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Original research

Evaluation of shoulder joint position sense in both asymptomatic and rehabilitated professional rugby players and matched controls

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ABSTRACT

Objective: To assess if joint position sense (JPS) in the shoulder differed between un-injured rugby players, matched control subjects and previously injured rehabilitated rugby players.
Design: Mixed design.
Setting: University biomechanics laboratory.
Participants: 15 asymptomatic professional rugby union players, 15 previously injured professional rugby union players, 15 asymptomatic matched non-rugby playing controls had their JPS assessed.
Main outcome measures: JPS was assessed using two criterion angles in the 90° shoulder abduction position (45° and 80° external rotation).
Results: The study found a significant difference between groups in error score ($p = 0.02$). The testing angle also had a significant effect on error score ($p = 0.002$), with greater error scores occurring in the mid range position.
Conclusion: This study showed rugby players to have better JPS than controls, indicating JPS might not be related to injury risk. Poor JPS appears to be related to injury, players having sustained an injury have decreased JPS despite surgery and/or rehabilitation and returning to sport without incident.

1. Introduction

Stability within the glenohumeral joint is maintained via anatomical factors such as the degree of bony congruity, integrity of the capsuloligamentous structures and neuromuscular feedback loops involving the joint and musculotendinous mechanoreceptors that are integrated within the central nervous system (Suprak, Osternig, van-Donkelaar, & Karduna, 2006). Despite this highly integrated passive and active control system the glenohumeral joint is regarded as one of the least stable joints within the body. The passive ligamentous and capsular structures are often exposed to deleterious loads due to the failure of the active muscular control systems of the glenohumeral joint. This failure of active muscular control system reported in the literature has in part at least been blamed on a failure of proprioception (Janwantanakul, Magarey, Jones, & Danise, 2001).

The term "proprioception" was introduced by Sherrington in 1906 who described it as a type of feedback loop from the limbs to the central nervous system. It has recently been described as a combination of joint position sense, the ability of a person to identify the position of a limb in space, and kinaesthesia, the perception of active and passive motion. (Aydin, Yildiz, Yanmis, Yildiz, & Kalyon, 2001). The awareness of the position of the joint; joint position sense (JPS), is obviously an important aspect of proprioception. An intact JPS has been shown to be necessary for normal muscle coordination and timing, and this has been shown to be evident where active muscle forces play a significant role as in glenohumeral joint stability (Blasier, Carpenter, & Huston, 1994). JPS is thought to be provided by the slowly adapting musculotendinous (muscle spindles, golgi tendon organs) and capsuloligamentous (ruffini, and golgi tendon organ like endings) mechanoreceptors, which are stimulated by deformation of their parent tissues (Janwantanakul et al., 2001).

In the current literature it is generally agreed that tension in muscles, capsuloligamentous structures, and skin at a joint varies at the different points in the joint's range of movement (Allegrucci, Whitney, Lephart, & Fu, 1995; Dover, Kaminski, Maister, Powers, & Horodyski, 2003; Janwantanakul et al., 2001; Sullivan, Hoffman, & Harter, 2008). Because mechanoreceptors in tissues are activated by tension exerted on them, their activation would be expected to

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vary at different points in range as the tension in tissues around the joint varied. Consequently, position sense acuity may alter from one joint position to another. The accuracy of joint position reproduction at different criterion angles during JPS testing has been found to vary in studies involving the shoulder (Janwantanakul et al., 2001). In addition, Allegrucci et al. (1995) and Blasier et al. (1994) noted greater movement sense acuity at the shoulder complex, measured by the threshold for detection of movement test, at the end of range than in the mid joint range. This study used two different index angles one in a mid range and one in an outer range position in an attempt to identify if the potential differences outlined above occurred in the population studied. The base position of 90° shoulder abduction was chosen to mimic the shoulder position during tackling, in an attempt to replicate what might happen during a tackling scenario.

Joint position sense has been demonstrated to differ between participants in different sports and non-sporting individuals. Dover et al. (2003) showed baseball pitchers to have significantly decreased JPS at the extreme of external shoulder rotation than controls. This lack of awareness of joint position could potentially expose the glenohumeral joint to deleterious loading and result in injury. When looking at cervical spine JPS, Pinsault and Vuillerme (2009) found elite freeflyers to have better JPS than matched controls, indicating sports training may improve JPS. This lack of clarity in the literature would indicate the need for further study into the effect of sport training on JPS.

