Shoulder proprioception: How is it measured and is it reliable? A systematic review

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A B S T R A C T

Study Design: Systematic review.

Introduction: Constituents of proprioception include our awareness of the position (joint position sense [JPS]) and motion (kinesthesia) of our limbs in space. Proprioceptive deficits are associated with musculoskeletal disorders but remain a challenge to quantify, particularly at the shoulder. Purpose of the Study: To report the psychometric values of validity, reliability, and responsiveness for shoulder JPS and/or kinesthesia protocols. Methods: A review of 5 databases was conducted from inception to July 2016 for studies reporting a psychometric property of a shoulder proprioception protocol. The included studies were evaluated using the QualSyst checklist and COSMIN 4-point scale. Results: Twenty-one studies were included, yielding 407 participants and 553 evaluated shoulders (n). The included studies support excellent methodological scores using the QualSyst checklist (88.1 ± 9.9%) and good psychometric scores with the COSMIN for reliability (71.1%) and moderate-to-low quality score (50%) for criterion validity. Weighted average intraclass correlation coefficients (ICCs) for intrarater reliability were highest for passive JPS and kinesthesia, ICC = 0.92 ± 0.07 (n = 214) and ICC = 0.92 ± 0.04 (n = 74), respectively. The most reliable movement and tool are internal rotation at 90° of abduction, ICC = 0.88 ± 0.01 (n = 53), and the dynamometer, ICC = 0.92 ± 0.88 (n = 225). Only 2 studies quantify an aspect of validity and no responsiveness indices were reported among the included studies. Conclusion: Based on the results of the included studies, the evaluation of shoulder proprioception is most reliable when using a passive protocol with an isokinetic dynamometer for internal rotation at 90° of shoulder abduction. Standardized protocols addressing the psychometric properties of shoulder proprioception measures are needed. Level of Evidence: Level 1a: systematic review.

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Introduction

Proprioception is not a new concept, first introduced as our “muscular sense” by Charles Bell in 1826 and later elaborated by Charles Sherrington, who coined the term “proprioception” in 1906, as “our perception of joint movement and positioning in space in the absence of visual feedback.”1 Proprioception has evolved over time to become an overarching theme, including the subcategories of kinesthesia, the awareness of passive or active joint movement, joint position sense (JPS), the reproduction of joint angles actively or passively,2,3 as well as our ability to detect vibrations,4 level of force production,5 and changes in limb or joint velocity.6 The role of proprioception is well depicted in the context of the shoulder joint. Due to its vast mobility, it is inherently an unstable joint,7 relying heavily on the synchronicity of its active and passive structures for dynamic neuromuscular control.8,9 The

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Proprioception itself remains a challenge. As proprioception has been linked to the persistence of impairments and physical limitations, it would be advantageous to measure it objectively in a clinical setting.

The psychometric properties of protocols are important to understand to objectively quantify an individual’s level of impairment, physical limitations, and/or restrictions of participation. Such qualities include strong validity, reliability, and responsiveness measures to establish the credibility and usefulness of a measure for quantifying neuromuscular function.

The purpose of this systematic literature review was to identify and report the psychometric values of validity, reliability, and responsiveness from studies quantifying shoulder proprioception in adults, measured as JPS or kinesthesia. Presentation of this systematic review follows the recommendations outlined by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).

**Methodology**

**Literature search and study identification**

A literature search was conducted by 2 reviewers (A.L.A. and M.R.) using 5 databases including PubMed (Ovid MEDLINE), Embase, CINAHL, PEDro, SPORTDiscus, the reference system EBSCO, and a manual search of references from all retrieved articles. The search was performed from inception to July 15, 2016, and included the key terms proprioception (proprio*), kinesthesia (kinesthes*), joint position sense, clinical tool*, clinical measure*, outcome measure*, validity, reliability, responsiveness, sensitivity, specificity, and diagnostic accuracy. Combined controlled vocabulary specific to each database was used (eg, Medical Subject Headings [MeSH] for MEDLINE and Emtree for the Embase). The search strategy was developed with the guidance from a technician in documentation.

