Upper limb joint position sense during shoulder flexion in healthy individuals: a pilot study to develop a new assessment method

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Abstract

Background: Altered shoulder joint position sense (JPS) following shoulder injury has been demonstrated in the literature and may increase the risk of injury. A JPS assessment targeting the shoulder will provide the clinician with an objective marker. The present study aimed to develop an assessment method of JPS using an active relocation test (ART).

Methods: In total, 40 healthy participants were recruited. A laser-pointer attached to the index finger during an ART allowed measurement (mm) of JPS by measuring the distance between the target and relocated position. Participants were blindfolded and stood an arm's length (approximately 1 m) away from the wall. Whilst keeping the wrist in neutral and elbow extended, the participant actively moved to the target position (90° glenohumeral flexion), held for 5 seconds, returned their arm to their side and actively returned to the target position. A mean was calculated from three trials to provide an ART score.

Results: The mean (SD) dominant and nondominant ART score was 89.2 (SD 35.5) mm (95% confidence interval = 77.87 mm to 100.5 mm) and 94.1 (34.5) mm (95% confidence interval = 83.1 mm to 105.2 mm), respectively. Arm dominance did not significantly affect ART scores.

Conclusions: No significant difference was demonstrated between the dominant and nondominant arm using an ART assessing JPS acuity. Further studies are needed to establish inter-rater and intra-rater reliability.

Keywords

objective outcome measure, proprioception, upper limb

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Introduction

The shoulder girdle is comprised of the glenohumeral joint (GHJ), acromioclavicular joint and sternoclavicular joint. The GHJ allows a large range of motion at the sacrifice of bony congruency.¹ This is overcome by structures providing static and dynamic stability.² Stability from passive restraints is considered to be relatively insufficient under dynamic conditions.³ Protective reflex activity⁴ and muscle contractions of force couples, enabling muscle stiffness adjustments and co-contractions,^{5,6} is crucial for maintaining ideal alignment of head of the humerus in the glenoid.

Mechanoreceptors within the ligaments and muscles provide afferent feedback. The integration of these in

the central nervous system and the efferent signals sent in response maintain stability, postural and motor control at the GHJ⁷ and is also known as proprioception. Proprioception has been termed as the integration of joint position sense (JPS), kinaesthesia and sensation of

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force from afferent feedback of the ‘proprioceptive field’/‘proprioceptors’.³ JPS is ‘the ability of a person to identify and reproduce the position of a limb in space’.⁸

Many activities of daily living are conducted in standing at shoulder height or below.⁷ In this range, the ligaments of the GHJ are lax^{9,10} and the forces of gravity are most influential.¹¹ Therefore, precise muscle co-contraction, reflex activity and co-ordination of force couples are needed to prevent dysfunction. Altered afferent and efferent impulses can result in reduced GHJ stability and microtrauma.¹² Previous literature has demonstrated patients with shoulder instability,^{13–16} osteoarthritis,¹⁷ painful shoulders,^{18,19} subacromial impingement²⁰ and rotator cuff dysfunction^{21,22} have altered proprioception.

Studies assessing JPS have used the active relocation test (ART) and passive relocation tests.^{16,17,23,24} The studies have measured JPS with an isokinetic dynamometer,^{17,23,24} video motion analysis^{25,26} and manipulandum.^{27,28} The equipment is rarely available outside of research laboratories. The position of the participant is often sitting in a constrained position and difficult for a practising clinician to replicate.

A laser pointer attached to the dorsum of the wrist has been used by Balke et al.⁷ to assess an ART of the upper limb. The method showed promise but involved participants being instructed to move the laser beam to pre-plotted target angles. This method would be time consuming and therefore impractical to replicate in a clinical setting. The study also advocated the method as an assessment of shoulder JPS, although the upper limb was not immobilized. There are no other studies using the laser pointer for ART assessment of the upper limb. The aim of the present study is to pilot an alternative assessment for JPS of the upper limb using a laser pointer attached to the hand using an ART. It is hoped this will allow the clinician to use an ART test that is functional, standardized and quantifiable.

Materials and methods

Participants

Healthy participants with no current or previous shoulder injury, trauma or pain were recruited ($n=40$) who did not compete in upper limb sports. Ethical approval was provided by The University of Nottingham Medical School Research Ethics committee and the Research and Development Department at Burton Queens Hospitals. After providing their written informed consent, participants were asked their age and hand dominance. Participants were also asked about their amount of physical exercise activity and alcohol consumption in the preceding 24 hours as a result of

Figure 1. Participant set-up.

previous studies having demonstrated that these factors influence JPS.⁷ Their height and length of the arm from the acromion to the third fingertip was measured (cm).

Participant set-up

The ART was conducted in a clinical setting. The participant was blindfolded using blackout goggles preventing visual cue's aiding JPS acuity (Figure 1). To prevent clothing providing proprioceptive feedback of limb position, participants were bare to the chest if male and to either a bra or vest top if female. Participants stood an arm's length (approximately 1 m) from the wall. A piece of tape was applied to the floor ensuring the same starting point if the participant moved.