Several authors have highlighted that shoulder injuries are becoming more frequent and severe within professional rugby (Brooks, Fuller, Kemp, & Reddin, 2005a). The consensus amongst these authors and others is that tackling or being tackled is responsible for a majority of these reported shoulder injuries (Brooks et al., 2005a, Brooks, Fuller, Kemp, & Reddin, 2005b). The tackle within rugby appears to be the phase of play associated with the greatest risk of injury overall. (Brooks et al., 2005b; Garraway & MacLeod, 1995), yet there appears to be scant published research regarding the anatomical and biomechanical stresses that are placed on the shoulder and surrounding structures during its execution. No literature exists which examines shoulder JPS in rugby players to establish if there is decreased JPS in those individuals whom become injured or better JPS in those individuals who avoid injury than a non-rugby playing population.

This study undertook the JPS technique most frequently used in the literature; passive setting of the index angle, followed by active reproduction of that angle. When using this method especially in combination with the absolute error score, previous research has found it to be an accurate and reliable method of measuring JPS (Beynnon, Renstrom, Konradsen, Elmqvist, Gottlieb, & Dirks, 2000, chap. 12).

The aim of this study is to evaluate JPS in the shoulders of professional rugby players. The study will attempt to identify if JPS differs within subjects between different joint angles; one in mid range and one in a position replicating that of a rugby tackle and also if limb dominance affects JPS. The study will also carry out between subjects analysis of JPS to identify if JPS differs between rugby players and matched control subjects. Finally, the study will evaluate the effect of previous shoulder injury on JPS compare this group both to a peer group of rugby players and matched controls.

2. Method

2.1. Design

The design was a mixed one looking for within group differences in joint position sense between limbs (left and right and injured and non-injured) and target angle (45° and 80°) and between group differences in joint position sense between limbs of different status (control rugby, injured rugby, matched control).

2.2. Subjects

Non-injured group, fifteen professional rugby union players aged 22.7(+/−4) years (range 18–31 years) without any reported upper limb, spinal or neurological impairments or injuries; Recovered previously injured group, fifteen professional rugby union players aged 24.8(+/−3) years (range 18–33 years) with reported shoulder injuries related to shoulder instability (SLAP lesion, anterior instability or dislocation) and in some cases subsequent surgery (Fig. 1), occurring no greater than 2 years ago and no more recently than 3 months ago, but who had been passed medically fit and returned to full training and competition for at least the last two months, following an unremarkable but complete rehabilitation programme; matched control group, fifteen age 22.0(+/−4.9) years (range 18–31 years) and sex (male) matched physically active (non-rugby playing, but participating in at least 10 h sport per week) healthy males without any reported upper limb, spinal or neurological impairments or injuries participated in the study. All gave informed consent and the study was approved by the institutional research ethics committee.

2.3. Procedures

Subjects attempted to reproduce one of two shoulder joint external rotation index angles (45° and 80°) in 90° shoulder abduction. Angle order along with limb order was block ordered for each subject, with either 45 or 80°, left or right carried out first. Shoulder joint position index angle and reproduced angle were measured by taking a digital photograph of the subject using a Fuji Finepix S304 digital camera (with a picture resolution of 3 megapixels). The camera was positioned on a tripod 5 m away from the subject, the subject was framed within the picture to maximise the limb within the frame, and the settings of the camera remained unchanged until all pictures were taken. The photograph was then loaded onto a PC and the angles were calculated using ImageJ computer software (http://rsb.info.nih.gov/ij). The angle was measured at the intersection of two lines at the olecranon of the elbow. The first line comprised of a horizontal line parallel to the edge of the treatment couch the subject was lying on. The second line was one from the olecranon to the ulnar styloid at the wrist (replicating the method of Herrington, Horsley, Whittaker, & Rolf, 2008).

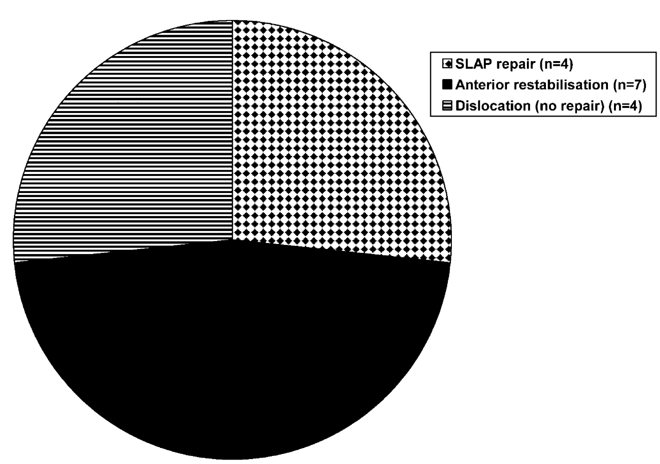

Fig. 1. Injury profile of the injured players used in the study.