**Study selection**

Two evaluators (A.L.A. and M.R.) independently reviewed the titles and abstracts of each article for screening eligibility. Subsequently, the 2 raters reviewed each article, addressed the inclusion criteria, and came to a consensus for inclusion. An article was accepted for a full review if it met the following inclusion criteria: (1) reported on at least 1 psychometric property addressing either JPS or kinesthesia of the shoulder (laboratory or clinical measure); (2) written in French or English; and (3) included adult participants with or without an MSK disorder of the shoulder. An article was excluded if it referenced the psychometric properties of a previous study and if it evaluated the sense of vibration, detection of joint or limb velocities, or perceived levels of force production. Articles evaluating either JPS or kinesthesia were selected because they are the most used methods for quantifying shoulder proprioception.

**Data extraction and shoulder proprioception measurements**

Information was extracted by 1 evaluator (A.L.A.) systematically using a standardized form, which included the population, type of proprioception investigated, evaluation methods and equipment, direction of shoulder movements, and reported psychometric values of the protocols. The information was then verified by 2 other evaluators (M.R. and A.F.B.).
JPS and kinesthesia measures were the main outcome for this review, which included active JPS (AJPS): actively moving the limb to a target angle; active path of joint motion replication (PJMR): the reproduction of a specific angular trajectory; threshold to detection of passive motion (TTDPM): the detection of motion externally initiated at the joint; and reproduction of passive positioning (RPP): where the limb is moved passively by the evaluator or a device.18 Ipsilateral and contralateral matching tasks were included.

Quality assessment

Three evaluators (A.L.A., M.R., and A.F.B.) independently assessed all included articles with 2 checklists: the Standard Quality Assessment Criteria for Evaluating Primary Research Papers (QualSyst)30 and the COSMIN 4-point scale31,32 for psychometric assessment. The raters then met to openly discuss each article and to reach a consensus. This process allowed us to address any disagreements in the interpretation of the data or the scoring process. When no consensus was reached, the evaluators applied the default option of the lowest awarded score. If any rater was uncomfortable with this resolution, a fourth rater (J.S.R.) reviewed and scored the article. A preconsensus interrater absolute agreement was calculated using an intraclass correlation coefficient (ICC) to evaluate the level of agreement between the raters.

Intraclass correlation coefficient calculation:

\[ ICC(3) = \frac{BMS - EMS}{BMS + (k-1)EMS} \]

Where, \( BMS = \) Between target Mean Square.

\( EMS = \) Residual Mean Square.

\( k = \) means of several ratings.

Weighted average for intrarater and interrater reliability ICC calculations:

\[ \text{Weighted average} = \frac{\text{SUMPRODUCT(ICC value, total } N)}{\text{total } N} \]

Where, \( N = \) shoulders evaluated.

Standard quality assessment criteria for evaluating primary research papers

The QualSyst is a quality appraisal tool developed by Kmet et al30 that evaluates the methodological quality and risk of bias of quantitative and qualitative studies with varying study designs. It is composed of 14 items; however, for the purpose of this review, items 5 (random allocation), 6 (blinding of investigators), and 7 (blinding of subjects) were removed from the scoring because the included studies were mainly methodological. Item 9 (sample size) was also excluded because it was assessed using the COSMIN 4-point scale. Each item was assessed using a 3-point scale (0–2), for a total score of 20 points, which was then normalized to 100%. Because there is currently no classification threshold associated with the scale, we categorized each article based on its awarded percentage, \( \geq 75\% \) being an excellent quality study, 51%–74% representing a good study, and \( \leq 50\% \) suggesting a moderate- to low-quality study.

COSMIN 4-point scale

The COSMIN 4-point scale is a checklist developed by Terwee et al31,32 and is recommended for use in systematic reviews of

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Fig. 1. Graphical depiction of the shoulder proprioception pathway. Proprioception includes bilateral symmetry with crossed representation. This suggests that proprioception information from the right side of the body is process in the somatosensory cortex in the left hemisphere.
measurement properties such as validity, reliability, and responsiveness. Each box of the COSMIN tool represents a different psychometric property. Only the evaluation boxes that specifically address the psychometric property of the included studies were used. Box B of the COSMIN 4-point scale was used to evaluate reliability, and box H was used to assess criterion validity. Because the COSMIN 4-point scale uses qualitative descriptions for scoring, the scoring system was converted to obtain a quantitative score (excellent = 4, good = 3, fair = 2, and poor = 1). Box B for reliability has a maximum potential score of 44 points, seeing as items 12, 13, and 14 were excluded (representing dichotomous, nominal, or ordinal scores). Box H for criterion validity has 7 items and using the same quantitative scoring technique of 1–4, a total score of 28 points was possible. As with the QualSyst checklist, the total was normalized to 100% and categorized for quality assessment.

