants. This might have had an impact on the participants' responses towards the interview questions, thus the study might have potential reporting bias. Another limitation I not only interviewed and also analysed the data. I might therefore, have brought my own set of intentions to the analysis through my personal background as a physiotherapist educator on the interpretation process. In order to counteract these particular limitations, several approaches have been taken to reduce bias.

During the data collection process, I positioned myself as a post-graduate student and introduced myself as a research student to the participants at recruitment and prior to the interviews. This was to allow participants' willingness to talk openly about their experiences and freely to critique during the interviews because they might see me as a neutral person who is free from any position in healthcare professional or educator organisations and has no prejudice towards them. Therefore, I could focus on the importance of understanding participants' experiences and their explanations. During the interview, one participant disclosed that she seldom auscultates the patient with respiratory condition in her clinical practice. This made me feel shocked because this is unusual practice for a respiratory physiotherapist, however, I tried to maintain a neutral attitude throughout the session because I recognised my role as a researcher. During the interview sessions, I always focused myself to remain neutral towards participants' views and explanations so that it would not influence the way they responded to the interview questions. Therefore, they would freely express their experiences and views during the interview sessions.

Another approach that I used to counteract my bias during data analysis was conducting an independent coding with a second person (AS) who has a physiotherapy research background during the thematic analysis. Therefore, this process would limit me bringing my own set of intentions to the analysis of generating coding from the transcripts. In order to ensure credible findings of qualitative results, our findings of generated codes were discussed and reviewed together before we decided to agree the final codes from the data sets. For example, participant's view towards the training on how to detect Velcro crackles was extracted as,

*'Yes, I found this **(training is very beneficial)**. After the training, **(I gain more and better understanding about IPF and skill)** how to detect the Velcro crackles…And **(the significance of knowing the sound and in fact it can be detected earlier). (I can differentiate the fine and coarse crackles.')***

In this case, we agreed that the initial generation codes were **'helpful'**, **'gain knowledge and skill'**, **'create awareness'** and **'distinguish Velcro crackles'**. These codes were compared based on differences and similarities for all the interview transcripts and sorted into themes and sub-themes. This process of independent coding with the second person and examples of agreement of generated codes were also discussed earlier in the section 5.3.15.3.

I also found that analysing the qualitative data required time and efforts. As a researcher, I have to be concerned with the quality of data, hence asked for help from my colleague who is also a researcher and has physiotherapy background to do the backward translation, another two colleagues who have the same physiotherapy and researcher background to do peer debriefing during data analysis process. The peer debriefing was very beneficial during coding and analysing of the themes, in order to get the accurate themes for the findings.

The interview sessions were conducted via face-to-face at participants' work place, in physiotherapy department. Therefore, I was also mindful that I was a guest in the participants' work place, and it is important for me to be polite, respectful, and considerate with the participants to allow of the benefit of gaining rapport, good interaction and collaboration with participants. Reflecting back on participants' attitudes during the interviews, all of them were very easy to work with and friendly, they seemed to be comfortable in their workplace, and willing to share their opinions and views during the sessions. In addition, I chose to speak in Malay language as all the participants were Malays. This allowed participants to express their opinions and views freely when using their native language.

Understanding my own attitudes, values and biases might be a useful tool to gain deeper insight to the research and ensure my focus remains on the research. Besides, using a clear outline of the methods of data collection and analysis used in the qualitative component, it was possible to provide a clear account for analysing and interpreting the research data (May and Pope 2000).

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Appendices

Appendix A: Assessment form (study one)

UNIVERSITY OF Southampton

Assessment Form

CD 1: File 1-20

Please fill in (✓) the chart while you listening to the recording.

No.	Question		C1 F1	C1 F2	C1 F3	C1 F4	C1 F5	C1 F6	C1 F7	C1 F8	C1 F9	C1 F10	C1 F11	C1 F12	C1 F13	C1 F14	C1 F15	C1 F16	C1 F17	C1 F18	C1 F19	C1 F20
1.	Can you hear crackles in this recording?	Yes																				
		No																				

***Please proceed to the rest of the questions only if you heard some crackles somewhere in the recording (no. 2-3).**

No.	Question		C1 F1	C1 F2	C1 F3	C1 F4	C1 F5	C1 F6	C1 F7	C1 F8	C1 F9	C1 F10	C1 F11	C1 F12	C1 F13	C1 F14	C1 F15	C1 F16	C1 F17	C1 F18	C1 F19	C1 F20
2.	If yes, which crackles could you hear? A- Coarse crackles B- Fine crackles C- Both *see definitions	A																				
		B																				
		C																				
3.	Do you think these crackles are fibrotic/ Velcro in nature?	Yes																				
		No																				

*Definitions:

Fine crackle: nonmusical, short, explosive; heard on mid-to-late inspiration and occasionally on expiration; unaffected by cough, gravity-dependent, not transmitted to mouth.
Coarse crackle: nonmusical, short, explosive sounds; heard on early inspiration and throughout expiration; affected by cough; transmitted to mouth. (Bohadana et al. 2014)

Date: 1st October 2014 Version: 2 Ethics number: 12611

1

Appendix B: Letter of invitation (study one)

UNIVERSITY OF Southampton

Letter of Invitation

Dear physiotherapist,

Study title: Respiratory physiotherapists' ability to detect fibrotic crackles in recordings from idiopathic pulmonary fibrosis patients

This letter is an invitation to take part in my research study. I hope to involve physiotherapists with a minimum of 2 years clinical practice in respiratory physiotherapy who are currently practicing clinically in the respiratory field at the the Universiti Kebangsaan Malaysia Medical Centre (UKMMC), Kuala Lumpur, Malaysia.

The aim of this study is to evaluate health professionals' ability to detect the fibrotic crackles that are typical of Idiopathic Pulmonary Fibrosis from recordings of lung sounds. If you are willing to take part you will be asked to listen to four CDs of recorded lung sounds and answer three simple questions about each recording. You can listen to the CDs at any convenient computer. There will be two sessions of assessment in this study. The enclosed Participant Information Sheet gives you more details about the study. The information we gather will be used to develop and 'train' an algorithm for detecting these crackles automatically.

