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**Original Article**

**MOVEMENT RETRAINING PROGRAMME IN YOUNG FOOTBALL AND RUGBY FOOTBALL PLAYERS: A FEASIBILITY AND PROOF OF CONCEPT STUDY**

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**ABSTRACT**

**Introduction**: Movement screening to identify abnormal movement patterns can inform development of effective interventions. The primary objective of this study was to evaluate the feasibility of using a movement screening tool in combination with a tailored movement control retraining programme in young soccer and rugby football players. A secondary objective was to investigate changes in movement control patterns post-intervention, to provide proof of concept (PoC) for movement retraining.

**Methods**: 52 male amateur players, including 34 soccer players (mean age 15±2 years) and 18 rugby players (mean age 15±1 years) participated. They were screened for movement control ability using a shortened version of theHip and Lower Limb Movement Screening (Short-HLLMS) and completed an eight-week movement control retraining programme. Evaluation of feasibility included consent from players invited, adherence, attendance at the exercise sessions, drop-out and adverse events. Short-HLLMS total score and The Copenhagen Hip and Groin Outcome Score (HAGOS)were analysed to provide PoC for retraining movement control.

**Results**: feasibility outcomes were favourable. Significant statistical changes occurred post-intervention in the Short-HLLMS total score (paired-samples t-test) and in three HAGOS subscales (symptoms, physical function in daily living and in sport and recreation) (Wilcoxon-Signed Rank Test) in both groups.

**Conclusions**: Feasibility of using the Short-HLLMS in combination with a movement control retraining programme in soccer and rugby players was promising. The data provided PoC for the potential application of a shortened version of the HLLMS to evaluate changes in movement control and to inform targeted motor control programmes.

**Keywords:** Soccer, Rugby Football, Feasibility studies, Proof of Concept, Hip joint, Warm-Up Exercise

**INTRODUCTION**

Youth participation in sport is high, with consequent health benefits as well as increased injury risk accounting for more than 30% of injuries (Pickett et al 2005). Sports injuries can result in early abandonment of sport participation and lead to secondary degenerative diseases including post-traumatic osteoarthritis (OA) (Caine & Golightly 2011). Soccer and rugby football are among those team sports presenting high injury incidence in adolescents, with an overall incidence ranging from 2.0 injuries to 19.4 injuries per 1000 hours of exposure in soccer (Pfirrmann et al 2016) and accounting for 5.9 injuries/1000 player hours in rugby (Orr et al 2021). Hip and groin injuries are common in both rugby and soccer, with an estimated incidence of 21.3 (95% CI: 13.2-34.2) per 1000 match-hours in rugby (Moore et al 2015) and accounting for 4% to 19% of all seasonal injuries in soccer players (Waldén et al 2015). This high incidence in these populations is most likely due to the involvement of sport-specific movements, such as sharp changes in direction, pivoting, repetitive kicking and sprinting, which place high repetitive mechanical stress on the hip joint (Nepple et al 2015). The repetitive execution of such movements in combination with inadequate dynamic neuromuscular control (i.e., ability to functionally drive and control a movement, and a precondition for joint stability) is a cause of repeated stress to tissues, abnormal loading on joints and increased susceptibility to injury (Kiesel et al 2007). Consequently, those players showing poor neuromuscular control may be exposed to a greater risk of injury (Kolodziej et al 2021). Furthermore, repetitive stress at the hip joint secondary to participation in high impact sports during musculoskeletal development can increase the risk of acquiring abnormal hip morphology, such as femoroacetabular impingement (FAI) (Palmer et al 2018), a significant risk factor for OA development (Zhang et al 2015). As neuromuscular control is a modifiable factor (Hanlon et al 2020), appropriate movement screening tools can identify control deficits and inform interventions to address dysfunctional movement patterns (Mottram & Blandford 2020). However, research is needed to determine the role of exercise programmes to help reduce injuries and damage to joints, through the concept of improving movement control (Hanlon et al 2020, Mottram & Blandford 2020, Mottram et al 2019), which the present study addresses.

Movement impairments at the hip, pelvis and trunk may change tibiofemoral and patellofemoral kinematics, triggering injuries down the kinetic chain (Reiman et al 2009). Early evidence suggests that altered movement patterns in the hip and pelvis can be changed by neuromuscular retraining programmes, improving symptoms (Mottram et al 2019, Wilson et al 2018).

Changes in symptoms can be adequately measured using patient reported outcome questionnaires. The Copenhagen Hip and Groin Outcome Score (HAGOS) was specifically designed and validated to assess young, physically active individuals with hip and groin pain (Thorborg et al 2011). The HAGOS questionnaire has been used in studies of soccer players (Thorborg et al 2014) and rugby players (Farrell et al 2016).