Data analysis

Weighted averages (WAs) of ICC measures for both intrasession and intersession reliability were calculated and weighed according to the number of shoulders evaluated (n). WAs were calculated for
the type of proprioception measured, direction of shoulder movement, and type of equipment used during the protocol. Studies that reported interrater reliability or a correlational value was not included in the WA calculations. Studies included could not be pooled into a meta-analysis due to the variability between proprioception protocols performed in each study.

Results

Description of the studies

The literature search resulted in 262 articles, from which 167 duplicates were removed and the remaining 95 articles had their titles, abstracts, and results screened for eligibility. Seventy-four articles were excluded; therefore, 21 articles were included and the full texts were assessed (Fig. 2). A total of 407 participants and 553 shoulders (n = 553) were evaluated for the psychometric properties of the shoulder proprioception protocols.

Quality of the included studies

Scores from the QualSyst checklist ranged from 12/20 (60%) to 20/20 (100%), with a mean score of 88.1 ± 9.9%. The COSMIN 4-point scale checklist box B scores ranged from 27/44 (61.3%) to 39/44 (88.6%), with a mean score of 71.1 ± 8.0%. Two studies were evaluated using the COSMIN box H for criterion validity and earned identical scores of 14/28 (50%). Preconsensus interrater agreement on the total scores were good for the QualSyst scale (ICC = 0.71 [95% confidence interval (CI): 0.63-0.77]) and excellent for the COSMIN 4-point scale box B (ICC = 0.90 [95% CI: 0.88-0.92]) and box H (ICC = 0.99 [95% CI: 0.97-0.99]).

Specific findings

Population

Different populations were investigated among the included studies: 14/21 (66.7%) used healthy participants (n = 435), 5 (23.8%) used healthy athletic populations (n = 74), and lastly, 2 studies (9.5%) tested individuals with pathological shoulders (n = 44), which included participants affected by chronic rotator cuff pathologies and multidirectional instability of the shoulder.

Type of proprioception evaluated

The proprioception measures of our review address either JPS, which includes AJPS, PJPS, RPP, and PJMR tasks, or kinesthesia, which includes TTDPM tasks (Fig. 3). AJPS was evaluated in 16 studies (n = 479). Among the AJPS studies, variability existed as to whether the movement was actively or passively demonstrated and then actively executed, respectively. Five studies promoted an active/active protocol (n = 112), 1 study prompted an active-assisted protocol (n = 10), and 12 studies performed a passive/active protocol (n = 337). Eight studies evaluated passive joint position sense (PJPS or RPP; n = 454). Two studies evaluated PJMR (n = 10), and 6 studies evaluated TTDPM (kinesthesia) (n = 114). Interestingly, nearly all proprioception protocols used an ipsilateral task (95.2%), with the exception of Ramsay and Riddoch who used a contralateral matching task.

The intra- and inter-session WA ICCs indicate that PJPS has the strongest reliability (0.92 ± 0.07, n = 214), followed by passive/active protocols (WA ICC of 0.90 ± 0.1, n = 204), and TTDPM (0.92 ± 0.04, n = 74), respectively. The active/active protocol revealed the lowest intra- and inter-session WA ICC (0.34 ± 0.1, n = 22). Intersession calculations reveal a similar pattern with TTDPM demonstrating the strongest reliability (0.92 ± 0.10) followed by AJPS protocols (0.87 ± 0.14, n = 314).

Direction of movement

The included studies used various movements of the shoulder complex to quantify proprioception, including flexion (n = 112), internal rotation (IR) at 90° of abduction (ABD) (n = 154), external rotation (ER) at 90° of abduction (n = 389), scaption (n = 66), scapular movements (elevation, depression, retraction, and protraction) (n = 20), horizontal adduction and ABD (n = 10), pure ABD (n = 8), and combined movements (F/ABD/ER through E/adduction/IR) (n = 11) (Fig. 4).

