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Variability of shoulder girdle proprioception in 44 healthy volunteers

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ABSTRACT

Background: Improved knowledge of normal shoulder girdle proprioception should benefit the treatment and rehabilitation of shoulder disorders. Whereas many of the available methods for assessing joint position sense (JPS) are costly and complex, Balke et al. have described a simple test. The primary objective of this study was to use this test to identify factors that influence shoulder-girdle JPS evaluation in healthy individuals. The secondary objective was to determine reference values based on the values obtained and on the factors associated with their variability.
Hypothesis: Age and dominant limb influence the results of shoulder girdle JPS evaluation, creating a need for reference values that take these factors in account.
Patients and methods: A single-centre prospective study of healthy volunteers was performed between September 2012 and January 2013. In each volunteer, shoulder repositioning accuracy was assessed bilaterally as described by Balke et al. A line was drawn on the floor parallel to and 1 metre away from a wall. A target on the wall showed marks corresponding to three angles of arm elevation: 55°, 90°, and 125°. The volunteer was asked to raise the arm to the three positions, in abduction and in flexion, while memorising the joint positions, then to replicate the same positions with the eyes closed. The absolute differences between the replicated positions and the reference positions, designated angle deviations, were measured in degrees. Age, sex, and dominant upper limb were recorded.
Results: The 88 shoulders of 44 healthy volunteers were studied. No significant difference was found between males and females ($p > 0.05$). The only significant difference between sides was better replication by the dominant arm of flexion at 55° ($p = 0.03$). By univariate analysis, age was the only factor significantly associated with repositioning errors ($p = 0.003$); neither dominant limb nor sex were significant ($p = 0.29$ and $p = 0.59$, respectively). In flexion, the angle deviation increased significantly with movement amplitude. The measurements were used to create a chart of expected angle deviations in healthy individuals according to age and to plane and amplitude of movement.
Discussion: The test described by Balke et al. is simple and feasible in everyday practice. Age, dominance, and plane of movement should be considered when evaluating abnormal shoulders. Further studies in larger numbers of individuals are needed to better define normal angle deviations related to these factors.
Level of evidence: IV.

1. Introduction

The shoulder girdle is a mobile biomechanical complex whose anatomical configuration results in considerable instability. Dynamic stability is provided by various passive and active restraints. Several studies have highlighted the key role of proprioceptive information supplied by specific mechanoreceptors (Golgi, Pacini, and Ruffini) that reside within the joints, ligaments, tendons, and skin [1–5]. These mechanoreceptors may be damaged in patients with conditions such as rotator cuff tears or gleno-humeral instability [6,7].

Shoulder proprioception has been a focus of growing attention in sports medicine in recent years. Impaired proprioception has been reported to result in musculo-skeletal lesions, whose recurrence is more likely if the impairments persist [8]. To determine whether surgical procedures and/or rehabilitation programmes are effective in improving proprioception, accurate methods for measuring proprioception are needed.

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Fig. 1. The individual stands 1 metre away from the wall, in front of a target, and raises the arm in abduction and flexion, aiming at the three angles marked on the target (55°, 90° et 125°).

Proprioception can be divided into three components, namely, joint position sense (JPS), kinaesthesia, and sensitivity to resistance. The tests currently being developed focus on JPS and often require specific measurement tools, many of which are both costly and challenging to use [9,10]. JPS testing during active movements provides a more accurate picture, as the muscle contraction generates afferent input, contributes to stability, and replicates events that occur during the activities of daily living [11].

Balke et al. [12] have developed a simple and inexpensive test for measuring JPS at the shoulder. This test requires no specific equipment and can be performed in everyday clinical practice. The primary objective of this study was to use this test to identify factors that influence shoulder girdle JPS in healthy individuals. The secondary objective was to determine reference values based on the measurements obtained and factors associated with variability. The working hypothesis was that age and dominant limb influence the results of shoulder girdle JPS evaluation, creating a need for reference values that take these factors in account.

2. Patients and methods

A single-centre prospective study was performed over the 4-month period from September 2012 to January 2013 at the university hospital in Besançon, France. The study participants were healthy volunteers with no constitutional or acquired shoulder girdle abnormalities, normal active and passive range of motion at both shoulders, and no shoulder pain. All volunteers received oral and written information about the study. In each, the ability to replicate shoulder positions was assessed bilaterally.

