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Accuracy of movement quality screening to document effects of neuromuscular control retraining exercises in a young ex-footballer with hip and groin symptoms: a proof of concept case study

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ABSTRACT

Hip and groin pain is common in footballers and altering movement patterns can reduce symptoms. Observational tests of movement control are thought to identify abnormal movement patterns, but their accuracy needs yet to be confirmed by comparison with an objective measure. To assess the accuracy, using 3D motion analysis, of observational movement control tests and their ability to detect changes, and document changes in symptoms following a neuromuscular control exercise programme in an ex-footballer with hip and groin pain. A 25-year-old male with chronic bilateral hip and groin pain had their movement control ability rated and kinematic data collected using 3D motion analysis while performing Small Knee Bend (SKB) and SKB with Rotation (SKB Rot) tests pre-and post-neuromuscular control exercise training. Movement control was rated as at fault if they were unable to control specific trunk and pelvic movements during the tests. The Copenhagen Hip and Groin Outcome Score (HAGOS) was used to assess symptoms. Following the intervention, observational rating during the SKB test improved from fault to no fault for anterior pelvic tilt, which decreased by 17° and 16° during right and left leg SKB tests respectively. The HAGOS symptoms subsection improved from 36% to 61%. Observational movement screening ratings were supported by 3-D motion analysis. These findings indicate that the screening tool was accurate for detecting improvements in trunk and pelvic movement control following an exercise programme in an ex-footballer who had presented with hip and groin pain.

INTRODUCTION

Hip and groin injuries are common in football [1]. One possible diagnosis for hip and groin pain is femoroacetabular impingement (FAI), which involves limited joint clearance between the femoral neck junction and the acetabular rim [2,3]. High levels of cam impingement, a type of FAI, were reported in elite soccer players, with 68% demonstrating radiographic evidence [4]. However, high levels of FAI may not correlate with symptoms as Kapron et al. [5] reported 95% of collegiate American Footballers had one or more radiographic signs of FAI but were largely asymptomatic.

While FAI is thought to be a structural problem, Austin et al. [6] proposed that symptoms may be caused by an interaction of bony morphology with certain movement patterns. Therefore, changing movement patterns could reduce symptoms. Changing pelvis and trunk movement patterns through the use of exercises has been shown to reduce hip and groin symptoms in a case series [7]. However, the changes in trunk or pelvis movement were not reported [7]. Additionally, FAI symptoms were reduced during a step down activity by changing movement patterns in a case study, but there was no follow up [6]. There is a lack of evidence that neuromuscular exercise programmes can change movement patterns and symptoms in the hip but some evidence supports such a link for the shoulder joint [8].

To identify abnormal movement patterns that could lead to symptoms such as hip and groin pain, movement control (“movement screening”) is being used increasingly used [9,10]. For example, increased hip and trunk flexion during the small knee bend (SKB) test which assesses hip movement control were observed in male academy footballers with

MRI confirmed morphological changes associated with FAI [11]. The SKB test is commonly used in the literature [12-15], and participants with poor SKB test scores exhibited weaker and slower muscle activation of the hip abductors, indicative of hip muscle dysfunction [16]. Trunk rotation is required in sports that involve actions such as kicking, sprinting and changes of direction, which are common in football. Holding the SKB and then rotating the trunk in the SKB rotation test assesses relative stiffness (restrictions) of thoracolumbar rotation, while maintaining pelvic control [17]. However, to increase our understanding of the link between movement and symptoms, accurate measurement of movement is required. Using specific observational movement tests to assess movement patterns needs to be compared to an objective measurement, such as 3D motion analysis [18,19].

Relevant patient reported outcome measures are important to accurately measure changes in symptoms. The Copenhagen Hip and Groin Outcome Score (HAGOS) was developed for use with hip and or groin pain [20]. One of the six subscales of the HAGOS is the symptoms scale, in which symptoms are rated from 0 (representing extreme problems) and 100 (no hip and/or groin problems). Several authors have used the HAGOS with FAI [21,22] and recommend its use [23].

The aim of the present single case report was to document observational ratings of hip and pelvic movement control during small knee bend (SKB) and SKB rotation (SKB Rot) tests and examine whether the ratings were confirmed by kinematic changes using 3D motion analysis both before and after an exercise programme in an ex-footballer with hip and groin pain. Changes in symptoms were also examined using the HAGOS.

MATERIALS AND METHODS

Ethics approval was granted from the University of Southampton, Faculty of Health Sciences Ethics Committee prior to data collection (Ethics no. 12680). The participant, a 25-year-old male (body mass 74.3kg, height 182cm, body mass index 22.3) had a nine-year history of bilateral hip and groin pain. He played football from the ages of 6-19 and was at the highest level of non-professional football in Italy before he had stop due to symptoms. Based on a diagnosis of FAI the participant underwent arthroscopic surgery on the left hip in July 2013 and had a labral repair and acetabular trimming. No physiotherapy or any other treatment was carried out prior to surgery. Following surgery, the participant had 22 sessions of physiotherapy rehabilitation that included stretches and strengthening around the hip joint but was unable to return to football.