IR and ER protocols support the strongest WA ICCs for both intra- and inter-session reliabilities. IR leads with an ICC of 0.88 ± 0.01 (n = 53) (intrasession) and 0.98 ± 0 (n = 31; inter-session), closely followed by ER WA ICC = 0.83 ± 0.04 (n = 303; intrasession), WA ICC = 0.97 ± 0.04 (n = 41; inter-session).
is the least reliable direction of movement with an intrasession WA ICC of 0.34 ± 0 (n = 33).

Equipment

The isokinetic dynamometer was used the most frequently for both JPS\textsuperscript{12,33,37,40,45} and kinesthesia\textsuperscript{12,37} (n = 225; Fig. 5). Other proprioceptive equipment included an inclinometer\textsuperscript{2,38} (n = 56), laser pointer\textsuperscript{38} (n = 25), goniometer\textsuperscript{38} (n = 25), continuous passive motion device\textsuperscript{47} (n = 10), fabricated laboratory equipment\textsuperscript{39,42,48} (n = 50), purpose built active movement extent discrimination assessment (AMEDA) tool\textsuperscript{35} (n = 24), and motion analysis system\textsuperscript{34,36,43,46} (n = 100). Furthermore, 3 studies conducted a photograph analysis with a goniometer\textsuperscript{36,44,49} (n = 19), 1 study used an Apple fourth-generation iPod touch using internal sensors of the device (accelerometers and gyroscopes)\textsuperscript{41} to evaluate AJPS (n = 24), and finally, 2 studies\textsuperscript{12,16} used a proprioceptive testing device (n = 30).

WA ICC calculations demonstrate that the isokinetic dynamometer is the most reliable tool for measuring shoulder proprioception (intrasession: 0.92 ± 0.08, n = 225), succeeded by the continuous passive motion device (intersession 0.91, n = 10). The least reliable equipment includes the goniometer (intersession 0.6 ± 0, n = 25), motion analysis system (intrasession 0.66 ± 0.27, n = 55), and fabricated lab equipment (intersession 0.69 ± 0.12, n = 30).

Validity, reliability, and responsiveness

All included studies (21) reported a measure of reliability, which included intrarater ICCs (21/21, 100%), interrater ICCs
Table 1
Comparison of psychometric properties of different shoulder proprioception protocols