Neuromuscular retraining programmes are based on exercises targeting sensorimotor deficiencies and functional instability by enhancing proprioception, neuromuscular and sensorimotor abilities (Ageberg & Roos 2015). Neuromuscular programmes involve strength, coordination, balance and proprioceptive exercises (resembling motion conditions of daily life or more demanding sport-specific movements) that stimulate low threshold motor control to improve muscle activation patterns and central sensorimotor mechanisms responsible for joint stabilization in static and dynamic situations (Ageberg & Roos 2015). The investigation of warm-up neuromuscular programmes to reduce sports-injuries is common in soccer players (Herman et al 2012, Thorborg et al 2017) while is somewhat scarce in rugby players. Only two randomised controlled trials (RCTs) investigated the efficacy of neuromuscular exercise programmes in reducing injuries in youth rugby players, providing encouraging evidence of their efficacy (Attwood et al 2018, Hislop et al 2017).

Poor movement control can be described as an inability to control motion at one joint, while concurrently producing an active movement at another joint (Mottram & Blandford 2020, Whittaker et al 2015). The efficiency of movement control can be assessed with movement control tests (CMCTs), using comparison against benchmark standards (Mottram & Blandford 2020). The Hip & Lower Limb Movement Screen (HLLMS) was developed to identify altered movement patterns of the hip, pelvis and lower limb (Booysen et al 2019). The HLLMS is intended to inform exercise programmes to reduce abnormal joint loading to prevent damage to joints (Booysen et al 2019). A PoC case study investigated the accuracy of the HLLMS using 3D motion analysis, indicating validity (accuracy and sensitivity) of the HLLMS to detect changes in movement patterns pre-to post-treatment (Wilson et al 2018). Reliability of the HLLMS was demonstrated in young male soccer players, showing excellent intra-rater reliability (percentage agreement [PA] 96%, first order coefficient [AC1] 0.93) with strong inter-rater reliability (PA 88%; AC1 0.82) (Booysen et al 2019). The aim of the present study was to assess the feasibility of using a shortened version of the HLLMS (Short-HLLMS) in combination with a movement control neuromuscular retraining programme in young amateur soccer and rugby football players. A secondary objective was to explore PoC of an eight-week exercise intervention programme for retraining movement control.

**METHODS**

**Participants and recruitment**

A total of 70 players were recruited for this study (Figure 1). Forty-eight male adolescent amateur soccer players (age 15±2 years) and 22 male amateur rugby players (age 15±1 years) were recruited from local soccer and rugby clubs that were contacted by phone by the first author (PD). Coaches and team managers were invited to an instruction course to introduce the study purpose and the intervention programme. At this point, they received a log-diary to record data on adherence, attendance and adverse events. All players were resident in Italy, studying at compulsory school or high school. Inclusion criteria were: 1) age between 13 and 19 years; 2) players had to train at least two times a week plus a weekly match; and 3) be able to perform the Short-HLLMS and the intervention programme. Players were excluded if diagnosed with: any neurological or systemic diseases; lumbar spine pathology; bone or joint pathology; being injured and unable to take part in training and games before the start of the study. Players who were injured during the study duration, unable to take part in further training or games, were excluded from the study at the point of injury.

Completed follow-up assessment (n=52)

Included in the analyses (n=52)

Did not complete follow-up assessment (n=18)

Reasons:

- left the club (n=9)

- school workload (n=7)

- injury (n=2)

Assessed for eligibility (n=70)

Enrolled (n=70)

Completed baseline assessment (n=70)

Enrolment

Baseline

Follow-up

Analyses

**Figure 1. Recruitment - Flow diagram**

**Setting and study design**

This was a feasibility and PoC study conducted at amateur soccer and rugby clubs in Turin (Italy) involving an eight-week movement retraining programme. Ethics approval was granted from the Ethics Committee of the University of Turin prior to data collection (Ethics no. 40221). To minimize bias in data collection, all the measurements were conducted by the same researcher, using the same equipment, procedures and protocols. All participants (ages 13-19 years) received oral and written explanation regarding the procedures and written informed consent was obtained from all the players aged 18 years or older. For the minors (ages below 18), informed consent to participate was signed by their parents or legal guardians.

**Sample size**

Due to the feasibility nature of the study, no formal power calculation was required. This study aimed to recruit a convenience sample of n  = ~ 50 participants. The estimated sample size was based on sample size recommendation for feasibility studies (Julious 2005). Results of this feasibility study will provide preliminary data for a formal power calculation for future research.

**Outcome Measures and Data Collection**

The participants underwent two data collection points: immediately pre- and immediately post- the eight-week intervention programme. Feasibility was assessed by consent from players invited, adherence to exercise programme, attendance at the exercise sessions, drop-out and high level of safety defined as the absence of adverse events. To provide PoC for retraining movement control, measures of movement quality, and symptoms and function were performed to explore possible significant changes of movement control patterns following the programme.

***Feasibility Primary Outcome Measures***

The primary outcomes (related to feasibility) included the following criteria (Hansen et al 2018): ≥ 80% consent from players invited; ≥ 80% adherence to exercise programme; ≥ 80% attendance at the exercise sessions; ≤ 20% drop-out; high level of safety, defined as the absence of adverse events. Adherence to the study protocol was defined as the commitment of the coaches, trainers and players to follow the intervention programme (Hawley-Hague et al 2014). The overall adherence was measured as the mean percentage of how many times the coaches, trainers and players dedicated part of the warm-up to the intervention programme as required (i.e. at least three times per week) during the study period. Attendance to the exercise session was defined as the count of the number of total exercise sessions attended by each player (Hawley-Hague et al 2014). The overall attendance was calculated as the mean percentage of the total number of sessions attended by the players divided by the possible total sessions (i.e. total number of exercises sessions executed). Measurements of adherence and attendance have been calculated for both soccer and rugby players.