Included with this letter are the Participant Information Sheet and Reply Slip. If after reading this letter and the Participant Information Sheet, you would like to take part in this study, please complete and return the Reply Slip to me in the envelope provided. I shall then contact you via telephone or email to arrange a suitable time to meet with you to explain further.

Thank you very much for taking time to read this letter.

Yours sincerely,

Nor Azura Azmi,
MPhil/PhD student,
Faculty of Health Sciences,
University of Southampton, Highfield, Southampton, SO17 1BJ.
Email: naa3g09@soton.ac.uk; Tel: Malaysia +60192512685; UK+44(0)459397607

Date: 1st October 2014 Version: 2 Ethics number: 12611

Appendix C: Participant information sheet (study one)

Participant Information Sheet

Study Title: Physiotherapists' ability to detect fibrotic crackles in recordings from idiopathic pulmonary fibrosis patients

Researcher: Nor Azura Azmi

You are being invited to take part in a research study. Before you decide it is important for you to understand the purpose of the research and what it will involve. Please read this information carefully before deciding to take part in this research.

What is the research about?
Idiopathic pulmonary fibrosis (IPF) is a progressive lung disease with a poor prognosis. Clinicians have noted the presence of abnormal lung sounds in IPF and reported the presence of 'velcro-type' or fibrotic crackles as being characteristic of the disease. These sounds can be heard easily with a standard stethoscope, but have yet to be quantified. It has been suggested that using the acoustic characteristics of these lung sounds might be a cost-effective way to diagnose IPF earlier, to help optimise therapy and improve prognosis. However, we still know very little about fibrotic crackles recorded in IPF patients under clinical conditions. This proposed study is part of a PhD programme of work investigating fibrotic crackles in IPF. In this study we should like to evaluate the ability of health professionals' to detect fibrotic crackles in IPF patients recorded in clinical conditions. Another researcher is recruiting medical clinicians in a parallel study (in Italy), while this piece of work focuses on physiotherapists (in Malaysia). Data from both studies will subsequently be shared.

Why have I been chosen?
You have been approached because you are respiratory physiotherapist who is currently working at the Universiti Kebangsaan Malaysia Medical Centre (UKMMC), Kuala Lumpur, Malaysia and you have a minimum of 2 years of clinical practice in respiratory physiotherapy. We need 10 people like you to participate in the study.

What will happen to me if I take part?
Your participation is voluntary. If you are happy to take part, please reply to a reply slip within this information pack and return it to me in the addressed envelope provided. The researcher will contact you to arrange to meet at your convenience. The study will be explained to you again and you will have the opportunity to ask questions. You will then be asked to sign a consent form.

You will be randomly assigned into two groups which will be matched for number of years of working experience in respiratory physiotherapy (senior physiotherapy with more than five years of experience and junior physiotherapy with a minimum of two years of experience). There will be two sessions of assessment in this study. Prior to the first assessment session, participants from Group A will receive a training session for fibrotic crackles detection, while Group B will not receive any training. Group A will be allowed to listen to five files of recorded fibrotic crackles sounds from a CD before the assessment. You will be allowed to listen to them repeatedly using standard headphones provided until you are confident to start the assessment.

Then, Group A and Group B will be given two CDs with 20 files on each CD (each file is a 15 second recording of lung sounds). You will also be given an assessment chart to record your findings. You will be provided with some headphones to use while listening to the recorded lung sounds.

You can listen to the files at any convenient computer. There will be a simple instruction sheet describing how to listen to the recorded files using Audacity Software prior to listening. This software can be freely accessed and downloaded online from audacity.sourceforge.net onto your computer. You will be asked to listen to the files from the two CDs and record your findings using the assessment chart given. There are 3 questions to answer about each file. You can stop/start the CDs as you wish. We estimate that it will take approximately 30 minutes to complete your assessment of both CDs. We would like you to complete this task within one week of receiving the CDs and equipment. After completing your first assessment, please inform the researcher by email or phone and she will come and collect the CDs and assessment chart from you.

Then, you will be given another two CDs with 20 files of lung sounds on each CD and a new assessment chart for the second assessment. During the second assessment, Group B will receive as same training as Group A. However, no extra training session to be given to Group A. After that, same procedure described earlier will be repeated in this second assessment. Once you have completed your second assessment, the researcher will again collect the data form, CDs and headphone from you.

Are there any benefits to taking part?
There are no direct benefits from you taking part in this study. However, the information we get from this study may help health professionals to detect fibrotic crackles in idiopathic pulmonary fibrosis patients earlier in their condition.

Are there any risks involved?
There are no risks from taking part in this study.

Will my participation be confidential?
All information which is collected about you during the course of the research will be kept strictly confidential according to the Data Protection Act/University policy. Your anonymity will be preserved as you will be assigned an identity code which will be used throughout the study so that you will not be able to be identified. The information will be stored on a password protected personal computer and the hard copy data will be stored in a locked cupboard within the university.

What happens if I change my mind?
You have the right to withdraw from this study at any time without your legal rights being affected.

What happens if something goes wrong?
In the unlikely event of anything going wrong or if have a complaint or concern, you can contact Research Governance Manager, Research Governance Office, Building 37, University of Southampton, Highfield, Southampton, SO17 1BJ (Tel: +44 (0)2380 595058; Email: rgoinfo@soton.ac.uk). The Research Governance Manager is completely independent of this study and will be happy to deal with any problems or concerns that may arise and can provide you with an official complaints form.

What will happen to the results of the research study?
The results of the study will be incorporated into a PhD Thesis and may be published in academic journals or at conferences. However, if this happens you will not be identified in any report or publication.