Motion Analysis

A Vicon Motion Capture System with 12 cameras (6 x T40 and 6 x T160) recording at 100Hz was used to capture 48 retroreflective marker locations (Figure 1). Markers were attached to the incisura jugularis (IJ), processus xiphpodeus (PX), C7 and T8 vertebra and bilaterally to the anterior superior iliac spine (ASIS), posterior superior iliac spine (PSIS) and iliac crests. Markers were placed on the anterior, lateral and posterior of the thigh and shank, lateral and femoral condyles and lateral and medial malleoli of the tibia. Markers were also placed on the heel (posterior calcaneus), dorsal aspect of 5th metatarsal head and the dorsal aspect of 1st metatarsal head to define the foot. The participant performed a star movement to functionally determine hip joint centres, and knee flexion/extension to functionally determine knee axis [24,25].

Figure 1: Anterior view of reflective marker placement for motion capture and EMG placement.

For both the SKB and SKB Rot tests the aim was to perform prescribed movements, with the ability to do so graded against benchmark criteria. The tests were designed to assess control of body segments while other segments moved based on the principle of movement control.

During the tests the aim was to keep the non-weight bearing thigh vertical and the knee flexed to 90°. To standardise the depth of the squat the weight bearing knee was flexed to move approximately 2cm past the toes (corresponding to approximately 50° of knee flexion) [26]. Depth of squat was chosen to try and challenge the participant's movement control and similar to the methodology used in a previous studies [15,27-38]. The participant was given instructions on how to perform the test (Table 1). Up to four practice trials were permitted. Feedback was given to try and correct movement as the tasks are designed to test ability to control movements and not assess natural performance. The rater (NB) stood in front or to the side of the participant to rate the test manoeuvre as either demonstrating sufficient control (no fault) or no control (fault) against the benchmark criteria (Table 1). Three trials were rated, and movements recorded using 3D motion analysis which was set up and recorded by DW.

Table 1: Small Knee Bend (SKB) test instructions and scoring from Botha [39], with permission

Verbal Instruction	Outcome		
• Stand on one leg with your foot pointing forward. • Place the unsupported foot behind you by bending your knee 90°. • While keeping your body upright, keeping your pelvis and heel in position, bend your knee so that your knee is in line with your 2nd toe and moves past it until you can no longer see the tape line. • Do you understand the instructions?		Right	Left
	Does the trunk lean forwards (flex)?	Y=1; N=0	Y=1; N=0
	Does the pelvis tilt forwards (anterior)?	Y=1; N=0	Y=1; N=0
	Total Score		

The SKB Rot test was performed in a similar manner compared to the SKB with the addition of rotating the trunk around the longitudinal axis by approximately 30° whilst keeping the pelvis facing forwards. The participant rotated towards the side of the weight bearing leg initially and then to the opposite side and scored against benchmark criteria (Table 2).

Table 2: Small Knee Bend with Rotation (SKB Rot) test instructions and scoring, from [39], with permission

Verbal Instruction	Outcome	Right	Left
• Stand on one leg with your foot pointing forward. • Place the unsupported foot behind you by bending your knee 90°.	Does the hip and pelvis follow the trunk?	Y=1; N=0	Y=1; N=0
• While keeping your body upright, keeping your pelvis and heel in position, bend your knee so that your knee aligns along your 2nd toe.	Does the trunk lean forwards (flex)?	Y=1; N=0	Y=1; N=0
• While holding this position turn your upper body to the left and right looking over your shoulder 30° • Do you understand the instructions?	**Total Score**		

The faults identified from the movement tests were used to design a personalised exercise programme, which the participant was taught how to move correctly. The participant was asked to carry out their exercises at home twice a day, similar to the methodology used in a motor control retraining study [8] and complete a diary to record adherence.

The participant visited the laboratory every two weeks and was observed performing their exercises to assess progress and alter the programme as applicable. Based on the poor movement control of the hips, pelvis and trunk identified from the movement test the intervention included exercises such as the lunge, clam, bridge, squat, hip extension and abduction. Correct technique was emphasised, such as during the clam, the participant was instructed to keep the trunk and pelvis still and in neutral alignment, while moving the upper leg. Difficulty of the intervention was progressed as judged to be clinically appropriate (by NB).