A velcro strap was used to attach the laser pen to the posterior aspect of the middle phalanx of the index finger. This ensured that the tip of the laser pointer would not be obstructed by the distal phalanx and limited movement would occur at the proximal or distal interphalangeal joint. The participant was asked to ensure that their fingers remained extended and together in the position shown in Figure 2.

The active relocation test

Each participant was randomized to start with either their dominant or nondominant arm. Randomization was completed using a randomization package (Research Randomizer, version 3.0; <http://www.randomizer.org>). One practice attempt was undertaken followed by three trials for each arm.

The participant was asked to bring their arm up in front of them until 90° glenohumeral forward flexion was achieved with no movement at the elbow, wrist or fingers. Therefore, the only movement occurring would be at the shoulder girdle. This was measured with an inclinometer placed on the mid shaft of the humerus (inter-rater intra-class correlation coefficient = 0.62; intra-rater intra-class correlation coefficient = 0.65²⁹). The participant was instructed that this was the target angle and held the position for 5 seconds. A pen mark was placed on the paper attached to the wall to represent the target angle. The participant was instructed to return their arm to their side (keeping the arm straight) and to bring it back to the starting point at a steady pace, ensuring their trunk, elbow, wrist and fingers did not move and the motion was from the shoulder girdle. The participants indicated 'yes' at the end point, which was marked with a further dot. The distance between the start and end was measured, indicating the ART score.³⁰ The instructions for conducting the ART were scripted to ensure all participants received the same instructions. To prevent adaptation no feedback

was given to the participant about their performance until all measures had been collated.³¹

Statistical analysis

Initial descriptive analysis of age, sex and hand dominance was completed to assess the range of ages of participants and sex and hand dominance. The ART score numerically represents the JPS acuity of participants. It was calculated by measuring the distance between the dot representing the initial laser pointer mark (target angle) and the dot placed on the wall after the participant had returned to the target angle (Figure 3).

The Kolmogorov–Smirno test was used to establish whether the data was normally distributed. The data were normally distributed. The three ART measures gained was averaged for the dominant and nondominant arm to give the absolute error (AE) representing the ART score and the SD from the mean representing the variable error (VE). To compare dominant and nondominant arm JPE scores from the ART, an unpaired *t*-test was used.

Results

The study recruited 40 participants (34 females). The mean (SD) age was 37.98 (10.78) years, mean (SD) weight was 72.57 (14.82) kg and mean (SD) height was 166.86 (8.34) cm. Of the 40 participants, 37 reported that their dominant arm was the right.

Table 1 outlines the results of the ART. No significance difference between the dominant and

Figure 2. Arm and hand position.

Table 1. Results of the active relocation test.

	Dominant arm (mm)	Nondominant arm (mm)
Absolute error	89.2 (95% CI = 77.87 to 100.50)	94.10 (95% CI = 83.10 to 105.20)
Variable error	35.50	34.5

CI, confidence interval.

Figure 3. Active relocation test (ART) score measurement method.

Figure 4. Error bar plot for dominant and nondominant arm active relocation test (ART) score mean and 95% confidence interval (CI).

nondominant arm was found ($p .880$). The results are illustrated in Figure 4.

Discussion

The results from the present study establish that healthy individuals have a mean ART score of 89.0mm on the dominant arm and 94.1mm on the nondominant arm. Analysis of the data showed a 95% confidence interval (CI) of the ART score of 77.87mm to 100.5mm on the dominant arm and 89.2mm to 105.2mm on the nondominant arm. There was no clinical significance in ART scores between the dominant and nondominant arm. Therefore, if a patient was able to return to the target position within 105 mm (upper 95% CI), this would imply that they have a normal level of JPS acuity regardless of whether their dominant or nondominant arm was affected. The results of the present study could also be used by a clinician to compare the JPS acuity of an affected upper limb with a patient's non-affected limb using the VE (35.5mm on the dominant and 34.5mm in the nondominant arm). If the ART score was greater than 35.5 mm on the affected arm versus the non-affected arm, this could suggest a proprioceptive dysfunction of the upper limb. Assessment of reliability and validity was not possible with the present study; therefore, it cannot be recommended for clinical use at this time. If a clinician used this ART to measure JPS acuity, one would have to consider the effect of pain, muscle weakness, fatigue, learning affect and

neurological compromise also influencing the ART score and not just altered JPS.

The method used a functional movement of the shoulder in standing at the sacrifice of stabilizing other upper and lower limb joints and the spine. It cannot therefore be advocated as an ART assessment method that specifically assesses the shoulder girdle in isolation. However, gross movement was from the shoulder girdle; therefore, one could argue that it would be more suited to a functional, unconstrained method to assess primarily shoulder girdle JPS.