Who has reviewed the study?
The study has been ethically reviewed by the Faculty of Health Sciences Ethics Committee (Ethics number: 12611) and Research Ethics Committee Universiti Kebangsaan Malaysia (Ethics number:)

Where can I get more information?
If you would like further information you can call or write to:

Nor Azura Azmi
MPhil/PhD student, Faculty of Health Sciences, University of Southampton, Highfield, Southampton, SO17 1BJ; Telephone: Malaysia +60192512685; UK+44(0)7459397607; Email: naa3g09@soton.ac.uk

Prof Anne Bruton (Research Supervisor)
Professor of Respiratory Rehabilitation, Faculty of Health Sciences, University of Southampton, Highfield, Southampton, SO17 1BJ; Telephone: 023 8059 5283; Email: ab7@soton.ac.uk;

Assoc. Prof Dr. Ayiesah Ramli (Co-Research Supervisor for data collection in Malaysia)
Physiotherapy Programme, School of Rehabilitation Sciences, Faculty of Health Sciences, Universiti Kebangsaan Malaysia, Jalan Raja Muda Abdul Aziz, 50300 Kuala Lumpur; Telephone: +603-2691 8037; Email: ayiesha@fsk.ukm.my

Thank you very much for reading this information sheet.

Appendix D: Reply slip (study one)

Reply Slip

Study title: Physiotherapists' ability to detect fibrotic crackles in recordings from idiopathic pulmonary fibrosis patients

Researcher: Nor Azura Azmi

I (Print your name): ____ would like to

participate in this research.

Telephone : _____________________

Email : ______________________

Signature : ______________________

Date : _______________________

Return to: Nor Azura Azmi, (MPhil/PhD student, University of Southampton), Physiotherapy Programme, Faculty of Health Sciences, Universiti Kebangsaan Malaysia, Jalan Raja Muda Abdul Aziz, 50300 Kuala Lumpur, Malaysia.

Appendix E: Consent form (study one)

CONSENT FORM

Study title: Physiotherapists' ability to detect fibrotic crackles in recordings from idiopathic pulmonary fibrosis patients

Researcher name: Nor Azura Azmi

Please initial the box(es) if you agree with the statement(s):

I have read and understood the information sheet (insert date /version no. of participant information sheet) 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 without my legal rights being affected.	☐

Data Protection

I understand that information collected about me during my participation in this study will be stored on a password protected computer and that this information will only be used for the purpose of this study. All files containing any personal data will be made anonymous.

Name of participant (print name)…………………………………………………

Signature of participant……………………………………………………………..

Name of person taking consent…………………………………………………

Signature of person taking consent……………………………………………

Date………………………………………………………………………………

Appendix F: Demographic form (study one)

DEMOGRAPHIC FORM

Study Title: Physiotherapists' ability to detect fibrotic crackles in recordings from idiopathic pulmonary fibrosis patients

Researcher Name: Nor Azura Azmi

To be completed by the researcher

Participant Code: ……………………………….

Age: ………………………………………………….

Gender: Male ☐

Female ☐

Year qualified as a physiotherapist: ……………………..

Number of years of experience in respiratory physiotherapy: ………………..

Do you have any experience with idiopathic pulmonary fibrosis patients? YES ☐

NO ☐

Have you ever heard of the term 'Velcro crackles'/'fibrotic crackles' YES ☐

NO ☐

Would you recognise 'Velcro crackles'/'fibrotic crackles' if you heard them? YES ☐

NO ☐

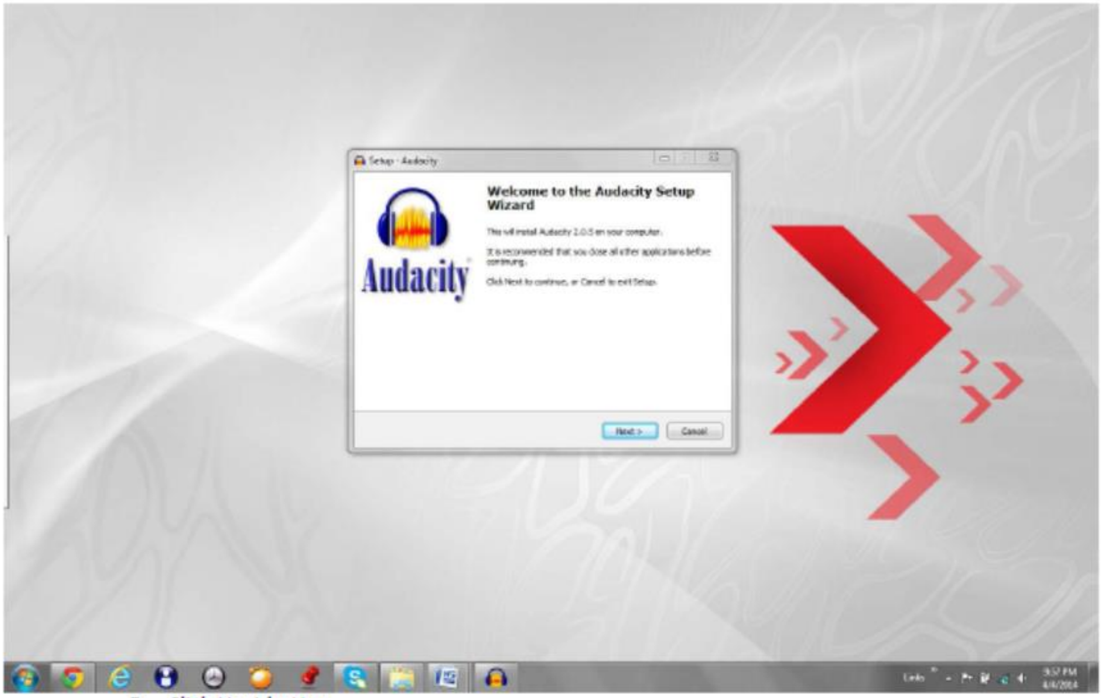
Appendix G: Audacity guideline

UNIVERSITY OF Southampton

Guide to using Audacity Software

1. Download and Install Audacity for Windows

1. Go to the Audacity Website at http://audacity.sourceforge.net/
2. Click the Download Tab.
3. Click the Audacity for Windows.
4. Click the Audacity 2.0.5 installer.