All measurements were performed by the same examiner as described by Balke et al. [12] (Fig. 1). The volunteer stood on a line drawn parallel to and 1 metre away from the wall. A target hung on the wall showed the points the volunteer had to aim for to achieve 55°, 90°, and 125° of arm elevation in flexion and in abduction. The point corresponding to 90° was at the centre of the target. The height of the target on the wall was adjustable so that the centre could be aligned with the gleno-humeral joint of the volunteer. To avoid stimulation of the skin, the volunteers did not wear clothes that covered the shoulders. The wrist was immobilised in a removable brace to avoid errors due to wrist movements. A laser pointer was affixed to the wrist on the side being tested. The volunteer was then asked to memorise the joint positions while raising the arm to each of the three levels (55°, 90°, and 125°), in forwards flexion and abduction. With the eyes covered, the volunteer then attempted to replicate each position, on three different occasions, and the degree of flexion or abduction was measured at each attempt. Thus, 18 measurements were obtained for each shoulder and 36 measurements for each volunteer. The difference between each value obtained with the eyes covered and the theoretical value (55°, 90°, or 125°) was computed and designated by the term 'angle deviation'. For each volunteer, age, sex, and dominant limb were recorded.

Table 1
Main features of the 44 healthy volunteers.

Age, years, mean ± SD	31.5 ± 10.4
Males, *n*	23
Right-handed, *n*	39

2.1. Statistical analysis

Quantitative variables were described as mean ± SD and qualitative variables as *n* (%). Quantitative variables were compared between groups by applying the Wilcoxon-Mann-Whitney test. Univariate linear regression was used to assess associations between repositioning errors and age, sex, and dominance. The statistical analyses were performed using R version 3.5.0 and RStudio version 1.1.453 (R Foundation for Statistical Computing, Vienna, Austria). Values of p lower than 0.05 were taken to indicate significant differences.

3. Results

3.1. Population

The 88 shoulders of 44 healthy volunteers were studied (Table 1). There were 23 (52.3%) males and 21 (47.7%) females) with a mean age of 31.5 years (range, 16–54 years). Of the 44 volunteers, 39 (88.6%) were right-handed and 5 (11.4%) were left-handed.

3.2. Statistical associations

No differences were found between males and females for any of the levels of flexion or abduction (Fig. 2). The only significant difference according to handedness occurred for forwards flexion at 55°, for which repositioning was significantly more accurate on the dominant side (mean angle deviation, 8° vs. 9° on the non-dominant side, $p = 0.03$) (Fig. 3). By univariate analysis, only age was associated with repositioning errors ($p = 0.003$); no significant association was found for dominant side or sex ($p = 0.29$ and $p = 0.59$, respectively).

In abduction (Fig. 4), mean angle deviations differed significantly between 125° and 90° and between 125° and 55°. No significant differences in repositioning errors were found between 55° and 90° of abduction. In forwards flexion, mean angle deviations showed significant differences across the three levels.

3.3. Reference values

The values obtained were used to determine the expected angle deviations in healthy individuals according to age, plane of motion, and range of motion (Table 2).

4. Discussion

In this study, age significantly influenced the results of shoulder JPS testing using the method described by Balke et al. Expected repositioning errors in healthy individuals were determined.

To date, no consensus exists about the best method for evaluating shoulder proprioception. Many different methods have been

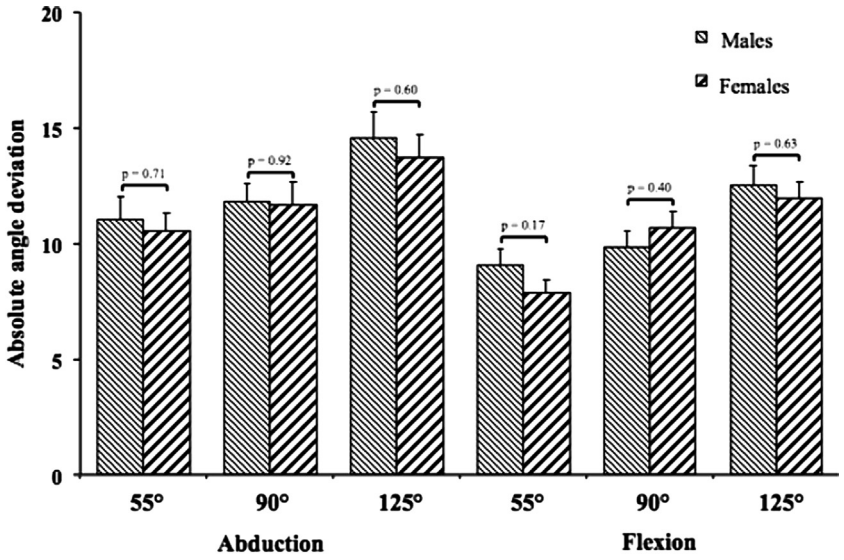

Fig. 2. Mean angle deviations in males and females for the three positions tested, in abduction and forwards flexion. No significant difference was found.

