JSES Reviews, Reports, and Techniques 5 (2025) 922–930

Contents lists available at ScienceDirect

JSES Reviews, Reports, and Techniques

journal homepage: www.jsesreviewsreportstech.org

Proprioceptive deficits following a traumatic anterior shoulder instability: a systematic review

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ARTICLE INFO

Keywords:
Anterior shoulder dislocation
Proprioception
Proprioception deficit
Shoulder instability
Systematic review
Traumatic injury

Level of evidence: Level IV; Systematic Review

Background: Proprioception, our limb awareness in space, plays a vital role in maintaining shoulder stability through neuromuscular control. Following traumatic anterior instability (TAI), proprioceptive deficits can exist, potentially impairing upper limb function. However, the extent and nature of these deficits vary, with each injury potentially presenting unique proprioceptive deficit profiles. The aim of this systematic review was to summarize the available evidence on proprioceptive deficits following TAI, compared to healthy controls, or the contralateral upper-limb.

Methods: Literature was searched in PubMed, Scopus, Academic Search Premier, and SPORTDiscus databases from inception until December 2024. Selected articles were systematically assessed, and the methodological quality was established using the JBI Critical Appraisal Checklist. Included articles focused on TAI and conscious proprioceptive testing, including comparison with healthy controls or the unaffected arm. Data were systematically extracted concerning study design, participant demographics, type of surgery and surgical status, proprioception subcategories, proprioception outcome measures, and study findings.

Results: Fifteen studies met the inclusion criteria, with nine scoring five or higher on the JBI Critical Appraisal Checklist, indicating a low risk of bias. Proprioceptive deficits were observed in individuals with TAI before surgery and up to 6 months postsurgery, compared to the unaffected limb and or control group, although some studies reported no significant differences. Deficits, in general, were reported as resolved eight months postsurgery. Variability in results across studies emphasized the importance of evaluating the different subcategories of proprioception to identify specific proprioception deficits in a population affected by TAI.

Conclusion: This review confirms that proprioceptive deficits are present with TAI, across proprioception sub-categories. Deficits can be identified through different proprioception outcomes; however, proprioceptive outcomes vary based on, for example, testing methods, timings, and joint angles. Future research should focus on developing consistent proprioceptive outcome measures to enhance clinical reliability and applicability for clinicians working in rehabilitation.

Shoulder instability is prevalent in sports medicine, especially among young male athletes.[32] Despite its high occurrence, the precise definition of shoulder instability remains ambiguous due to the lack of consensus on its classification.[40] Kuhn (2010)[25] proposed a classification system based on several factors, including the frequency of occurrence (first-time vs. recurrent), etiology (traumatic vs. nontraumatic), direction (anterior, posterior, inferior, or multidirectional), and severity (subluxation vs. dislocation). Shoulder instability can result from both traumatic and atraumatic mechanisms, with dislocation being the primary event causing traumatic anterior instability (TAI). The most prevalent form of TAI occurs following a traumatic anterior dislocation of the humeral head within the glenoid fossa, which accounts for over 90% of instability cases,[40] with dislocation rates reaching up to 3% per year.[32,46] Traumatic dislocation often compromises mechanical restraints and damages mechanoreceptors and proprioceptors, which are essential for the sense of proprioception.

Institutional review board approval was not required for this systematic review.

The study was registered with PROSPERO under the title "Proprioceptive Deficits in Traumatic Anterior Instability: A Systematic Review" (CRD42020209136).