5. Click Next button.

Date: 1st April 2014 Guide to use Audacity Software Version 1 Ethics: 12611

Appendix H: Ethical approval, University of Southampton Research Committee (Study one)

~~ERGO [ergo@soton.ac.uk]~~

Actions

To:
Azmi N.A.
Deleted Items

14 October 2014 13:46

You forwarded this message on 15/10/2014 15:14.

Submission Number 12611:
Submission Title Health professionals' ability to detect fibrotic crackles in recordings from idiopathic pulmonary fibrosis patients (Amendment 1):
The Research Governance Office has reviewed and approved your submission

You can begin your research unless you are still awaiting specific Health and Safety approval (e.g. for a Genetic or Biological Materials Risk Assessment) or external ethics review (e.g. NRES).The following comments have been made:

"

Submission ID : 12611
Submission Name: Health professionals' ability to detect fibrotic crackles in recordings from idiopathic pulmonary fibrosis patients (Amendment 1)
Date : 14 Oct 2014
Created by : Nor Azmi

"

ERGO : Ethics and Research Governance Online
http://www.ergo.soton.ac.uk

DO NOT REPLY TO THIS EMAIL

Appendix I: Ethical approval, Universiti Kebangsaan Malaysia Research Committee (Study one)

UNIVERSITI KEBANGSAAN MALAYSIA

The National University of Malaysia

Pusat Perubatan UKM | ***UKM Medical Centre***

Jawatankuasa Etika Penyelidikan UKM — **UKM 1.5.3.5/244/NN-176-2014**

13 Febuari 2015

Profesor Madya Dr. Hajah Ayiesah Haji Ramli
Program Fisioterapi
Pusat Pengajian Sains Rehabilitasi
Fakulti Sains Kesihatan
Universiti Kebangsaan Malaysia

Puan,

Kelulusan Etika Menjalankan Penyelidikan di UKM

Tajuk : *Health Profesionals' Ability To Detect Fibrotic Crackles In Recordings from Idiopathic Pulmonary Fibrosis Patients*

Kod Projek : **NN-176-2014**

Perkara yang tersebut di atas adalah dirujuk.

Sukacita dimaklumkan, Jawatankuasa Etika Penyelidikan UKM meluluskan permohonan penyelidikan puan bagi tajuk diatas. Tempoh kelulusan kajian adalah daripada **12 Febuari 2015 - 11 Febuari 2016.** Sila kemukakan sebarang **Laporan Kesan Sampingan, Laporan Kemajuan Setiap 6 Bulan** dan **Laporan Akhir** sebaik sahaja penyelidikan tamat kepada Jawatankuasa Etika Penyelidikan UKM.

Sekian, terima kasih.

Yang benar,

Profesor Madya (K) Dato' Dr. Fuad Ismail
Pengerusi
Jawatankuasa Etika Penyelidikan
Universiti Kebangsaan Malaysia

s.k. - **Timbalan Dekan (Penyelidikan & Inovasi)**
Fakulti Sains Kesihatan
Universiti Kebangsaan Malaysia

- **Ketua Program Fisioterapi**
Pusat Pengajian Sains Rehabilitasi
Fakulti Sains Kesihatan
Universiti Kebangsaan Malaysia

- **Puan Suriah Ahmad**
Unit Fisioterapi
Jabatan Perkhidmatan Pemulihan Perubatan
Pusat Perubatan Universiti Kebangsaan Malaysia

Sekretariat Etika Penyelidikan Universiti Kebangsaan Malaysia

Appendix J: Invitation letter (study two)

Letter of Invitation

Dear physiotherapist,

Study title: The impact of training on respiratory physiotherapists' competency to detect Velcro crackles in patients with idiopathic pulmonary fibrosis.

This letter is an invitation to take part in my research study. I hope to involve physiotherapists with a minimum of 2 years clinical practice in respiratory physiotherapy who are currently practicing clinically in the respiratory field at one of these sites, Hospitals of Ministry of Health Malaysia (Kuala Lumpur General Hospital, Klang Hospital and Sungai Buloh Hospital) and private physiotherapy centres (Pantai Integrated Rehab. Services, Your Physio and Columbia Asia Hospital) in Malaysia.

The aim of this study is to evaluate the impact of training on respiratory physiotherapists' competency to detect Velcro crackles in patients with idiopathic pulmonary fibrosis. If you are willing to take part you will be asked to listen to 3 CDs of recorded lung sounds and answer three simple questions about each recording. You are also will be interviewed by the researcher during this study period. The enclosed Participant Information Sheet gives you more details about the study. The information obtained from this study will be used to develop and improve the training package of Velcro crackles, which will help health professionals to detect Velcro crackles in idiopathic pulmonary fibrosis patients earlier in their condition.

Included with this letter are the Participant Information Sheet and Reply Slip. If after reading this letter and the Participant Information Sheet, you would like to take part in this study, please complete and return the Reply Slip to me in the envelope provided within 4 weeks from the date you have received this letter. I shall then contact you via telephone or email to arrange a suitable time to meet with you to explain further.

Thank you very much for taking time to read this letter.

Yours sincerely,

Nor Azura Azmi,
PhD student,
Faculty of Health Sciences,
University of Southampton, Highfield, Southampton, SO17 1BJ.
Email: naa3g09@soton.ac.uk; Tel: Malaysia +60192512685; UK+44(0)7459397607

Appendix K: Participant information sheet (study two)

Participant Information Sheet

Study Title: The impact of training on Malaysian respiratory physiotherapists' competency to detect Velcro crackles in patients with idiopathic pulmonary fibrosis.