During the shoulder JPS testing the subject lay supine on a treatment couch; shoulder abducted to 90° and in neutral rotation (radius and ulna vertical) and blindfolded, with the olecranon 10 cm from the edge of the plinth. The subject then had their shoulder passively externally rotated to the first of the two target angles, by the same tester each time (Fig. 2). The tester was blind to the study hypothesis. The tester verbally cued the subjects to hold the position, for the photograph to be taken. They held this position for five seconds and then the limb was returned passively back to the start position. During the passive movement the examiner attempted to move the arm at approximately 45°/s, that is take 2 s to position the limb for the 80° criterion and 1 s for the 45° criterion, they returned the arm to the start position at approximately the same speed. After a five-second rest the subject attempted to actively reproduce the target angle. The subjects were asked to say "OK" when they had achieved the angle and hold the position whilst a photograph was taken. This procedure was repeated two further times for this target angle and three times for the second target angle.

The between session (test–retest) reliability of the method was tested on a separate group of players. The absolute error scores were found for both target angles for a group of five players, these were then reassessed 30 min later. A comparison of first and second measurement using intra-class correlation coefficient (model 2,1) revealed a strong correlation of $r = 0.92$ ($p = 0.001$) between the two measurements and no statistically significant differences ($p = 0.67$) on testing with repeated measures t-test. Mean difference between the two measurements was 0.6° (+/−0.4°) with 95% confidence interval of 0–1.4°. This data then gives a minimal detectable difference score of 0.9° calculated using the formula presented by Eliasziw, Young, Woodbury, and Fryday-Field (1994), this indicates that any differences between groups larger than 0.9° are real differences and not related to measurement error. Pilot work was also carried out on the measurement technique to ascertain intra-tester reliability. Ten subjects photographs (target and reproduced angle pictures) were selected randomly for reassessment of angle, comparison of first and second measurement using intra-class correlation coefficient (model 2,1) revealed a strong correlation of $r = 0.98$ ($p = 0.001$) between the two measurements and no statistically significant differences ($p = 0.47$) on testing with repeated measures t-test. Mean difference between the two measurements was 0.5° (+/−0.3°) with 95% confidence interval of 0–1.1°.

2.4. Analysis

For each subject the target angle was subtracted from the reproduced angle to give a resultant absolute error score (angle), an average was taken from the three trials for each angle and the range of error scores was also calculated for each angle. The average absolute error scores were then statistically analysed using a SPSS (version 12) statistical package. The difference in level of both mean and the range error scores was analysed for the within group comparison with a factorial ANOVA with two factors; limb (left/right, previously injured/non-injured) and angle (45° and 80°). The critical alpha level chosen was $\alpha = 0.05$. Paired t-tests were used to evaluate specific differences and with the Bonferroni correction. The between group comparison was carried out using a further factorial ANOVA with two factors; injury status (non-injured rugby, previously injured rugby, matched control) and angle (45° and 80°). The critical alpha level chosen was $\alpha = 0.05$. Paired t-tests were used to evaluate specific differences and with the Bonferroni correction.

3. Results

3.1. Within subject comparison (previously injured to non-injured shoulder)

The results of this element of the study are shown in Fig. 3; this graph shows absolute error score for the previously injured shoulder was 6.7 +/− 3.4° at the 45° test angle and 4.1 +/− 0.8° at the 80° test angle. For the un-injured shoulder absolute error score was 3.7 +/− 1.8° at the 45° test angle and 2.3 +/− 1.2° at the 80° test angle.

The 2-way factorial ANOVA used for comparison indicated that the main effect of testing angle (45 and 80°) had a significant effect on absolute error score ($p = 0.025$), the other main effect of injury status also had a significant effect on absolute error score ($p = 0.002$). The interaction of injury status and angle had a non-significant effect on absolute error score ($p = 0.35$); therefore, although injury status appears to have a different effect on absolute error score, which differs with joint testing angle, the relationship between these two factors as defined by the interaction remains fairly constant. In this case the injured shoulder demonstrating a consistent deficit in JPS regardless of joint angle tested.