<table>
<thead>
<tr>
<th>Author and year</th>
<th>n (a)</th>
<th>Proprioception outcome</th>
<th>SEM (95) angular displacement error</th>
<th>MDC (95)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vafadar et al, 2016</td>
<td>25</td>
<td>AJPS (ipsi)</td>
<td>Laser pointer:</td>
<td>Laser pointer:</td>
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<td></td>
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<td></td>
<td>• Inter: 0.8°-1.1°</td>
<td>• Inter: 1.8°-3°</td>
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<td>• Intra: 0.8°-1.1°</td>
<td>• Intra: 2.3°-3.1°</td>
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<td>Inclinometer:</td>
<td>Inclinometer:</td>
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<td>• Inter: 0.8°-1.4°</td>
<td>• Inter: 2.4°-3.9°</td>
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<td></td>
<td>• Intra: 0.9°-1.2°</td>
<td>• Intra: 2.7°-3.4°</td>
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<td></td>
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<td>Interception and intra</td>
<td>Goniometer:</td>
<td>Goniometer:</td>
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<td></td>
<td></td>
<td>session</td>
<td>• Inter: 0.8°-2°</td>
<td>• Inter: 2.4°-5.5°</td>
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<td></td>
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<td></td>
<td>• Intra: 0.7°-2.2°</td>
<td>• Intra: 2.1°-6.2°</td>
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<tr>
<td>Lonn et al, 2000</td>
<td>10</td>
<td>AJPS and PJPS (ipsi)</td>
<td>Passive: 1.02°</td>
<td>Not reported</td>
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<td></td>
<td></td>
<td>Interception</td>
<td>Semi-passive: 0.51°</td>
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<td>Active: 0.54°</td>
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<td>Combined: 0.41°</td>
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<td>Sole et al, 2015</td>
<td>30</td>
<td>TTDPM and RPP (ipsi)</td>
<td>TTDPM: 0.15°</td>
<td>Not reported</td>
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<tr>
<td>Anderson and Wee 2011</td>
<td>20</td>
<td>AJPS (ipsi)</td>
<td>Affected limb</td>
<td>Not reported</td>
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<td>Interception</td>
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<td>Scapular depression</td>
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<td>• Rotation 0.15-0.41°</td>
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<td>• Displacement 0.03-0.08 cm</td>
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<td>Scapular elevation</td>
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<td>• Rotation 0.21-0.49°</td>
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<td>• Displacement 0.08-0.26 cm</td>
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<td>Scapular protraction</td>
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<td>• Rotation 0.46-0.57°</td>
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<td>• Displacement 0.03-0.10 cm</td>
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<td>Scapular retraction</td>
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<td>• Rotation 0.39-0.68°</td>
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<td>• Displacement 0.04-0.20 cm</td>
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<td>Dominant:</td>
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<td></td>
<td>Scapular depression</td>
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<td>• Rotation 0.16-0.62°</td>
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<td>• Displacement 0.02-0.13 cm</td>
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<td>Scapular elevation</td>
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<td>• Rotation 0.27-0.93°</td>
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<td>• Displacement 0.09-0.26 cm</td>
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<td>Scapular protraction</td>
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<td>• Rotation 0.16-0.39°</td>
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<td>• Displacement 0.06-0.23 cm</td>
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<td>Scapular retraction</td>
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<td>• Rotation 0.69-1.13°</td>
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<td>• Displacement 0.08-0.25 cm</td>
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<td>Nodehi-Moghadam et al, 2012</td>
<td>10</td>
<td>TTDPM and RPP (ipsi)</td>
<td>TTDPM: 0.25°</td>
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<td>Suprak et al, 2006</td>
<td>22</td>
<td>AJPS (ipsi)</td>
<td>RPP: 0.29°</td>
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<td>Interception</td>
<td>Plane/elevation (°)</td>
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<td>• 35/30 = 3.99°</td>
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<td>• 35/50 = 3.03°</td>
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<td>• 35/70 = 3.51°</td>
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<td>• 35/90 = 1.90°</td>
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<td>• 0/90 = 3.72°</td>
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<td>• 20/90 = 4.07°</td>
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<td>• 60/90 = 2.55°</td>
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<td>• 80/90 = 2.39°</td>
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<tr>
<td>Kaya et al, 2012</td>
<td>11</td>
<td>AJPS (ipsi)</td>
<td>Eyes open = 4.5°</td>
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<td></td>
<td></td>
<td>Interception</td>
<td>Eyes closed = 3.87°</td>
<td></td>
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</tbody>
</table>

ABD = abduction; AJPS = active joint position sense; CRCP = chronic rotator cuff pathology; MDC (95) = minimal detectable change with a 95% confidence interval; RPP = reproduction of passive positioning; SEM (95) = standard error of measurement with a 95% confidence interval; TTDPM = threshold to detection of passive motion.  
(a) represents the number shoulders evaluated per protocol.
(3/21, 14.28%),33,38,44 standard error of measurement (8/21, 38%),34,37-40,42,43,47 minimal detectable change (2/21, 9.5%)35,39 (Table 1), intratester reliability as a correlation between measurements (2/21, 9.5%),10,40 or a Cronbach alpha value (1/21, 4.76%).44 Only 2 studies (9.5%)38,39 presented validity values, expressed as a Pearson product-moment correlation coefficient (r), with 95% of agreement as an estimate for criterion validity. Vafadar et al (2016) compared their protocol to the Vicon motion capture system and found all 3 of their instruments to have a high correlation to the Vicon: the laser pointer (r = 0.85), inclinometer (r = 0.80), and goniometer (r = 0.77). Deng and Shih15 evaluated the validity of their scapular repositioning error by using a 3-dimensional electromagnetic tracking device and a scale ruler (r = 0.74-0.98). None of the included studies presented any measures of responsiveness.