The only similar study using a laser pointer to assess the ART is that by Balke et al.⁷ Both the study by Balke et al.⁷ and the present study have established that hand dominance does not affect JPS, which agrees with previous research findings of Zuckerman et al.³² who used an isokinetic dynamometer to measure ART. Balke et al.⁷ used a laser pointer attached to the dorsum of the participant's wrist. Balke et al.⁷ commented that some participant's dorsiflexed their wrist, which disrupted the laser beam, and the trial had to be repeated. To overcome this, the present study attached the laser pointer to the posterior aspect of the index finger with velcro.

Previous studies have used a Jobst Air-Band (Jobst Institute Inc., Toledo, OH, USA) to secure the joints of the upper arm preventing movement at the elbow or wrist.^{16,32–34} The present study did not secure the elbow or wrist: first, to ensure the assessment method replicated how the upper arm is used in functional tasks and, second, to ensure that minimal equipment was

used to allow easy replication by a clinician. There have been no studies establishing whether using a Jobst Air-Band affects proprioception. Kinesiology tape has been found to aid JPS,³⁵ suggesting that the pressure applied to the arm may provide a stimulus, therefore aiding proprioception. Although the Jobst Air-Band may add pressure to the arm and aid sensory feedback, it does allow the ART or passive relocation test to be focused to the shoulder. Firm conclusions cannot be made and further investigations are needed to establish whether a Jobst Air-Band affects JPS acuity.

The target angles reported in Balke et al.⁷ were pre-calculated and labelled on a wall chart in front of the participant. This may prove difficult to replicate for clinicians because of the time needed to pre-calculate and plot the co-ordinates. Balke et al.⁷ used a second examiner to mark the laser pointer position on the board. In the present study, the examiner had to measure when the participant had achieved 90° of forward flexion and mark the starting point on the paper. To overcome this issue, a pre-marked target angle aligned at the participant's laser pointer at 90° forward flexion could be used.

Other studies assessing ART to different target angles have assessed the same target angle in succession. For example, all three trials to a target angle of 90° flexion would be conducted before assessing another target position. In the study by Balke et al.,⁷ the participant held the target position of 90°, and then at either 125° or 55°. They were then instructed to replicate any one of these three angles. It was not clear why the study chose to assess JPS in this way. The method used may have resulted in the participant becoming fatigued and therefore affecting the ART scores. Individual testing positions should be utilized in future ART studies to prevent fatigue affecting the error scores and to standardize the assessment method.

The participant position for assessing ART differs between studies. Many assessed the participant sitting^{8,34,36,37} or standing.⁷ Seating the participant prevents rotation at the torso, which may limit variability in the ART scores but the chair may provide proprioceptive feedback.³⁸ The present study chose to replicate the functional position of standing. It is recognized that choosing this assessment position may allow body movements to affect the repositioning error of the upper limb but ensures that the integrity of the aim of the study was retained.

The aim of the present study was to develop an ART assessment method to measure the proprioceptive acuity of the upper limb which was functional, standardized, and quantifiable. After comparing the current study with previous literature and reviewing the methodology, it is clear the methods used cannot be advocated as a pure assessment of the shoulder girdle

proprioceptive acuity but rather of the upper limb in standing as a result of the unconstrained nature of the assessment method. If the trunk, elbow, wrist and fingers were constrained by assessing the participant in sitting and using a brace to prevent movement of the elbow, wrist and fingers, this may prevent clinicians easily replicating the assessment method in a clinical setting.

Clinical relevance

Hand dominance did not influence ART scores. If the affected arm ART score was greater than the non-affected arm by more than 35.5 mm (the VE), it could be assumed that the JPS acuity may be affected. The highest band of the 95% confidence interval was 105 mm for the nondominant arm and therefore it could be assumed that, if a patient had an ART score less or equal to 105 mm, they would have a normal level of JPS acuity. To be able to recommend this assessment method for clinical practice, further inter- and intra-reliability studies are required.

Conclusions

The aim of the present study was to develop and use a method of data collection providing an ART score of the GHJ using a laser pointer that clinicians can easily replicate. As a pilot study, it was hoped the current study would allow further research projects to use the methods and results to determine inter- and intra-reliability.

The present study has developed a functional, unconstrained method of assessing JPS of the upper limb using an ART in standing. Shoulder flexion was the primary movement during the ART and therefore could be used as an ART focused on the shoulder girdle. It cannot be recommended as an assessment method of JPS of the shoulder girdle alone because the participants were standing and the elbow, wrist and small hand joints were not constrained. The study found an ART score of 89.2 mm on the dominant arm and 94.1 mm on the nondominant arm when assessed with this ART, with a VE of 35.5 mm and 34.5 mm for the dominant and nondominant arm, respectively. There was no significant difference between the dominant and nondominant arm. Therefore, it could be postulated that, if the affected arm's ART score was more than 35.5 mm worse than the non-affected arm, the patient may have a proprioceptive dysfunction.

The present study provides a platform for further studies to first establish inter-rater and intra-rater reliabilities and then consider comparing healthy populations with participants exhibiting primarily shoulder

and/or upper limb dysfunction or pathology. The results of these studies will establish whether this assessment method could be recommended for clinical use.

Declaration of Conflicting Interests

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Ethical review and patient consent

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