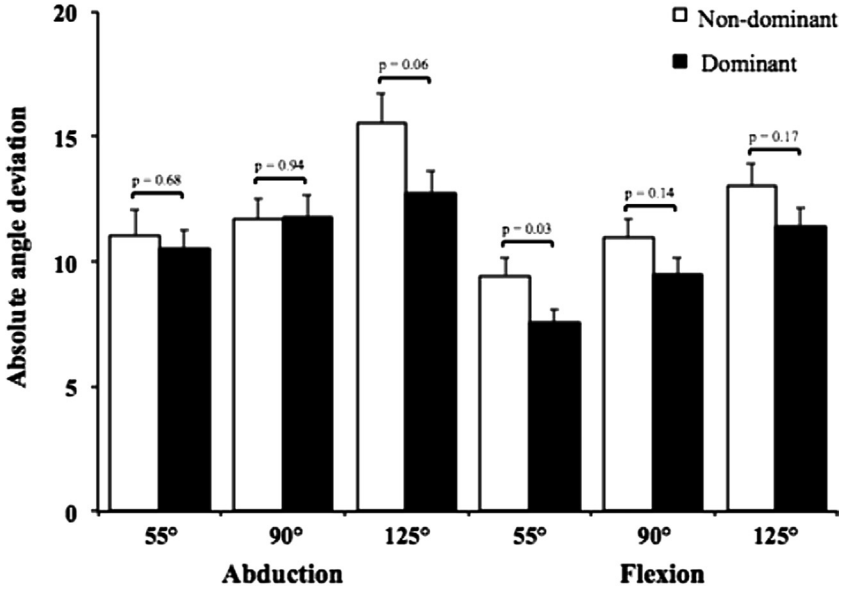

Fig. 3. Mean angle deviations for the dominant and non-dominant limbs in the three positions tested, in abduction and forwards flexion. Accuracy was significantly better for the dominant limb at 55° of forwards flexion.

described [10]. The link established in several studies between instability and SLAP tears or Bankart's tear indicate an association between impaired proprioception and damage to the joint capsule [13–15]. Gleno-humeral proprioception is impaired in patients with chronic shoulder instability but improves gradually after stabilising surgery [16,17]. However, in one study, surgery after a single episode of anterior gleno-humeral dislocation failed to improve proprioception [18]. Studies of tests to assess JPS were done in small numbers of patients, all of whom were young, and failed to consider inter- and intra-individual variations.

The testing method devised by Balke et al. [12] is simple and inexpensive, requires no specific equipment, and exhibits satisfactory intra-observer repeatability [10]. We used it to conduct a larger study of gleno-humeral JPS in healthy volunteers and to establish reference values for purposes of comparison when assessing abnormal shoulders (glenoid impingement, instability, post-operative recovery) and the effects of treatment.

Age-related impairments in proprioception may be partly ascribable to muscle fatigability [19]. An increase in muscle fatigue with advancing age seems plausible. Studies of individuals with similar physical capabilities divided into different age groups would be needed. JPS testing during passive movements would eliminate any bias due to muscle fatigue, as the muscles would then serve merely as proprioception effectors and not as movement effectors. However, this approach does not seem satisfactory, as proprioception is less effective during passive than active movements, as muscles supply proprioceptive information when they are contracted [11,20].

Sex was not significantly associated with JPS, as previously reported [1,12]. Consequently, data from males and females can be pooled.

Proprioception seemed more effective on the dominant side, although the difference was statistically significant only for forwards flexion at 55°. Aydin et al. [16] contended that the dominant limb performed better due to its more frequent use providing