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https://doi.org/10.1016/j.xrrt.2025.08.001
2666-6391/

Proprioception, a critical component of the somatosensory system, can be understood as sensory inputs for self-position and movement awareness.[37] It includes joint position sense (JPS; active and passive), kinesthesia, sense of force (SoF), and velocity (SoV),[3] as well as senses like vibration, pressure, and balance.[35] Consequently, TAIs affect mechanical and sensorimotor components, essential to maintaining dynamic shoulder stability. Studies have shown that a decreased sense of proprioception is associated with shoulder instability.[29,35]

Proprioception outcome measures have become more common to evaluate the efficacy of rehabilitation interventions. Often, proprioception outcomes will measure proprioceptive accuracy (PA), an individual's ability to perceive proprioceptive information,[8] through quantifying the proprioceptive error (PE). A PE, the difference between a targeted position, force, or angle and the participant's reproduced estimation, can be presented in centimeters, newton, or joint angles.[3,5] Various methods exist for measuring proprioception.[14,19] These include, but are not limited to, active or passive JPS (AJPS or PJPS),[4,19] active movement extent discrimination apparatus,[6] threshold to detection of passive motion (TTDPM), and force or velocity reproduction tests.[11] Rehabilitation approaches for TAI are multifaceted and often include elements of joint mobilization, strengthening, and functional exercises to improve proprioception and neuromuscular control.[24] Indeed, enhancing shoulder proprioception is the key in TAI rehabilitation to restore motor control and prevent gleno-humeral (GH) joint instabilities. Recent systematic reviews on proprioceptive deficits in patients with shoulder injuries or pain have reported inconsistent findings, suggesting that proprioception is dependent on the specific pathology, joint, and the type of test used.[2,16] PA may also vary based on specific stimuli, such as the speed of motion or target joint position.[20]

Given that TAI is one of the most common causes of shoulder instability and reoccurring dislocations, especially among young athletes, it is important to understand proprioceptive deficits specific to this condition. Although understanding of shoulder proprioception has advanced, clinicians still lack a comprehensive overview linking specific proprioceptive deficits to particular pathologies such as TAI. By focusing on deficits of the different proprioception subcategories (JPS, kinesthesia, SoF, SoV), this review aims to provide a clear synthesis of current knowledge on proprioceptive deficits among individuals affected by TAI. It also offers avenues for future research and helps clinicians better understand the factors that may influence proprioceptive measurements, allowing them to integrate this understanding into the design of more effective rehabilitation programs.

Material and methods

The systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.[33]

Search strategy

A systematic search of abstracts and titles of articles was conducted across multiple databases (PubMed, Scopus, Academic Search Premier, and SPORTDiscus), without limiting the search to free-text articles or publication dates. Filters were applied for human participants and studies published in English. The search was initially conducted in January 2023 and repeated in December 2024. A proprioceptive deficit was defined as a reduction, or impairment, in PA when comparing the injured upper limb to the contralateral healthy upper limb or control group (CG). To account for the varying definitions of shoulder instability, studies involving participants with either a first-time episode or recurrent shoulder dislocation were included, encompassing instabilities by dislocation or subluxation of the GH joint. Only instances of anterior instability with a traumatic injury mechanism were considered.

Inclusion criteria required confirmed instability through surgery, diagnostic imaging, a need for reduction, clinical testing with apprehension and relocation tests, or any other study detailing at least one episode of traumatic anterior dislocation of the shoulder. The search strategy systematically covered all aspects of conscious proprioception,[23] including AJPS and PJPS, kinesthesia (often measured using TTDPM), SoF and SoV. We did not include studies examining senses of vibration, pressure, tension, or balance. The search strategy characteristics as well as the inclusion and exclusion criteria are detailed in Table I.

Study selection

Following the removal of duplicates across different databases, two independent reviewers (X.A. and M.F.) screened the titles and abstracts of each study to identify studies that might meet the eligibility criteria. Studies that appeared to satisfy the inclusion/exclusion criteria, or those whose eligibility could not be determined from the title/abstract screening, were retrieved for a full-text review. Both reviewers (X.A. and M.F.) independently

Table I
Search strategy.