Players were required to perform the exercise intervention programme at least three times per week, with a total of minimum 24 exercise sessions within the eight weeks. Adverse events, defined as possible pain, falls, injuries and discomforts, were recorded to assess the safety of the intervention.

***Secondary Outcome Measures***

Movement quality, symptoms and function were assessed to explore possible significant changes of movement control patterns following the eight-week intervention programme. These measures included:

***The Hip and Lower Limb Movement Screen (HLLMS)***

The HLLMS tool comprises five tests that can be performed in a clinic or field environment and do not require specific equipment (Booysen et al 2019). In case of time restrictions, the HLLMS can be applied in a shortened version (1-3 tests) (Booysen et al 2019). Considering this study was conducted in a field environment and that all screening procedures were carried out by one observer (PD), time restrictions were an important factor. Thus, the Short-HLLMS was used. The rationale for including two tests: small knee bend (SKB) test and SKB with trunk rotation (SKB Rot) test was based on the following reasons: 1) altered movement patterns (increased hip and trunk flexion) were identified in young soccer players with the SKB test (Botha et al 2014); 2) the SKB is widely used to assess movement control (Ressman et al 2019) and can detect weaker and slower muscle activation of the hip abductors, indicative of hip muscle dysfunction (Crossley et al 2011); 3) the SKB with trunk rotation is a test assessing relative stiffness (restrictions) of thoracolumbar rotation, while maintaining pelvic control (Comerford & Mottram 2012); 4) trunk rotation is an important movement component of sports that involve actions such as changes in direction, pivoting, repetitive kicking and sprinting. The Short-HLLMS data were collected by an experienced kinesiologist (7 years), trained by the developers of the HLLMS tool (Booysen et al 2019). A detailed description of the tests and the scoring criteria is reported elsewhere (Booysen et al 2019). Briefly: in both tests the aim was to evaluate the participant’s ability or inability to control movement cognitively at a specific joint, in a particular direction, while moving an adjacent joint to a benchmark standard (Mottram & Blandford 2020). Each benchmark criterion in the Short-HLLMS was rated in response to a question based on the speciﬁc movement quality of one or more joints on a dichotomous scale, rated as ‘yes’ (movement fault is present) or ‘no’ (movement fault is absent) (Booysen et al 2019). The investigator gave instructions to the participant on how to execute the test. Up to three practice trials were permitted. The participant received feedback to correct movement and posture as the tasks are designed to test ability to control movements and not assess natural performance. The rater observed the participant’s performance (three trials were rated) from the front or the side to evaluate movement control, rating optimum control (no fault) or no control (fault) against the benchmark criteria. The SKB and the SKB Rot tests include a total of 9 ‘yes’ or ‘no’ questions for each side. The scores of the single tests can be summed into a total score that can be used as an outcome measure as a surrogate, demonstrating changes in overall movement quality over time in response to targeted interventions (Booysen et al 2019). A reduction in total score indicates improvement in movement quality. In the present study, a total score of 18 points maximum was calculated by summing the SKB score of both right and left sides (maximum possible score: 10 points), and the SKB Rot score of both right and left sides (maximum possible score: 8 points).

***Copenhagen Hip and Groin Outcome Score (HAGOS) Questionnaire***

Hip and groin disability was assessed using the HAGOS (translated and validated in Italian) (Negrau et al 2020). The HAGOS is a valid, reliable and responsive self-report questionnaire to quantitatively measure hip and groin disability in young to middle-aged people with longstanding hip and/or groin pain (Thorborg et al 2011) covering six dimensions (pain, symptoms, physical function in daily living, physical function in sport and recreation, participation in physical activities, hip and/or groin-related quality of life (QoL)) (Thorborg et al 2011). Each question is answered on a five-item Likert scale and each subscale is transformed into a 0-100 scale, where 0 represents extreme hip and/or groin problems and 100 represents the absence of hip and/or groin problems (Thorborg et al 2011).

**Intervention**

The intervention consisted in a movement control retraining programme, based on neuromuscular principles (Ageberg & Roos 2015) and was devised to improve quality of movements addressing the movement faults recorded from the Short-HLLMS (Booysen et al, 2022a, in preparation). The exercises were devised based on the 11+ programme (formerly the FIFA 11+ programme), which was adapted to comprise exercises to address the movement characteristics observed in academy soccer players, which included altered hip flexion and medial rotation control (Botha et al 2014) (Booysen et al 2022b, in preparation). In the present study, the programme was implemented as part of the warm-up session during training and before games, and was required to be no longer than 15 minutes. The intervention programme had to be carried out at least three times a week, on non-consecutive days (48 hours rest) during eight consecutive weeks (Rey et al 2018). Coaches and trainers received a two-hour workshop to introduce how to lead and supervise the exercises. They received printed instructions and illustrations on the exercise programme and were invited to contact the first author (PD) to discuss any questions. Fidelity to the study was checked by the main investigator (PD) visiting each club weekly to ensure that the exercises were performed correctly and to ensure compliance with the programme. The programme was divided in two levels with increasing difficulty: level one for the first four weeks and level two for the last four weeks (see Supplement File 1, for the full exercise programme in detail).