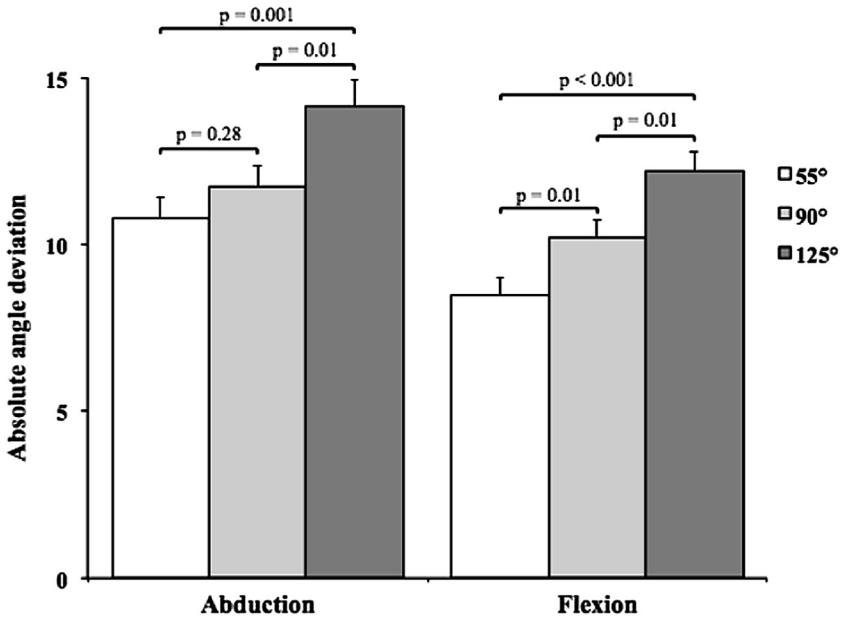

Fig. 4. Mean angle deviations for each level of forwards flexion and abduction: in forwards flexion, angle deviation increased with amplitude.

Table 2
Expected angle deviation according to age, plane of motion, and movement amplitude in healthy individuals.

	Age < 25 years	Age 25 to 35 years	Age > 35 years
Abduction			
55°	10°	11°	11°
90°	11°	12°	12°
125°	16°	11°	16°
Flexion			
55°	6°	9°	10°
90°	9°	9°	13°
125°	11°	9°	17°

greater opportunities for learning. Furthermore, the repeated use of forwards flexion at 55° to carry out activities of daily living may improve performance as it can be likened to intensive training. Nevertheless, in our study, the only significant difference between the dominant and non-dominant sides was a 1° difference in forwards flexion at 55°. Such a small difference is not clinically significant. A study in a larger number of individuals would improve our knowledge of the performance of the dominant limb in this sector of the motion range.

The ability to achieve accurate repositioning in forwards flexion decreased as the amplitude of the movement increased. In abduction, a non-significant trend towards diminished accuracy was seen between 55° and 90°. In contrast, in earlier studies performance was best in the plane of the gleno-humeral joint (90°) [1,12]. This finding was ascribed to the greater tension on muscle and tendons as amplitude increased, translating into greater recruitment of tendon mechanoreceptors, which are the main proprioceptive organs [5]. In our study, repositioning errors increased (i.e., accuracy decreased) with increasing amplitude. Lönn et al. [21] reported that repositioning accuracy improved when the starting point was an intermediate position, that is, when the movement arc was shorter. In addition, muscle fatigability increases with movement amplitude and impairs JPS, thereby decreasing repositioning accuracy [22,23].

Dvir et al. [24] underlined the importance of assessing the clinical significance of statistically significant differences between measured values. A statistically significant difference is not necessarily associated with a change that is clinically meaningful to the patient. Based on the values obtained in our study, we suggest that angle deviations may be clinically significant if greater than 15°.

5. Conclusion

The evaluation of shoulder proprioception raises both practical and analytical challenges. The test devised by Balke et al. is simple and inexpensive. JPS at the shoulder is associated with age but not with sex or dominance. Repositioning errors increase with the amplitude of forwards flexion. Further studies in larger numbers of individuals are required. Given its simplicity, the Balke test should prove useful for monitoring proprioception after the treatment of shoulder conditions. Additional work is needed to improve our understanding of normal angle deviations in healthy individuals. Finally, it would be of interest to assess potential correlations linking functional shoulder scores to JPS in order to shed light on the functional impact of impaired proprioception.

Disclosure of interest

Laurent Obert declare that he has no competing interest but has financial ties to FX solutions, Zimmer, Medartis, Evolutis, Biotech Wright, Lilly, the Besançon university hospital, the Bourgogne Franche Comté university, Elsevier, and Springer.

The other authors declare that they have no competing interest.

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Contributions of each author

Echalier C.: corrected the data and drafted the manuscript.
Ritter J.: corrected the data.
Uhring J., Rey P.B., Jardin E., and Rochet S.: evaluated the results.
Obert L. and Loisel F.: conceived the study and revised the manuscript.

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