3.2. Between subject comparisons

3.2.1. Rugby players to matched controls

The results of this element of the study are shown in Fig. 3. The 2-way factorial ANOVA used for comparison indicated that the main effect of side (left versus right) had a non-significant effect on absolute error score ($p = 0.98$), testing angle (45 and 80°) had a significant effect on absolute error score ($p = 0.002$), and the other main effect of sporting status also had a significant effect on absolute error score ($p = 0.008$). All interactions had a non-significant effect on absolute error score ($p > 0.05$). This results indicating that both groups (non-injured rugby and control) had bilaterally equal JPS which was significantly decreased in a mid

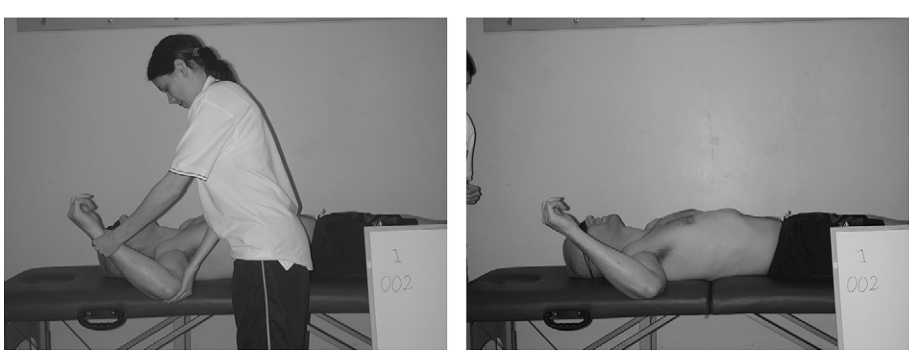

Fig. 2. Photograph representing passive positioning than active repositioning.

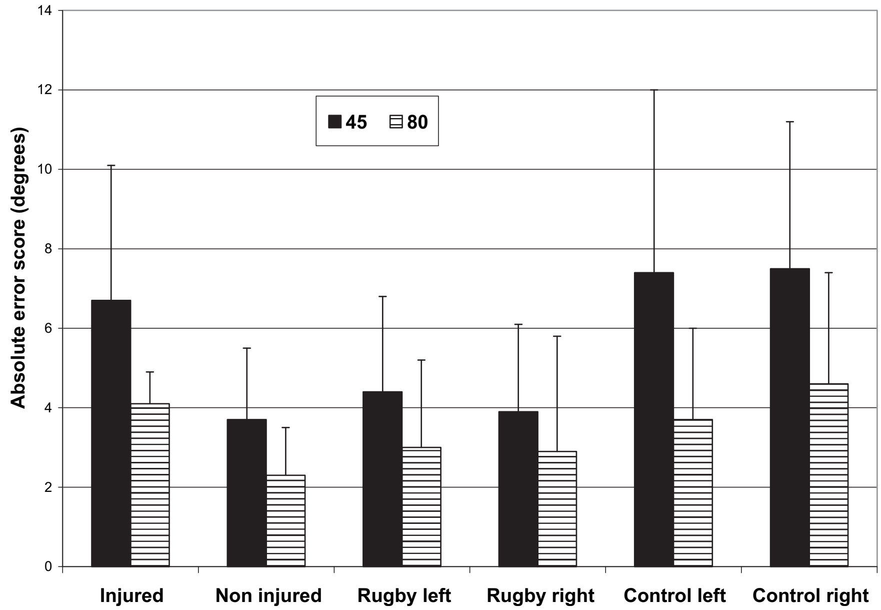

Fig. 3. Absolute error scores for the three groups.

range compared to an outer range position. The non-injured rugby group had superior JPS than the control group, which was consistent for both angles tested.

3.2.2. Rugby and non-rugby controls to previously injured players

Because of the non-significant difference in performance between limbs in the two control groups, for comparison with the injured group the right limb only was used. The 2-way factorial ANOVA used for comparison indicated that the main effect of testing angle (45 and 80°) had a significant effect on absolute error score ($p = 0.002$), the other main effect of injury/limb status also had a significant effect on absolute error score ($p = 0.012$). The interaction of injury status and angle had a non-significant effect on absolute error score ($p > 0.05$); therefore, although injury status appears to have a different effect on absolute error score, which changes with joint testing angle, the relationship between these two factors as defined by the interaction remains fairly constant. Paired *t*-tests (with Bonferroni corrections) showed there to be a significant difference in JPS between previously injured shoulder and non-injured rugby players at 45°, with all over comparisons showing non-significant difference ($p > 0.05$).

4. Discussion

The previously injured shoulder of the rugby players showed significantly increased error scores compared to the contra-lateral non-injured side regardless of criterion testing angle ($p < 0.002$). This finding supports the majority of current literature which shows bilateral differences in JPS following glenohumeral joint injury (Myers, Wassinger, & Lephart, 2006). It is beyond the scope of this study to determine if the deficit in JPS is related to the previous injury or exists prior to the injury. In either circumstance, all these players had returned to sport in spite of this deficit, which had not been examined or accounted for, prior to their return, whether this decrease in JPS predisposes them to further injury is unclear at present.