Name of investigator and institution: Nor Azura Azmi (Physiotherapy Department, Hospital Kuala Lumpur)

Name of sponsor: University of Southampton, United Kingdom

Introduction

You are invited to participate in a research study because you are respiratory physiotherapist who is currently working at the Kuala Lumpur General Hospital in Malaysia and you have a minimum of 2 years of clinical practice in respiratory physiotherapy. The details of the research are described in this document. It is important that you understand why the research is being done and what it will involve. Please take your time to read through and consider this information carefully before you decide if you are willing to participate. After you are properly satisfied that you understand this study, and that you wish to participate, you must sign this informed consent form.

Your participation in this study is voluntary. You do not have to be in this study if you do not want to. You may also refuse to answer any questions you do not want to answer. If you volunteer to be in this study, you may withdraw from it at any time. If you withdraw, any data collected from you up to your withdrawal will still be used for the study.

This study has been approved by the Medical Research and Ethics Committee, Ministry of Health Malaysia and Faculty Ethics Committee of University Southampton (Ethics number: 23380).

What is the research about?

Idiopathic pulmonary fibrosis (IPF) is a progressive lung disease with a poor prognosis. Clinicians have noted the presence of abnormal lung sounds in IPF and reported the presence of 'velcro-type' or fibrotic crackles as being characteristic of the disease. These sounds can be heard with a standard stethoscope, but recognition of Velcro crackles in IPF is controversial and quite challenging in clinical setting. Therefore, it is necessity that healthcare professionals could be taught and trained to detect the sound of these Velcro crackles during pulmonary auscultation as this might be a cost-effective way to diagnose IPF earlier, to help optimise therapy and improve prognosis. This proposed study is a mixed method research design, which would like to investigate the short-term and long-term (2 months) effect of training on the ability to detect Velcro crackles among respiratory physiotherapists and to gather their perceptions (via interview session) particularly about the usefulness of the training session for their clinical practice.

What will happen to me if I take part?

If you are happy to take part, there will be three sessions of assessment and three interview sessions in this study. During Assessment 1, you will be given a CD, CD1 consisting of 25 files of lung sound recordings to listen to using a laptop or desktop computer. You will be provided with a headphone to use while listening to the recorded lung sounds. You will be asked to listen to the files from the CD1 and record your findings using the assessment chart given. There are three questions to answer about each file. You can stop/start the CD as you wish. Then, the researcher will collect the assessment form once you have completed. After completing Assessment 1, the researcher will interview you face to face to explore your experience of Velcro crackle detection before the training session (Interview 1). Then, you will be given approximately 30 minutes of training regarding how to detect Velcro crackles. This training package will be presented via PowerPoint slides presentation, and you will be allowed to listen to seven files of recorded fibrotic crackles sounds repeatedly and compare to normal lung sounds using the standard over-ear headphones provided until you are confident to start the next Assessment 2.

Immediately after the training session, you will be asked to complete Assessment 2. The second CD2 consists of 25 lung sound files which will be given to you to listen to and complete the assessment form given once again using the same procedure as in Assessment 1. After that, you will be interviewed for the second time (Interview 2) by the researcher. A five minute break before the interview session will be given, to allow you to rest and prevent stress during the data collection. There will be a face to face, semi-structured interview in order to explore your experience of Velcro crackles detection and the training session. The interview session will be audio-recorded by the researcher. Data collection will be done at the out-patient clinics of Physiotherapy Units. Overall, the time required for completing Assessments 1, 2 and interview sessions will be approximately 90 minutes on the same day.

After the interview session, you will be given 'research diary' to record certain information including: 1) number of cases of IPF that you may detect Velcro crackle sounds; and 2) any leave (such as sick leave or annual leave) which you have taken during 2 months duration. Please keep this research diary until the next follow-up session at Assessment 3.

Prior to the 2 months follow-up session, the researcher will contact you by phone or email to set an appointment for Assessment 3. On the day of data collection, the researcher will collect the research diary. Then the third CD3 consists of 25 lung sounds recording files as before and will be given to you to listen to and record your findings using the same assessment form given as before. Again, the same procedure as in Assessment 1 and 2 will be repeated. Once you have completed Assessment 3, the researcher will collect the data form and headphone from you. After that, you will be interviewed by the researcher for the third time (Interview 3). This interview will explore whether there has been a transfer of this skill into clinical practice. Data collection will be done in the out-patient clinics of Physiotherapy Units. Overall, the time required for data collection of Assessment 3 and interview session 3 will be approximately 30 minutes.

Are there any benefits to taking part?

There are no direct benefits from you taking part in this study. However, the information obtain from this study may help to develop and improve the training package of Velcro crackle detection which will assist health professionals to detect Velcro crackles in idiopathic pulmonary fibrosis patients earlier in their condition.

Are there any risks involved?

This is a simple listening exercise with minimal risk for causing psychological and physical discomfort or distress. Potentially some participants may find using headphones uncomfortable which may cause physical distress during assessments of lung sounds, or they may find psychological distress when answering the questions during interview sessions. You will be given five minutes rest period within the assessments to alleviate physical distress due to using headphones. If you still feel distress during the assessments or interview you may stop at any time.

Will my participation be confidential?

All information which is collected about you during the course of the research will be kept strictly confidential according to the Data Protection Act/University policy, University of Southampton. Your anonymity will be preserved as you will be assigned an identity code which will be used throughout the study so that you will not be able to be identified. However, if you report any professionally negligent behaviour during interviews, the researcher is required to breach your confidentiality to ensure patient safety.

The information will be stored on a password protected personal computer and the hard copy data including copies of data CDs will be stored in a locked cupboard within the university. Data will be kept for 10 years in compliance with the data protection policy of the University of Southampton.

What happens if I change my mind?

You have the right to withdraw from this study at any time without your legal rights being affected.

Who is funding the research? This study is self-sponsored by the researcher.

What happens if something goes wrong?