Data management – pre-processing

Motion analysis data were post-processed via Vicon Nexus software (Version 2.3) and exported to Matlab (The Math-Works, Natick, USA) for kinematic analysis using custom Matlab code. A rigid body approach was adopted to define the trunk, pelvis, femur, tibia and foot segments. The Optimal Common Shape Technique (OCST) was used to reduce the effect of soft tissue artefact using a local optimisation method during the star movement [40]. A functional joint centre for the hip was determined using the Symmetrical Centre of Rotation Estimation (SCoRE) technique [41], and a functional knee flexion axis was determined from non-weight bearing knee flexion cycles from 0-90 ° using the Symmetrical Axis of Rotation (SARA) technique [42]. Local coordinate systems were used to define the 3D location and orientation of each segment where the positive X-axis was pointing to the right, the positive Y-axis forward and the positive Z-axis up (Table 3).

Table 3: Definitions of local coordinate orientation for thorax, pelvis, femur and tibia segments.

Segment	X	Y	Z
Thorax	Perpendicular to Z and Y axes pointing to the right	Line between C7 and IJ that is perpendicular to the Z axis pointing forwards	Line between midpoint of IJ and C7 and midpoint of PX to T8 pointing upwards
Pelvis	Line through right to left ASIS markers and perpendicular the Y axis pointing right	Line from midpoint between left and right ASIS and midpoint between left and right PSIS markers pointing forwards	Perpendicular to X and Y axes pointing upwards
Femur	Line between medial and lateral femoral condyle markers projected on functional knee axis and perpendicular to the Z axis pointing to the right	Perpendicular to Z and X axes pointing forwards	Line between hip joint centre and knee joint centre (midpoint of line between medial and lateral femoral condyles projected onto functional knee axis in the femur frame).
Tibia	Line between medial and lateral femoral condyle markers and perpendicular to the Z axis pointing to the right	Perpendicular to Z and X axes pointing forwards	Line between knee joint centre (midpoint of line between medial and lateral femoral condyles projected onto functional knee axis in the tibia frame).and ankle joint centre (midpoint of line between medial and lateral malleoli)

Euler angle decomposition was then performed to obtain joint kinematics in an X (flexion/extension), Y (abduction/adduction) and Z (internal/external rotation) order between proximal to distal segments, pelvis to femur, femur to tibia in local coordinate system. Thorax and pelvis kinematics were relative to global coordinate system.

An automated method was developed to identify the start and end of movement for the tests. Start of the movement was defined as when the angular velocity of the weight bearing knee flexion exceeded 10% of maximum angular velocity and non-weight bearing knee flexion >60 °. The end of the movement was defined as when angular velocity of weight bearing knee flexion < 10% of minimum knee angular velocity during the knee extension phase. The automated identification of start and end points was visually checked to ensure the true start and end points were identified and adjusted, if required. Kinematic data were normalised with respect to time through interpolation of the data to 1001 points from the start to end of the movement.

Outcome parameters were derived from the kinematics and consisted of peak excursion of trunk flexion and pelvic anterior tilt from the start of knee flexion (Table 4). The outcome parameter for the ‘does the pelvis follow the trunk?’ criterion/question of the SKB Rot test was the coupling angle derived from an angle-angle plot between the axial rotation of the trunk and pelvis (Seay et al. [43]). Four unique coordination patterns were identified from this coupling angle: in-phase coordination between pelvis and trunk (both segments moving simultaneously in the same direction); antiphase coordination between pelvis and trunk (both segments moving simultaneously in opposite direction); trunk-only motion; and pelvis-only motion.

Table 4: Details of how kinematic values were calculated for the movement faults from the SKB and SKB Rot tests

Test	Fault	Outcome parameter
SKB	Does the trunk lean forwards (flex)?	Peak trunk flexion excursion from the start of knee flexion
	Does the pelvis tilt forwards (anterior)?	Peak pelvis anterior tilt excursion from the start of knee flexion
SKB Rot	Does the hip and pelvis follow the trunk?	Percentage of time pelvis and trunk segment's axial rotation were in-phase from the start to end of trunk rotation
	Does the trunk lean forwards (flex)?	Peak trunk flexion excursion from start of knee flexion

The mean and standard deviation of the outcome parameters were calculated over three trials. Observational rating data were recorded onto a Microsoft Excel spreadsheet to compare pre- and post-intervention.

The participant completed the symptom section of the HAGOS pre- and post-intervention and a Microsoft Excel spreadsheet was used to calculate the percentage score [20].

RESULTS

Following a seven-week exercise intervention, comprising 22 sessions, HAGOS symptoms subsection scores improved from 36% to 61%. The participant reported that reduced hip and groin symptoms had led to increased physical activity, including restarting indoor football and climbing. Also, they were cycling more due to less pain when abducting their hip to get on and off their bicycle.

On observational movement quality assessment, the participant exhibited faults of both ‘anterior pelvic tilt’ and ‘trunk flexion’ pre-intervention, but no fault post-intervention during the SKB test. Kinematic data supported the improvement with substantial decrease in trunk flexion (Table 3); 12° on the right and 10° on the left (Table 3). Anterior pelvic tilt decreased by 17° on the right and 16° on the left (Table 5).