The study undertaken demonstrated that absolute JPS error is different depending on the degree of shoulder external rotation which supports the findings of Herrington et al., (2008) and Janwantanakul et al. (2001). Both this study and those of Herrington et al. (2008) and Janwantanakul et al. (2001) have shown JPS to be more accurate (decreased error scores) towards the end of range of lateral rotation in 90° abduction as opposed to mid range positions. This could be due to tension developing in muscles, capsule-ligamentous structures, and skin as the joint approaches the limit of movement, with this not being the case to such a great extent in the mid range position. Joint receptors within the capsule respond to mechanical deformation, thus if the joint capsule is not deformed mechanically the receptors will not be stimulated, resulting in minimal feedback on JPS (Allegrucci et al., 1995). Increased tensile loading of these structures, near the end of range may result in increased numbers of activated muscle spindles and mechanoreceptors in the joint capsule and ligaments. Thus, the summed discharge of these nerves may therefore be greater towards the end of range, resulting in improvement of position sense acuity.

Joint position sense in the glenohumeral joints of un-injured rugby players was superior to matched controls at both angles of external rotation. This finding is in contrast to that of Dover et al. (2003) who found baseball pitchers to have inferior JPS compared with controls. The differences between the findings may be related to the nature of the sports. Overhead throwing athletes have been shown to have increased range of external rotation (Herrington, 1998) as a result of repetitive deformation of the anterior/inferior capsule with the commensurate changes in muscle and capsule length it is believed that this could affect the mechanoreceptors of these tissues resulting in partial de-afferentiation and proprioceptive deficit (Myers et al., 2006). The rugby players having no need for these excessive ranges of motion for performance do not develop them. The nature of rugby training incorporating muscle strengthening and repetitive skills tasks (ball passing and catching and tackling) may have led to the development of more coordinate muscle contraction and general proprioceptive awareness, hence the superiority to the control group.

As with any study there are a numbers of limitations which may have confounded the validity of the study. The method undertaken to measure JPS is not the only one available and has limitations, for instance the subjects could count, to regulate index angle. This we did not control against, but our excellent reliability could either show the players were very good at cheating or the method was consistent. Previous research has shown this method to be the most accurate and reliable (Beynnon et al., 2000) but not without some potential for error and the reader must take that into account. The index angles were chosen to be representative of overall mid and outer range external shoulder rotation positions for this group of individuals. Individual range of movement was not tested, as a consequence, it may be that some players where closer or further away from their end of available range position than others, this may have had a significant effect on results, as specific angles have been shown to influence JPS error score (Janwantanakul et al., 2001), this is a limitation of the study and should be addressed in future studies. Another factor which may influence results and needs addressing in future studies is the muscle activity occurring. During the study undertaken the angle was achieved through eccentric muscle contraction of the medial rotators, in a tackle situation the arm is lifted into position using concentric contraction. This difference in muscle action and muscles involved may influence accuracy of measurement and requires further investigation.

In any study where the relative differences between groups are small, it is important to consider the ecological validity and clinical significance of these small differences and their true meaning. It is beyond the scope of this paper to discuss if a difference of 2–3° is a clinically significant difference in JPS, the only things which can be stated with confidence are that these differences are statistically significant and are of significant magnitude not to have occurred by chance or measurement error (that is they are greater than the minimal detectable difference found).

Injuries to the shoulder are becoming increasingly more frequent in professional rugby (Brooks et al., 2005a). This study shows professional rugby players to have superior JPS than controls, indicating JPS might not be related to injury risk, when assessed in a rested state. JPS would appear to be significantly affected by injury, players who have sustained an injury having inferior JPS, compared to their peers, despite surgery and/or rehabilitation and returning to sport without incident. The deficits in JPS following joint injury appear to be one of the causative factors of alterations of the neuromuscular response which affords joint stability (Lephart & Henry, 1996). Whether this deficit is as a result of the injury or predisposed the individual to injury is a matter for further research, what is certain is that more appropriate exercise programmes will need developing to return these players JPS to the level of their peers.

Conflict of interest statement

None.

Ethical approval

Participating subjects signed a consent form and the study protocol was approved by both Participating subjects signed a consent form and the study protocol was approved by both University of Sheffield, Division of Biomedical Sciences Ethics Committee, and the University of Salford Ethics Committee.

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