Keyword	("Proprioception"[mesh] OR Proprioception[tw] OR "Vestibular Sense"[tw] OR "Sense of Equilibrium"[tw] OR "Equilibrium Sense"[tw] OR "Labyrinthine Sense"[tw] OR "Position Sense"[tw] OR "Posture Sense"[tw] OR "Sense of Position"[tw] OR kinematic[tw] OR "proprioceptive information"[tw] OR "Joint position awareness"[tw]) AND ("Joint Instability "[mesh] OR "Joint Instabilities"[tw] OR "Joint Hypermobilities"[tw] OR "Joint Hypermobility"[tw] OR "Joint Laxities"[tw] OR "Joint Laxity"[tw] OR "surgically repaired"[tw] OR "unstable shoulders"[tw] OR "traumatic anterior dislocation[tw]" OR "shoulder dislocation"[tw] OR "previously injured"[tw] OR "Joint instability"[tw]) AND ("Shoulder Joint"[Mesh] OR "Shoulder"[Mesh] OR shoulder[tw] OR "Glenohumeral Joint"[tw] OR "Glenohumeral Joints"[tw] OR "Glenoid Labrum"[tw] OR "acromioclavicular joint"[tw] OR "acromioclavicular joints"[tw] OR "coracoclavicular joint"[tw] OR "coracoclavicular joints"[tw] OR "scapulothoracic joint"[tw] OR "scapulothoracic joints"[tw] OR "sternoclavicular joint"[tw] OR "sternoclavicular joints"[tw])
Database	PubMed, Scopus, Academic Search Premier, SPORTDiscus
Date	No restrictions on date of publication
Language	English only
Document type	Peer-reviewed article
Inclusion criteria	
Population	Traumatic anterior instability
Intervention	Any intervention including observational and interventional study
Comparison	Nonaffected upper limb and/or control group
Outcome	Proprioceptive accuracy through one or more conscious proprioceptive outcome measures (JPS/kinesthesia/SoF/SoV)
Exclusion criteria	Multidirectional instability, posterior luxation, hyperlaxity patients, and studies not related to shoulder joint or case study.

JPS, joint position sense; *SoF*, sense of force; *SoV*, sense of velocity.

assessed the full texts of each study. Any disagreements between the two reviewers were resolved through consultation with a third reviewer (J.V.C.), who was blinded to the decisions made by the other reviewers.

Data extraction and quality assessment

A standardized data extraction form was used to gather the following information systematically: author(s) and year of study, study design, sample size, age, sex, number of dislocation episodes, type of surgery (if applicable), time of measurement, included shoulders, proprioception submodalities, and proprioceptive outcome measures (Supplementary Appendix SI). The quality of the included studies was assessed using the JBI Critical Appraisal Checklist for analytical cross-sectional studies.[34] The checklist has eight questions, examining the inclusion criteria, participants, exposure measurement, objective and standard criteria, confounding factors, strategies for confounding factors, outcome measures, and statistical analysis for each study. Each question is answered with “yes”,” no”, or “unclear”. A score of “yes” for more than 5 responses indicates high methodological quality, whereas a “yes” for 3–4 responses indicate moderate quality, and 0–2 “yes” responses indicate low methodological quality.

Results

Study selection

A total of 603 studies were identified. After using Rayyan.ai (Rayyan Systems Inc., Cambridge, MA, USA) to remove 280 duplicates, 323 records remained. Following title and abstract screening, 288 studies were excluded. Of the 35 remaining studies, 20 were excluded after reading the full-text, resulting in 15 studies for the inclusion in this systematic review (Fig. 1). Among the 15 included studies, 11 were cross-sectional studies,[7,8,12,13,15,21,28,30,39,42,43] and 4 were prospective studies.[27,38,44,48] The full data extraction is available in Supplementary Appendix SI.