Table 5: Mean peak excursion kinematics related to movement faults for the SKB task, pre and post intervention

	Pre intervention			**Post intervention**	
Movement Faults	**Side**	**Fault present**	**Mean (SD)**	**Fault present**	**Mean (SD)**
Trunk flexion (°)	Right	yes	13.3 (1.3)	no	1.5 (1.9)
	Left	yes	10.9 (5.2)	no	0.8 (0.0)
Anterior pelvic tilt (°)	Right	yes	21.6 (2.2)	no	4.4 (0.5)
	Left	yes	20.4 (3.5)	no	4.8 (0.1)

The participant lost balance on trial 1 of pre-intervention on the left side and trial 3 post intervention on the right side during the SKB Rot test, therefore these trials were removed from analysis. The participant was observed to have ‘pelvis follow trunk’ and ‘trunk flexion’ faults pre-intervention, which were not present post-intervention. Analysis of trunk flexion kinematics revealed reductions of 6° on the right and 11° on the left (Table 4). The percentage when the trunk and pelvis were in phase decreased by 20% on the right and 27% on the left from pre-to post intervention (Table 4).

Table 4: Kinematics related to movement faults for the SKB Rot task, pre- and post-intervention

Movement Fault	Pre-intervention Side	Fault present	Mean (SD)	Post-intervention Fault present	Mean (SD)
Pelvis follow trunk (% trunk and pelvis in phase)	Right	yes	27.0 (11.3)	no	7.4 (1.9)
	Left	yes	47.1 (4.5)	no	20.5 (3.2)
Trunk flexion (°)	Right	yes	11.3 (3.3)	no	5.7 (4.0)
	Left	yes	14.1 (2.6)	no	2.9 (0.4)

DISCUSSION

The aim of the study was to examine whether changes in observational ratings of movement from SKB and SKB Rot tasks were supported by kinematics measured using 3D motion analysis following an exercise programme in an ex-footballer with hip and groin pain. The changes in observed movement patterns of the trunk and pelvis in the present study were supported by the objective changes in relevant kinematics measured using 3D motion analysis. These results suggest that observational rating can be an accurate method for detecting changes in the movement faults in the participant studied. The results of the present case study further suggest that movement patterns can be altered with an associated reduction in hip and groin symptoms.

The large improvement in the HAGOS symptoms sub-score from 36% to 61% can be considered a clinically relevant improvement as it is substantially above the smallest detectable change (SDC) value at an individual level previously determined to be about 18% (95% CI 14.1–23.2) [20].

Whilst causation cannot be established in the current study the reduction of symptoms in the present study could be associated with the decrease in trunk flexion during both the SKB and SKB Rot tests following the intervention. Increased trunk flexion is thought to be linked to poor hip muscle control leading to movement into end range hip flexion, which is associated with symptoms in FAI [39,44]. In support of the theory of poor hip muscle control and trunk movement, Crossley and co-workers [16] reported significant delay in onset of electromyography in anterior gluteus medius (p=0.07) and posterior gluteus medius (p =0.045) for those who were rated as poor compared to good performers of a single leg squat. Trunk flexion was not specifically rated but was included in the criteria for rating good or bad performance of the single leg squat. Although muscle activity was not evaluated in the present study, the results of Crossley et al. [16] suggest decreased trunk flexion could indicate improved hip muscle control, which was the focus of the intervention in the present study. Furthermore, reduction in pelvic anterior tilt, improved control of trunk rotation and trunk flexion suggest an increased ability to control the hip muscles in the present study.

Limitations of the present study include it being a single case study with limited follow up. The lack of blinding of the observational rater to knowing that the participant carried out an exercise programme aimed at improving their movement pattern could have caused bias. However, the changes in the kinematic data indicate that the observational ratings were accurate, so bias did not appear to influence them.

CONCLUSIONS

The results of the present study suggest that the observational rating of movement from the SKB and SKB Rot tasks may be accurate, as using 3D motion analysis there was a difference in the kinematics assessed to be at fault vs. those not at fault. Sensitivity to change in the observational movement screen was also established suggesting the observational tests may be an accurate tool to detect changes in movement patterns with treatment. Proof of concept of the effect of neuromuscular training was evidenced by the improved movement patterns of the trunk and pelvis achieved in a short space of time, which also led to a reduction in chronic hip and groin symptoms. A larger study is warranted to determine concurrent validity of the observational rating of the HLLMS which was indicated by this proof of concept study. Also, a study with a longer follow up that assesses hip muscle activation is warranted to improve our understanding of how movement patterns could be changed to reduce hip and groin symptoms.

Conflict of interest

The authors report no conflicts of interest

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