In the unlikely event of anything going wrong or if have a complaint or concern, you can contact Research Governance Manager, Research Governance Office, Building 37, University of Southampton, Highfield, Southampton, SO17 1BJ (Tel: +44 (0)2380 595058; Email: rgoinfo@soton.ac.uk). The Research Governance Manager is completely independent of this study and will be happy to deal with any problems or concerns that may arise and can provide you with an official complaints form.

Where can I get more information?

If you would like further information, you can call or write to:

Nor Azura Azmi PhD student, Faculty of Health Sciences, University of Southampton, Highfield, Southampton, SO17 1BJ Telephone: Malaysia +60192512685; UK+44(0)7459397607; Email: naa3g09@soton.ac.uk

Associate Prof Dawn-Marie Walker (Research Supervisor) Faculty of Health Sciences, University of Southampton, Highfield, Southampton, SO17 1BJ Telephone: 023 8059 5289 Email: dawn-marie.walker@soton.ac.uk

Appendix L: Reply slip (study two)

Reply Slip

Study title: The impact of training on respiratory physiotherapists' competency to detect Velcro crackles in patients with idiopathic pulmonary fibrosis.

Researcher: Nor Azura Azmi

I (Print your name): ____ would like to

participate in this research.

Telephone : ______________________

Email : _______________________

Signature : _______________________

Date : ________________________

Please return this slip within 4 weeks from the date you have received it to:
Nor Azura Azmi, (PhD student, University of Southampton), Physiotherapy Programme, Faculty of Health Sciences, Universiti Kebangsaan Malaysia, Jalan Raja Muda Abdul Aziz, 50300 Kuala Lumpur, Malaysia.

Appendix M: Participant consent form (study two)

PARTICIPANT CONSENT FORM

Study title: The impact of training on Malaysian respiratory physiotherapists' competency to detect Velcro crackles in patients with idiopathic pulmonary fibrosis.

By signing below I confirm the following:

• I have been given oral and written participant information sheet for the above study and have read and understood the information given.

• I have had sufficient time to consider participation in the study and have had the opportunity to ask questions and all my questions have been answered satisfactorily.

• I understand that my participation is voluntary and I can at anytime free withdraw from the study without giving a reason and this will in no way affect my rights. I am not taking part in any other research study at this time. I understand the risks and benefits, and I freely give my informed consent to participate under the conditions stated. I understand that I must follow the study investigator's instructions related to my participation in the study.

• I understand that information collected about me during my participation in this study will be stored on a password protected computer and that this information will only be used for the purpose of this study. All files containing any personal data will be made anonymous and will be treated as STRICTLY CONFIDENTIAL.

• I will receive a copy of this subject information/informed consent form signed and dated to bring home.

Participant:

Signature: **I/C number:**

Name: **Date:**

Investigator conducting informed consent:

Signature: **I/C number:**

Name: **Date:**

Appendix N: Assessment form (study two)

Research title: The impact of training on Malaysian respiratory physiotherapists' competency to detect Velcro crackles in patients with idiopathic pulmonary fibrosis
Participant code: ______________

Assessment Form 1
CD 1: File 1-25

Please fill in (✓) the chart while you listening to the recording.

No.	Question		C1 F1	C1 F2	C1 F3	C1 F4	C1 F5	C1 F6	C1 F7	C1 F8	C1 F9	C1 F10	C1 F11	C1 F12	C1 F13	C1 F14	C1 F15	C1 F16	C1 F17	C1 F18	C1 F19	C1 F20	C1 F21	C1 F22	C1 F23	C1 F24	C1 F25
1.	Can you hear crackles in this recording?	Yes																									
		No																									

*Please proceed to the rest of the questions only if you heard some crackles somewhere in the recording (no. 2-3).

No.	Question		C1 F1	C1 F2	C1 F3	C1 F4	C1 F5	C1 F6	C1 F7	C1 F8	C1 F9	C1 F10	C1 F11	C1 F12	C1 F13	C1 F14	C1 F15	C1 F16	C1 F17	C1 F18	C1 F19	C1 F20	C1 F21	C1 F22	C1 F23	C1 F24	C1 F25
2.	If yes, which crackles could you hear? A- Coarse crackles B- Fine crackles C- Both *see definitions	A																									
		B																									
		C																									
3.	Do you think these crackles are Velcro in nature?	Yes																									
		No																									

Definitions: **Fine crackle**: nonmusical, short, explosive; heard on mid-to-late inspiration and occasionally on expiration; unaffected by cough, gravity-dependent, not transmitted to mouth.
Coarse crackle: nonmusical, short, explosive sounds; heard on early inspiration and throughout expiration; affected by cough; transmitted to mouth. (Bohadana et al. 2014)

Appendix O: Interview schedule for qualitative data collection (study two)

Interview 1: Questions for the interview regarding Velcro crackles detection before the training session.	
Question	**Prompt topics**
How were the crackle sounds in these recordings?	• How did you decide the sound is Velcro crackles? • How would you describe the Velcro crackles that you heard in the recording? • How did you decide the sound is not Velcro crackles?
What are the difficulties in detecting Velcro crackles in these recordings?	• What difficulties did you face in detecting the Velcro crackles in these recordings? • How easy was it to detect the Velcro crackles in the recording?
Interview 2: Questions for the interview regarding Velcro crackles detection after the training session and the training session itself.	
Question	**Prompt topics**
How were the crackle sounds in these recordings?	• How did you decide the sound is Velcro crackles? • How would you describe the Velcro crackles that you heard in the recording? • How did you decide the sound is not Velcro crackles?
What are the difficulties in detecting Velcro crackles in these recordings?	• What difficulties did you face in detecting the Velcro crackles in these recordings? • How easy was it to detect the Velcro

	crackles in the recording?
Question	**Prompt topics**
What do you think about this training?	• How useful was the training session to you? • When is the optimum time for this training to be delivered? What was the effect of training on your knowledge and skills in detecting Velcro crackles?
What do you think of your ability to detect Velcro crackles after the training session?	• How competent do you feel to recognise Velcro crackles after the training session? • What was the effect of training on the way you detect the crackles?
What do you think the best way to improve the training?	• What else should be included in this training package? • What do you think the best way to get access to this training is? • Why do you prefer this training package in that way? • What do you think if this training is available online? • How do you think the best way to promote or advertise this training to clinicians would be?
What are the positive aspects of this training session?	• Could you expand a little on this?
What are the negatives of the training session?	• Could you expand a little on this?
Who else do you think that could benefit from this training package of Velcro	• Why do you think so?