**Statistical analysis**

Statistical analyses were performed using SPSS software Version 26 (IBM, USA). Demographic characteristics of participants were reported as mean and standard deviation.

***Feasibility data***

Consent from players invited, adherence to exercise programme, attendance at the exercise sessions, drop-out and adverse events were analysed to assess feasibility. For each outcome, the percentage of frequency counts was reported in both groups and compared against set criteria. The analyses on feasibility and safety objectives were run on all recruited participants as per pre-intervention assessment (soccer players n=48 and rugby players n=22).

***Movement control, hip and groin disability data***

Data distribution of pre-post scores of Short-HLLMS and HAGOS was assessed in both groups via the Shapiro-Wilk test and graphic visualization (QQ-plots and histograms). Pre- post-intervention change scores in Short-HLLMS and HAGOS within groups were analysed using a parametric statistical test (paired-samples t-test, supported by QQ-plots and Shapiro–Wilk statistics > 0.95) or non-parametric statistical test (Wilcoxon signed ranks test) according to data distribution. The significance level for all analysis was set at p<0.05 and all tests were two-tailed. Results were reported as mean and standard deviations. Comparison of means statistical tests were conducted on the ‘available case’ participants (no imputation for missing data) (Figure 1).

**RESULTS**

**Sample Characteristics**

Demographic characteristics of the players included in the analyses are shown in Table 1. Characteristics included age, weight, height and BMI.

**Table 1.** Demographics characteristics of the soccer (n=34) and rugby (n=18) players

|  |  |  |
| --- | --- | --- |
| Characteristic | Soccer players (n=34)  Mean ± SD | Rugby players (n=18)  Mean ± SD |
| Age (years) | 15 ± 2 | 15 ± 1 |
| Weight (kg) | 60 ± 11 | 74 ± 18 |
| Height (cm) | 172 ± 8 | 173 ± 8 |
| BMI (kg/m2) | 20 ± 3 | 25 ± 5 |
| Values are presented as mean ± standard deviation.  BMI, body mass index; cm, centimetres; kg, kilograms; m2, square metre; n, sample; SD, standard deviation | | |

**Feasibility and safety**

A total of 70 players (48 male amateur soccer players and 22 male amateur rugby players) were invited to participate in this study. All of the participants gave written informed consent to participate.Mean adherence to the exercise programme was excellent both in soccer and rugby players, respectively 90% and 100%. Soccer players completed the intervention with mean attendance of 75%, while mean attendance in rugby players was 92%. Results of safety and feasibility are summarised in Table 2.

**Table 2.** Feasibility and safety objectives for both the soccer (n=48) and rugby players (n=22) participants

|  |  |  |  |
| --- | --- | --- | --- |
| Feasibility outcome measures | Set Criteria | Soccer players (n=48)  Achieved (%) | Rugby players (n=22)  Achieved (%) |
| Consent from players invited | ≥ 80% | Yes (100%) | Yes (100%) |
| Adherence to the exercise programme | ≥ 80% | Yes (90%) | Yes (100%) |
| Attendance at the exercise session | ≥ 80% | No (75%) | Yes (92%) |
| Drop-out rate | ≤ 20% | No (29%) | Yes (18%) |
| A high level of safety was obtained |  | Yes | Yes |
| n, sample; %, percentage; ≥, greater than or equal; ≤, less than or equal | | | |

A total of 14 (29.2%) soccer players and four (18.2%) rugby players did not complete post intervention assessment (Table 3). Data on possible pain, falls, injuries and discomforts were recorded to assess the safety of the intervention. No adverse events were recorded during the exercise sessions. Injuries occurred during matches and not during the execution of the exercises.

**Table 3.** Reasons for drop-out in the two groups

|  |  |  |
| --- | --- | --- |
| Drop-out reason | Soccer players (n=48) n (%) | Rugby players (n=22) n (%) |
| School workload | 6 (12.5) | 1 (4.5) |
| Transfer to other clubs | 7 (14.6) | 2 (9.1) |
| Injury | 1 (2.1) | 1 (4.5) |
| Total | 14 (29.2) | 4 (18.2) |

n, sample; %, percentage

**Changes in movement control**

Significant changes were observed in movement control patterns in both soccer and rugby players. Comparison of means was run on both groups to determine whether there was a statistically significant mean difference between Short-HLLMS scores pre- compared to post-intervention. In soccer players, the Short-HLLMS total score significantly reduced (p<0.001) when comparing pre- (9.2 ± 3.1 points) to post-intervention (6.9 ± 3.8 points) scores. Similar results were observed in rugby players in which the Short-HLLMS total score significantly reduced when comparing pre- (11.3 ± 3.4 points) to post-intervention (7.5 ± 3.9 points) scores. Significant reduction in both the SKB and SKB Rot scores post-intervention were observed in both soccer and rugby players. Results are reported in details in Table 4.