Discussion

Proprioceptive acumen is essential for the optimization of shoulder neuromuscular control throughout the movement, yet continues to be a quantitative challenge today. Due to the lack of standardization of proprioception terminology and complexity of evaluation methods, it remains an area of psychometric contention. The purpose of this systematic review was to identify and summarize the current methods used for quantifying shoulder proprioception, specifically JPS and kinesthesia. Although shoulder proprioception impairment is deemed extremely important to evaluate and treat during rehabilitation, the protocols currently being used have not been thoroughly psychometrically tested. A proprioceptive outcome that is being used in a clinic without known psychometric qualities can lead to erroneous clinical decisions and provide a false impression that an evidence-based treatment is being used. Our WA values reveal that passive protocols demonstrate greater reliability and that protocols employing IR or ER at 90° of shoulder ABD are the most reliable over time. The isokinetic dynamometer supports the highest reliability measures and is the most used piece of equipment for the evaluation of shoulder proprioception, both for active and passive protocols. Furthermore, our results echo those of previous shoulder proprioceptive studies that there is currently no universally accepted method for quantifying a proprioceptive impairment of the shoulder.14,15,18

Similarly to our results, the systematic review by Hillier et al23 on proprioceptive measurements in the lower back, ankle, knee, and shoulder found few protocols that reported their psychometric properties, putting into question the robustness, and utility of such proprioceptive protocols in a clinical setting.23 Indeed, this has been mirrored by other reviews addressing proprioceptive deficits of the lower back,31 knee,52,53 and ankle34 which reported moderate-to-good psychometric properties at best. Moreover, these articles point out the small sample sizes of proprioceptive studies, suggesting overall weak statistical power and thus offering no clear guidelines for clinicians. Although Han et al15 more recently performed a thorough literature review of proprioceptive evaluation methods for the ankle, knee, and shoulder, they did not report any associated psychometric properties. Our review reports the psychometric values of shoulder proprioceptive protocols, thereby contributing to a more comprehensive and complete review of the current literature. This review provides clinicians with the confidence to use an outcome measure or protocol that is based on scientific support. Han et al15 did, however, outline the importance of a proprioceptive outcome demonstrating strong ecological validity,15 so that it may in turn be used in a clinical environment.

Ecological validity and the clinical application of proprioception

In addition to strong psychometric properties, a proprioceptive outcome must support a secure sense of ecological validity, which can be understood as “maintaining the integrity of the real-life situation in the experimental context while remaining faithful to the larger social and cultural context.”55,56 When evaluating proprioception, it is important that the procedures maximize the similarities between the testing setting and real-life functionality.55 From our review, kinesthesia measures demonstrated stronger reliability. This can be attributed to the fact that movement threshold testing relies solely on passive movements and structures,27-28 arguably better representing our afferent sensory feedback processing or proprioceptive sense.23,44 However, functional daily activities are performed predominantly with the use of our active muscular system,31,59,60 which is not activated during TTPDM except when stretched to end range. It can be said that active position-matching tasks are a stronger indicator of joint function than passive protocols.42,63,61,62 As such, although the TTPDM has a higher conceptual purity of proprioception,42 it conceivably has lesser ecological validity, which puts its true applicability in a clinic into question.

It is our deduction that the active protocols presented by Vafadar et al38 are the only shoulder proprioception evaluation methods included in this review that are applicable in a clinic. Because of their use of common clinical tools, notably the goniometer, inclinometer, and laser pointer, and their relatively simple trigonometry-based scoring system, their methods could prove the most technically simple, as well as cost and time efficient for clinicians.

Proprioception relies on the multicomponent sensory feedback from the tactile, vestibular, and visual systems,3,163 which are then integrated and processed on both the conscious and unconscious levels.52 To maintain a clinical orientation and strong ecological validity for our recommendations regarding shoulder protocols, our systematic review focused on JPS and kinesthetic awareness, both of which are conscious submodalities of proprioception.55 We further chose to take a functional approach to the review and consequently did not explore the possibility of the direct physiological measurement of proprioceptive neural pathways or the direct excitability of mechanoreceptors. Such methods generally involve complex and invasive experimental procedures that are not always readily available or applicable for clinicians.