crackle detection?	
Is there anything else you would like to say that has not been covered in today's interview?	
Interview 3 (at 2 month follow-up): Questions for the interview regarding transfer of the skill into clinical practice	
Question	**Prompt topics**
How is your ability to detect Velcro crackles over the last two months?	• How was your ability to retain this skill over a long period? • How competent do you feel in detecting Velcro crackles since the training over 2 months ago?
How important is this skill for you as a respiratory physiotherapist?	• How important is this skill in your clinical practice? • How many referrals of IPF patients have you made to pulmonologists/respiratory consultants/tertiary centres since the training session? • How do you think your referral rate has changed following the training session? • How do you disseminate this skill to others?
What are the barriers to apply the skill of Velcro crackles detection in your clinical practice?	• What are the constraints to apply this skill in your clinical practice?
Is there anything else you would like to say that has not been covered in today's interview?	

Appendix P: Demographic form (study two)

DEMOGRAPHIC FORM

Study Title: The impact of training on Malaysian respiratory physiotherapists' competency to detect Velcro crackles in patients with idiopathic pulmonary fibrosis.

Researcher Name: Nor Azura Azmi

Participant Code: ………………………………

To be completed by the participant

Age: …………………………………………………

Gender: Male ☐

Female ☐

Year qualified as a physiotherapist: ………………………

Employer: ………………………………………

Number of years of experience in respiratory physiotherapy: ………………..

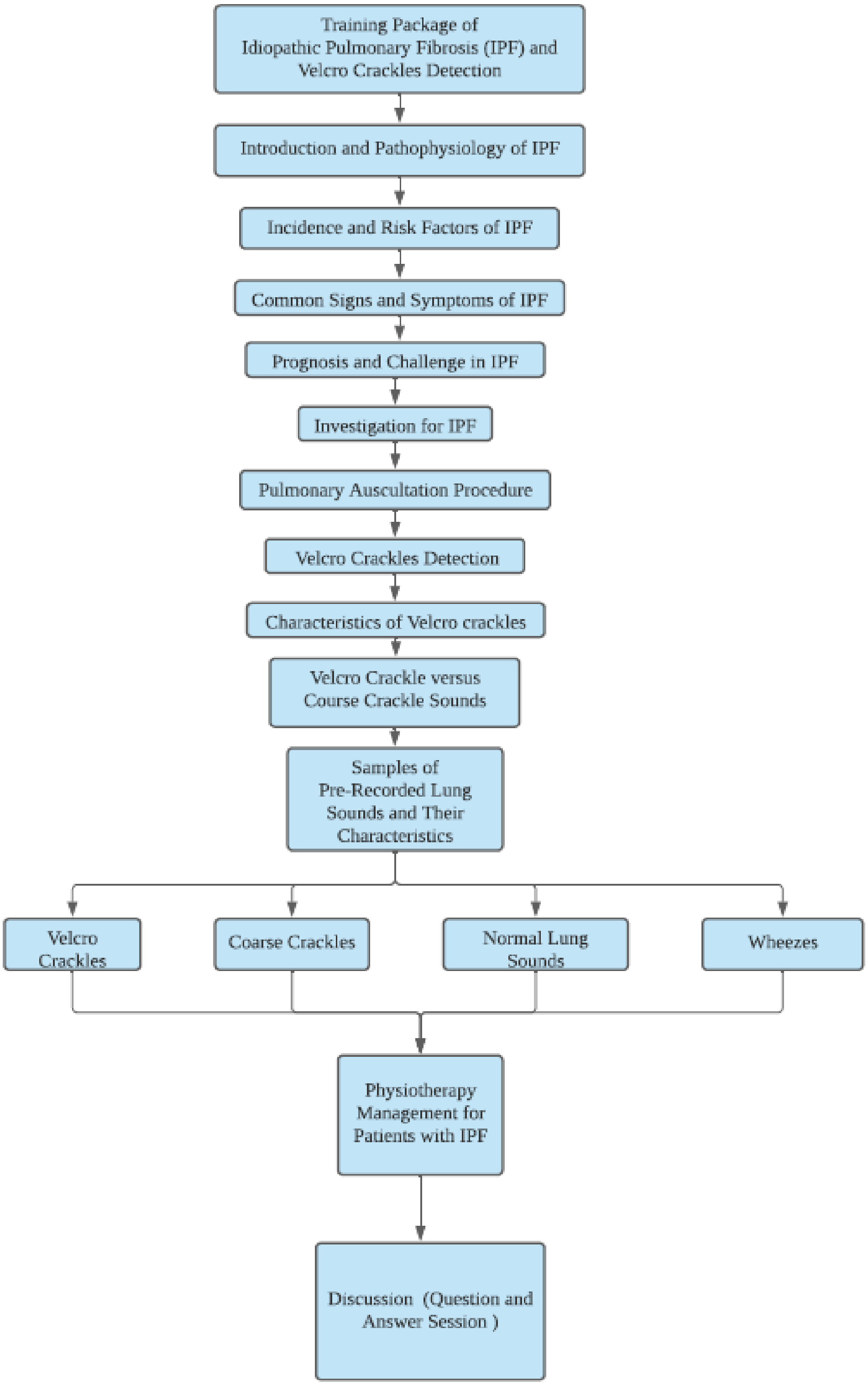
Number of cases of idiopathic pulmonary fibrosis that you treat per month: ……………………………….