**Table 4.** HLLMS mean total scores (out of a possible 18 points), SKB mean scores (out of a possible 10 points) and SKB Rot mean scores (out of a possible 8 points): Pre and Post-intervention comparison statistics of soccer (n=34) and rugby players (n=18)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Soccer players (n=34) | | | |  | Rugby players (n=18) | | | |
| HLLMS | Pre | Post |  |  |  | Pre | Post |  |  |
|  | Mean points ± SD  (range) | Mean points ± SD  (range) | t/z | p |  | Mean points ± SD  (range) | Mean points ± SD  (range) | t/z | p |
| HLLMS  total score | 9.2 ± 3.1 (4 – 16) | 6.9 ± 3.8 (1 – 15) | 4.4b | <0.001a |  | 11.3 ± 3.4 (4 – 17) | 7.5 ± 3.9 (2 – 16) | 6.0b | <0.001a |
| SKB | 5.2 ± 1.9 (2 – 9) | 4.0 ± 2.1 (0 – 8) | 4.3b | <0.001a |  | 6.6 ± 1.7 (3 – 9) | 4.4 ± 2.1 (2 – 9) | 5.8b | <0.001a |
| SKB Rot | 4.0 ± 1.4 (1 – 7) | 2.9 ± 2.0 (0 – 7) | -3.2c | .002a |  | 4.7 ± 1.9 (0 – 8) | 3.1 ± 1.9 (0 – 7) | -3.2c | .002a |

a) p<0.05

b) t values are from paired-samples t-test

c) z values are from Wilcoxon signed-rank test

ADL, Function in daily living; HLLMS, Hip and Lower Limb Movement Screen; n, sample; PPA, participation physical activities; QoL, Quality of life; SD, standard deviation; SKB, Small knee bend; SKB Rot, Small knee bend with trunk rotation; t, t-value; z, z-score; %, percentage.

A total of 56% (19 out of 34) of soccer players (Figure 2) and 94% (17 out of 18) of rugby players (Figure 3) reduced their Short-HLLMS total score.

**Figure 2. Column chart of HLLMS total score of both SKB and SKB Rot pre- post-intervention comparisons in soccer players (n=34).**

**Figure 3. Column chart of HLLMS total score of both SKB and SKB Rot pre- post-intervention comparisons in rugby players (n=18).**

When looking at individual criteria of the SKB in soccer players, all individual movements showed an improvement post-intervention (Figure 4). The most improvement was observed in pelvic control , with 22.1% of soccer players showing a better control of hip medial rotation to prevent pelvic drop (hitch) (Figure 4). In the SKB Rot test, the most improvement was registered in hip and pelvic control while rotating the trunk, 25.3% of the soccer players showed a better control of the hip medial rotation and lateral rotation independently of trunk rotation (Figure 5). No improvement was observed in the ability to reach at least 30° of thoracic rotation.

**Fig. 4. Small Knee Bend test cluster bar chart of the total percentage of soccer players (n=34) with the observed individual movement faults, comparing pre and post-intervention on both right and left side.**

**DV=Dynamic valgus; PD/H=Pelvic drop (hitch); BD=Benchmark distance knee less than 2cm past toe; TLF=Trunk lean forward; APT=Anterior pelvic tilt**

**Fig. 5. Small Knee Bend with trunk rotation test cluster bar chart of the total percentage of soccer players (n=34) with the observed individual movement faults, comparing pre and post-intervention on both right and left side.**

**HPFT=Hip and pelvis follow trunk, PD/H=Pelvic drop (hitch); BD=Benchmark distance knee less than 2cm past toe; TLF=Trunk lean forward**

In rugby players, all individual movements rated in the SKB and SKB Rot tests post intervention showed a significant improvement. The most improvement was observed in the control of trunk flexion. A total of 16.2% of the rugby players showed a better control of altered trunk flexion while performing the SKB test (Figure 6). Similarly to soccer players, 20.5% of the rugby players showed the most improvement in control of hip medial rotation and lateral rotation independently of trunk rotation, demonstrating better movement control post-intervention (Figure 7).

**Fig. 6. Small Knee Bend test cluster bar chart of the total percentage of rugby players (n=18) with the observed individual movement faults, comparing pre and post-intervention on both right and left side.**

**DV=Dynamic valgus; PD/H=Pelvic drop (hitch); BD=Benchmark distance knee less than 2cm past toe; TLF=Trunk lean forward; APT=Anterior pelvic tilt**

**Figure. 7. Small Knee Bend with trunk rotation test cluster bar chart of the total percentage of rugby players (n=18) with the observed individual movement faults, comparing pre and post-intervention on both right and left side.**

**HPFT=Hip and pelvis follow trunk, PD/H=Pelvic drop (hitch); BD=Benchmark distance knee less than 2cm past toe; TLF=Trunk lean forward**

**Changes in hip and groin symptoms and function**

Following the movement control intervention, the HAGOS sub-scales scores of symptoms and physical function in sport and recreation were significantly higher in both groups (p<0.05). Soccer players also showed improved physical function in activities of daily living sub-score (z=-2.3, p=0.023). The pain sub-scale mean percentage scores post-intervention were significantly higher in rugby players only (z=-2.4, p=0.015) while QoL sub-scale scores did not change significantly in either group (Table 5).