Lack of standardization

Because of the lack of standardization of the included studies, we were unable to pool our findings into a meta-analysis. The clear lack of commonalities between the protocols could be due to the particular challenge of quantifying proprioceptive impairments of a joint as mobile as the shoulder. Shoulder proprioception protocols demonstrated inconsistencies with regards to warm-up sessions, number of evaluated trials, rest periods between trials, and tactile feedback during limb manipulation. To overcome the lack of standardization, it is our recommendation that researchers and clinicians place greater emphasis on a detailed description of their protocols and their reproducibility, to encourage others to use the same protocol, thereby favoring benchmarking and increasing the statistical power and clinical applicability of their results.

Strengths and limitations of the review

The strengths of this review include the exhaustive search of the literature including 5 scientific databases and hand searches. The use of validated critical appraisal tools facilitated our systematic evaluation of the quality of the studies and the psychometric
properties of their protocols. The checklists used also act as a limiting factor, seeing as the objective quality ratings of each article depended on the selected checklist. The QualSyst checklist was limiting for our review because of our inclusion of mostly methodological studies. Although the QualSyst is appropriate for both randomized and nonrandomized studies, the total score does favor a randomized study design, thus potentially introducing a bias into our review which is comprised mostly of nonrandomized studies. The COSMIN 4-point checklist was also limiting because of the descriptions of each scoring category, which were frequently either lacking or unclear, thus leaving room for interpretation, introducing a bias to the awarded scores and lowering our interrater level of agreement. Further limitations include the narrowing of the definition of proprioception assessment to JPS and kinesthesia, as well as only considering articles written in English or French. Future work should include the assessment of other aspects of joint proprioception, notably the detection of vibration, muscle tension, muscular force, and velocities.

Moreover, only 19% (4 of 21) of the articles included in this systematic review were primary psychometric studies, meaning that their fundamental goal was to evaluate the robustness of their scientific method. The remaining 81% (17 of 21) of the included studies responded to a scientific question first and a psychometric inquiry second, potentially introducing a bias to the relative awarded scores of the modified checklists. Finally, the lack of validity and responsiveness studies remains a major limitation for the conclusions that can be associated with measuring shoulder proprioception.

Conclusions

The included studies of this review suggest that protocols that use IR or ER at 90° of ABD at the shoulder are most reliable. According to our WA calculations, JPS is the most reliable method for evaluating JPS and TTDPM for kinesthesia. The dynamometer currently has the greatest reliability potential; however, due to its cost, time-consuming installation, and the intricacies of the protocols, its applicability in a clinical setting remains questionable. The exact mechanisms of proprioceptive control at the shoulder remain unclear and should thus be interpreted with caution. Outcome measures for the evaluation of proprioception are limited by their complexity and use of intricate custom-built and electronic interfaces and are therefore difficult to apply to a clinical setting.55

Take home message for clinicians

To quantifiably appreciate proprioceptive impairments and physical limitations in a clinical setting, it is imperative to use evidence-based and psychometrically robust protocols. From the results of this review, we can encourage the preliminary use of a shoulder proprioceptive protocol which uses an isokinetic dynamometer, such as the Biodex, for either a passive protocol (JPS) or a detection of movement protocol (kinesthesia), evaluating the movements of IR or ER at 90° of shoulder ABD. Such methods support the strongest reliability measures over time and represent the best method for quantifying shoulder proprioceptive deficits in the clinic at this time.55

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Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jht.2017.05.003

References

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Quiz: #483

Record your answers on the Return Answer Form found on the
tear-out coupon at the back of this issue or to complete online
and use a credit card, go to JHTReadforCredit.com. There is
only one best answer for each question.

#1. The article design is
   a. prospective
   b. RCTs
   c. a case series
   d. a systematic review

#2. To evaluate proprioception it is key to evaluate
   a. coordination
   b. strength
   c. kinesthesia and joint position sense
   d. sensibility

#3. Two properties measured were
   a. TTDPM and RPP
   b. AROM and PROM
   c. MMT and 2PD
   d. IBM and GNP

#4. The strongest reliability was found to be
   a. AROM
   b. PJPS
   c. PROM
   d. TTDPM

#5. Shoulder proprioception assessment remains a subject of psy-
chometric contention
   a. false
   b. true

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