Have you ever received a formal training of Velcro crackles detection? YES ☐ NO ☐

If YES, when was the training: …………………………………………………

and where was the training:……………………………………………………

Appendix Q: The content flow of the complex training package of IPF and Velcro crackles detection



Appendix R: Research diary (study two)

1. Please fill in number of cases IPF patient that you could detect Velcro crackles WITHIN 2 MONTHS AFTER ASSESSMENT 2
2. Please fill in any medical leave (ML) and annual leave (AL) that you have in the calendar WITHIN 2 MONTHS AFTER ASSESSMENT 2.

3. Participant code: ______________

FEBRUARY 2017

Mon	Tue	Wed	Thu	Fri	Sat	Sun
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28					

RESEARCH DIARY

1. Please fill in number of cases IPF patient that you could detect Velcro crackles WITHIN 2 MONTHS AFTER ASSESSMENT 2
2. Please fill in any medical leave (ML) and annual leave (AL) that you have in the calendar WITHIN 2 MONTHS AFTER ASSESSMENT 2.
3. Participant code: ______________

MARCH 2017

Mon	Tue	Wed	Thu	Fri	Sat	Sun
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

Appendix S: Ethical approval, University of Southampton Ethics Committee (study two)

Your Ethics Submission (Ethics ID:23380) has been reviewed and approved
ERGO [ergo@soton.ac.uk]
Sent:30 January 2017 11:43
To: Azmi N.A.

Submission Number: 23380
Submission Name: The impact of training session on Malaysian respiratory physiotherapists' competency to detect Velcro crackles in patients with idiopathic pulmonary fibrosis (IPF).
This is email is to let you know your submission was approved by the Ethics Committee.

You can begin your research unless you are still awaiting specific Health and Safety approval (e.g. for a Genetic or Biological Materials Risk Assessment)

Comments
1.Thank you for making the revisions to the application. Good luck with the study.

2.Well done with such a comprehensive adn thorough revision of your documentation. Good luck with the study

Click here to view your submission
Coordinator: Nor Azmi

ERGO : Ethics and Research Governance Online
http://www.ergo.soton.ac.uk

DO NOT REPLY TO THIS EMAIL

Appendix T: Ethical approval, Malaysia Medical Research & Ethics Committee (Study two)

JAWATANKUASA ETIKA & PENYELIDIKAN PERUBATAN
(*Medical Research & Ethics Committee*)
KEMENTERIAN KESIHATAN MALAYSIA
d/a Institut Pengurusan Kesihatan
Jalan Rumah Sakit, Bangsar
59000 Kuala Lumpur

Tel.: 03-2287 4032/2282 0491/2282 9085
03-2282 9082/2282 1402/2282 1449
Faks: 03-2282 0015

Ruj.Kami:(5)KKM/NIHSEC/ P17-531
Tarikh: 12-April-2017

NOR AZURA BINTI AZMI
UNIVERSITY OF SOUTHAMPTON

Dato'/ Tuan/ Puan,

SURAT KELULUSAN ETIKA:

NMRR-16-2545-33501 (IIR)
No Protokol : NA
The impact of training on Malaysian respiratory physiotherapists' competency to detect Velcro crackles in patients with idiopathic pulmonary fibrosis.

Lokasi Kajian:
HOSPITAL KUALA LUMPUR

Dengan hormatnya perkara di atas adalah dirujuk.

2. Jawatankuasa Etika & Penyelidikan Perubatan (JEPP), Kementerian Kesihatan Malaysia (KKM) tiada halangan, dari segi etika, ke atas pelaksanaan kajian tersebut. JEPP mengambil maklum bahawa kajian tersebut hanya melibatkan pengumpulan data melalui:

i. **Temuramah**

3. Segala rekod dan data subjek adalah **SULIT** dan hanya digunakan untuk tujuan kajian ini dan semua isu serta prosedur mengenai *data confidentiality* mesti dipatuhi.

4. Kebenaran daripada Pegawai Kesihatan Daerah / Pengarah Hospital dan Ketua-Ketua Jabatan atau pegawai yang bertanggungjawab disetiap lokasi kajian di mana kajian akan dijalankan mesti diperolehi sebelum kajian dijalankan. Dato'/ Dr / Tuan / Puan perlu akur dan mematuhi keputusan tersebut. Sila rujuk kepada garis panduan Institut Kesihatan Negara mengenai penyelidikan di Institusi dan fasiliti Kementerian Kesihatan Malaysia (Pindaan 01/2015) serta lampiran *Appendix 5* untuk templet surat memohon kebenaran tersebut.

5. Adalah dimaklumkan bahawa kelulusan ini adalah sah sehingga **11-April-2018.** Tuan / Puan perlu menghantar dokumen-dokumen seperti berikut selepas mendapat kelulusan etika. Borang-borang berkaitan boleh dimuat turun daripada laman web Jawatakuasa Etika & Penyelidikan Perubatan (JEPP) (http://www.nih.gov.my/mrec).

i. ***Continuing Review Form*** selewat-lewatnya dalam tempoh 1 bulan (30 hari) sebelum tamat tempoh kelulusan ini bagi memperbaharui kelulusan etika.

ii. *Study Final Report* pada penghujung kajian.
iii. Mendapat kelulusan etika sekiranya terdapat pindaan ke atas sebarang dokumen kajian/ lokasi kajian/ penyelidik.

6. Sila ambil maklum bahawa sebarang urusan surat-menyurat berkaitan dengan penyelidikan ini haruslah dinyatakan nombor rujukan surat ini untuk melicinkan urusan yang berkaitan.

Sekian terima kasih.

BERKHIDMAT UNTUK NEGARA

Saya yang menurut perintah.

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DATO' DR CHANG KIAN MENG
Pengerusi
Jawatankuasa Etika & Penyelidikan Perubatan
Kementerian Kesihatan Malaysia

s.k HRRC Hospital Rehabilitasi Cheras