**Table 5.** HAGOS pre and post-intervention subscales scores of soccer (n=34) and rugby players (n=18)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Soccer players (n=34) | | | | Rugby players (n=18) | | | |
| **HAGOS**  **Domains** | Pre | Post |  |  | Pre | Post |  |  |
|  | Mean % ± SD (range) | Mean % ± SD (range) | z | p | Mean % ± SD (range) | Mean % ± SD (range) | z | p |
| **Pain** | 91.7 ± 7.7  (67.5 – 100) | 92.8 ±6.5  (77.5 – 100) | -1.1 | .253 | 88.6 ± 10.7  (52.5 – 100) | 91.1 ± 10.7  (55 – 100) | -2.4 | .015a |
| **Symptoms** | 89.2 ± 8.9  (57.1 – 100) | 91.3 ± 9.9  (53.6 – 100) | -2.3 | .022a | 84.3 ± 13.7  (46.4 – 100) | 88.3 ± 11.2  (57.1 – 100) | -3.0 | .003a |
| **ADL** | 95.3 ± 8.3  (70 – 100) | 97.4 ± 4.8  (80 – 100) | -2.3 | .023a | 94.2 ± 11.1  (55 – 100) | 95.3 ± 10.5  (60 – 100) | -1.3 | .206 |
| **Sport/Rec** | 90.3 ± 12.9  (37.5 – 100) | 93.8 ± 9.1  (65.6 – 100) | -2.7 | .007a | 84.4 ± 12.9  (50 – 100) | 88.7 ± 11.8  (53.1 – 100) | -3.0 | .003a |
| **PPA** | 85.7 ± 15.4  (25 – 100) | 85.7 ± 17.4  (25 – 100) | 0.0 | 1.0 | 88.9 ± 15.4  (50 – 100) | 94.4 ± 8.8  (75 – 100) | -2.1 | .039a |
| **QoL** | 94.1 ± 9.7  (65 – 100) | 95.7 ± 7.9  (65 – 100) | -2.5 | 0.13 | 92.8 ± 8.1  (75 – 100) | 93.9 ± 9.0  (75 – 100) | -1.3 | 0.206 |

p values for comparisons are from Wilcoxon signed-rank test

a) p<0.05;

ADL, Function in daily living; n, sample; PPA, participation physical activities; p, p-value; QoL, Quality of life; Sport/Rec, Sport and recreational; SD, standard deviation; %, percentage; z, z-score

**DISCUSSION**

This was the first feasibility study exploring the use of the Short-HLLMS in combination with a targeted intervention programme in both adolescent male soccer and rugby players. To provide further PoC of the practical potential of the Short-HLLMS in informing exercise intervention programmes to retrain movement control, post-intervention changes in movement control patterns were explored. The results of the present study suggest that the Short-HLLMS is a feasible versatile movement screening tool to assess movement control in adolescent soccer and rugby players when used in combination with a neuromuscular retraining programme. The Short-HLLMS may potentially detect alterations in movement control pre- and post-intervention in these cohorts. Furthermore, the neuromuscular retraining programme used in the present study appeared to improve movement control in the hip and pelvis, along with a reduction in hip and groin symptoms. Our results contribute to the evidence that the Short-HLLMS can be applied in different cohorts and settings.

Recruitment strategies were satisfactory and enabled us to reach a sufficient number of participants to demonstrate feasibility (Julious 2005). Overall, the study was accepted with great interest from the clubs and participants. Successful recruitment mainly appears to be due to the fact that all the activities involved in the study were carried out at the clubs. Furthermore, the versatility of the HLLMS, which can be performed in a shortened version, in combination with a brief intervention implemented within the warm-up routine, ensured good acceptance by coaches and players. Indeed, time required to complete an exercise programme is a common barrier for implementation and adoption (Dix et al 2021).

Adherence to the exercise intervention programme is a key factor that can influence the effects of interventions (Van Der Horst et al 2021). In the present study, we observed a high level of adherence (≥80%) in both groups, which is consistent with other studies investigating the effectiveness of intervention programmes to prevent injury in soccer players, respectively 91% (Petersen et al 2011) and 77% (Soligard et al 2008). Similar results were reported in rugby players showing 85% adherence to a movement control injury prevention programme (Attwood et al 2018). The high adherence observed in the present study was perhaps facilitated by ensuring correct delivery of the intervention programme through a dedicated practical workshop for coaches and trainers and providing delivery illustrative materials. These aspects have been shown to affect adherence (Steffen et al 2013).

A higher drop-out rate was reported in soccer (29%) compared to rugby players (18%). The main reasons for drop-out were lack of time due to school workload and transfers of players to other clubs at the end of the season. Thus, it is reasonable to believe that the higher drop-out rate and the lower mean attendance observed in soccer players was due to unfavourable period of the year in which the study took place. Steffen et al (2008) reported similar barriers investigating the effect of the 11+ on injury risk in female youth soccer players (Steffen et al 2008). These findings should be taken into account in view of future similar studies in order to minimize the drop-out rate. Possible adverse events were recorded in this study as suggested in a review of Herman and colleagues (Herman et al 2012). Only two players experienced injuries during the study period and these occurred during matches and not during the execution of the exercises. Thus, the execution of the exercises could be considered safe in terms of absence of adverse events. However, we did not record the appropriate data to conclude that the reported injuries were not in any way related to the exercise intervention. The present study found changes in movement control patterns in both groups after the eight-week movement control retraining programme. Fifty six percent of soccer players and 94% of rugby players showed a significant reduction in the Short-HLLMS total score post-intervention, suggesting that movement patterns in the hip and pelvis may be altered using neuromuscular retraining programmes. These changes were observed in conjunction with a reduction in hip and groin symptoms in both groups. This confirms previous reports (Mottram et al 2019, Wilson et al 2018) that improvement in movement control may be associated with improved symptoms when present, although relative cause and effect are not understood.

The minimal important change (MIC) values reported for the HAGOS subscales (Thorborg et al 2018) were not achieved in the present study. However, the statistically significant changes in the HAGOS scores post-intervention were within the 95% references intervals for injury-free soccer players (Thorborg et al 2014). This lack of clinically relevant change in HAGOS scores was probably due to the fact that this study did not include individuals diagnosed with hip or groin conditions. Indeed, the MIC of the HAGOS reported by Thorborg et al. (2018) was determined based on data collected from individuals who underwent first-time hip arthroscopy for FAI and/or labral injury (Thorborg et al 2018). Interestingly, the rugby players also showed a significant improvement in the pain subscale of the HAGOS that improved from 88.6 to 91.1. This may be a consequence of the higher adherence to the exercise programme and attendance at the exercise session observed in this group, but further research is needed to confirm this.

The present study did not investigate the impact of the exercise intervention programme on injury risk and it will be interesting to investigate possible effects of the neuromuscular exercise intervention on performance and physical adaptation. Recent evidence showed that the 11+ exercises improved power, agility and short-distance sprinting in adolescent soccer players (Zarei et al 2018).

Soccer and rugby are activities involving sport-specific movements, such as kicking, sprinting or cutting and pivoting, that place high demand on the hip joint. Unlike other screening tools, such as the functional movement screen (FMS) (Kiesel et al 2007), soccer injury movement screen (SIMS) (Mccunn et al 2017), the foundation matrix (Mischiati et al 2015) and the landing error scoring system (LESS) (Padua et al 2015), which were devised to predict injury, the Short-HLLMS focuses specifically on movement control of the hip and pelvic region. In the present study, we observed improvements in movement control in both groups. Twenty one percent of soccer players showed an improvement in hip medial rotation control while performing the SKB test and 16.2% of rugby players demonstrated a better control of excessive trunk flexion. Furthermore, 25.3% of soccer and 20.5% of rugby players showed improvements in control of medial rotation and lateral rotation of the hip independently of trunk rotation while performing the SKB with trunk rotation test. Uncontrolled hip medial rotation and knee valgus while performing a single-leg squat can be due to weaker hip abductors (Wilczyński et al 2020). In fact, hip muscle weakness may influence trunk, pelvic and hip kinematics (Smith et al 2014). Our intervention aimed to improve hip and pelvic control by targeting the gluteal muscles (Reiman et al 2012). The post-intervention changes in individual movement patterns observed in both groups suggest that the targeted movement control retraining programme used in the present study may improve movement control for identified hip and pelvic movement faults. Results from the Short-HLLMS may be used to inform neuromuscular retraining programmes to enhance biomechanical and neuromuscular changes, reducing abnormal loading on joints and, consequently, potentially prevent injury and joint overuse. Whether the neuromuscular exercises reduce abnormal loading on joints and, consequently, preventing injuries and joint overuse has yet to be investigated.

There were limitations to this study that should be acknowledged. The sample size was small and there was no control group. Thus, robust conclusions about the efficacy of the intervention should be avoided. The HAGOS questionnaire is validated to assess physically active individuals from 18 to 63 years (Thorborg et al 2011), while the present sample also included minors. However, there is one study showing that the HAGOS questionnaire is a reliable and responsive instrument for people aged 15 and above (Thomeé et al 2014). Moreover, data on adherence, attendance, drop-out and adverse events were based on self-reports from coaches but validity and reliability of these reports were not verified. The lack of blinding of the participants to the purpose of the study may be considered another limit because this might affect their behavior and responses to subjective outcome measures (Karanicolas et al 2010). Furthermore, we did not collect data on demographic characteristics of the coaches while there is evidence suggesting that overweight or less physically fit coaches tend to alter exercise delivery (Berthelot et al 2011). Finally, the lack of specific injuries monitored over time limits our ability to conclusively answer questions about the efficacy of the neuromuscular training programme on reducing injury risk in young soccer and rugby players.

Despite the limitations, this study has succeeded in providing evidence of the feasibility of the Short-HLLMS in young male amateur football and rugby players. Furthermore, we provided PoC for retraining movement control following an eight-week intervention programme informed from the results of the Short-HLLMS. Coaches and trainers of activities involving high repetitive mechanical stress on the hip joint (e.g. sharp changes in direction, pivoting, repetitive kicking and sprinting) are encouraged to adopt the Short-HLLMS to inform neuromuscular training programmes that they can implement as part of warm-up routines. The versatility of the Short-HLLMS and the short-duration of the exercise intervention appear to ensure good acceptance by coaches and players, thereby obviating one of the most common barriers for implementation and adoption of exercise intervention programmes (Dix et al 2021). Future studies with an appropriate powered sample size, with randomization and a matched cohort are warranted for a more robust analysis of the possible applications of the Short-HLLMS in combination with targeted interventions. Such comprehensive studies would enable the inter-relationships to be examined between movement quality, functional performance and injury risk in response to the neuromuscular exercise intervention, in different cohorts and settings.

**CONCLUSIONS**

The Short-HLLMS and the neuromuscular retraining programme were shown to be feasible in young soccer and rugby players. Improvements in movement control and symptoms demonstrated proof of concept of the neuromuscular exercise intervention. The Short-HLLMS is a versatile screening tool that can be used to identify abnormal hip and pelvic movement control pre- and post-intervention.

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**Declaration of interest**

We have no conflicts of interest to disclose.

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**CLINICAL RELEVANCE**

* The Hip and Lower Limb Movement Screen (HLLMS) is a novel movement screening tool which can inform neuromuscular retraining programmes to improve movement control.
* Results from the Short-HLLMS may be used to inform neuromuscular retraining programmes to enhance biomechanical and neuromuscular changes.
* Trainers of activities involving high repetitive mechanical stress on the hip (e.g. sharp changes in direction, pivoting, repetitive kicking and sprinting) are encouraged to adopt the Short-HLLMS to inform neuromuscular retraining programmes that they can implement as part of warm-up routines.

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**SUPPLEMENT FILE**

**Supplemental Content - Exercise Intervention Programme**

**Motor control training, strenght, balance**

|  |  |  |
| --- | --- | --- |
| **Level 1 (week 1-4)** | **Exercise** | **Movement faults addressing** |
|  | The bench static (11+) (Soligard et al 2008)  3 sets 20 sec hold | Trunk flexion  Hip flexion |
|  | Sideways bench static knees flexed  3 sets (20 sec each side) | Trunk side flexion  Medial rotation hip  Hip hitching  Axial rotation hip |
|  | Hamstrings Beginner (11+)  (Soligard et al 2008)  1 set (3-5 reps) | Trunk flexion  Hip flexion  Hamstring strenght |
|  | Single leg stance hold ball (11+) (Soligard et al 2008)  2 sets (30 sec on each leg) | Proprioceptive  Medial rotation hip  Trunk side flexion  Hip flexion |
|  | Squats with side step  (Selkowitz et al 2013)  2 sets (30 sec each side) | Medial rotation hip  Hip flexion  Trunk side flexion  Trunk forward flexion |
|  | Clam exercise  (Selkowitz et al 2013)  1 set lift hold 2 sec and lower (60 sec each side) | Medial rotation hip  Pelvic hitching  Pelvic rotation |
|  | Side leg bridge  (Selkowitz et al 2013)  3 sets hold 20 sec each side | Hip flexion  Trunk flexion |
| Dynamic stretches |  |  |
|  | Walking lunges  30 steps each side |  |
|  | Hip rotation dynamis stretch  30 steps each side |  |

|  |  |  |
| --- | --- | --- |
| **Level 2 (week 5-8)** | **Exercise** | **Movement faults addressing** |
|  | The bench alternate legs (11+) (Soligard et al 2008)  Lift leg with 2 sec holds (40-60 sec each side) | Trunk flexion  Hip flexion |
|  | Sideways bench rise and lower (11+) (Soligard et al 2008)  3 sets hold 20 sec and lower hip (each side) | Trunk side flexion  Medial rotation hip  Hip hitching  Axial rotation hip |
|  | Hamstrings Beginner (11+)  (Soligard et al 2008)  1 set (7-10 reps) | Trunk flexion  Hip flexion  Hamstring strenght |
|  | Single leg stance throw ball (11+) (Soligard et al 2008)  2 sets throw ball while hold balance (30 sec each leg) | Proprioceptive  Medial rotation hip  Trunk side flexion  Hip flexion |
|  | Squats lunge hold with heel rise  2 sets (10 rises each leg) | Medial rotation hip  Hip flexion  Trunk side flexion  Trunk forward flexion |
|  | Clam exercise  (Selkowitz et al 2013)  3 sets hold 20 sec each side | Medial rotation hip  Pelvic hitching  Pelvic rotation |
|  | Hip extension knee bend  (Selkowitz et al 2013)  3 sets hold 20 sec each side | Hip flexion  Trunk flexion |
| Dynamic stretches |  |  |
|  | Walking lunges  30 steps each side |  |
|  | Hip rotation dynamis stretch  30 steps each side |  |

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