Population

To further guide clinicians, individuals affected by a TAI were divided into two subgroups: those who underwent surgery (TAIS) and those who did not (TAINS). Descriptive results are presented in terms of participant demographics, proprioceptive outcome measures, and study results. Regarding the assessment of TAI, three studies provided specific details on how the initial diagnosis was confirmed; which included using the apprehension test[7,12] and radiography.[13] The remaining 12 studies noted the occurrence of TAI following at least one dislocation episode but did not provide additional details.

Demographics

In total, this review included 771 injured participants across all groups. The TAINS group was derived from 10 of the 15 included studies,[8,13,21,27,28,30,38,42,44,48] representing 386 participants, including 273 males (91%) and 28 females (9%), with a mean age of 27 (±4) years. Two studies did not report the sex ratio.[38,48] The TAIS group comprised 385 participants from 9 of the 15 reviewed studies,[7,12,15,27,38,39,43,44,48] consisting of 254 males (86%) and 43 females (14%), with a mean age of 26 (±4) years. Three studies did not report the sex ratio.[38,39,48]

Subcategories of proprioception

Regarding proprioceptive subcategories, assessments with the TAINS participants, AJPS was assessed in 4/10 (40%) studies,[13,21,28,44] PJPS in 7/10 (70%) studies,[12,21,27,30,38,42,48] and TTDPM in 5/10 (50%) studies.[12,27,38,42,48] Regarding TAIS participants, AJPS was evaluated in 3/9 (33.3%) studies,[7,39,44] PJPS in 6/9 (66.7%) studies,[12,15,27,38,43,48] and TTDPM in 4/9 studies (44.4%).[12,27,38,48]

Outcome measures

Joint position sense

In all studies investigating AJPS or PJPS, participants performed an ipsilateral angle reproduction task, with PEs measured in degrees between the target angle and the reproduced angles. The PEs were reported as mean values over several trials.

Kinesthesia

For kinesthesia, TTDPM was measured by recording the angular displacement in degrees at which participants detected passive movement. The angular displacement was also reported as a mean value over multiple trials.

Sense of force and velocity

No studies were identified for reporting an outcome of SoF or SoV.

Risk of bias

Of the 15 included studies, nine (60%) were rated as having a low risk of bias, with scores above 5/8.[22,23,25,26,28,30,31,34,36] Six studies (40%) were rated as having a moderate risk of bias, scoring above 3/8.[8,15,28,38,42,48] Common methodological shortcomings across the studies included unclear diagnosis criteria and the absence of statistical analyses to address potential confounding factors (see Table II for detail).

Synthesis of results

Based on statistical analyses of the included studies, two main comparisons were used to assess proprioceptive deficits following TAI: (1) affected vs. the unaffected contralateral upper limb and (2) affected side vs. a healthy CG, either dominant or nondominant upper limbs. In addition, four factors were identified that could influence PA results: (1) testing angle (same upper limb tested at different joint angles); (2) time of the progression on the injury (presurgery vs. postsurgery and/or postsurgical comparisons); (3) surgical intervention (same upper limb tested with various surgical techniques); and (4) the number of dislocations (affected upper limb vs. affected upper limb among different subpopulations). A detailed summary of the proprioceptive deficits, or lack thereof, is provided for each subcategory of proprioception, AJPS, PJPS, and kinesthesia, in Figures 2-4, respectively.

Active joint position sense

Affected upper limb vs. a control group

Two studies involving TAINS participants reported conflicting results with the movement of abduction in the frontal plan. One study found that the CG outperformed the injured side with differences of 46% at 60°, 31% at 90°, and 25% at 120°.[28] By contrast, Hung et al[21] reported no significant differences at 45°, 90°, and 135° of abduction. Concerning flexion, 1 study on TAINS participants found that the CG exhibited an improved PA, with differences of 22% at 90° and 27% at 120° of flexion.[28] Similarly, with TAIS participants, the CG outperformed the injured upper limb, with differences of 50% at 40° and 57% at 100° of flexion.[39]

In external rotation, findings were inconsistent across three studies involving TAINS participants. Two studies showed higher

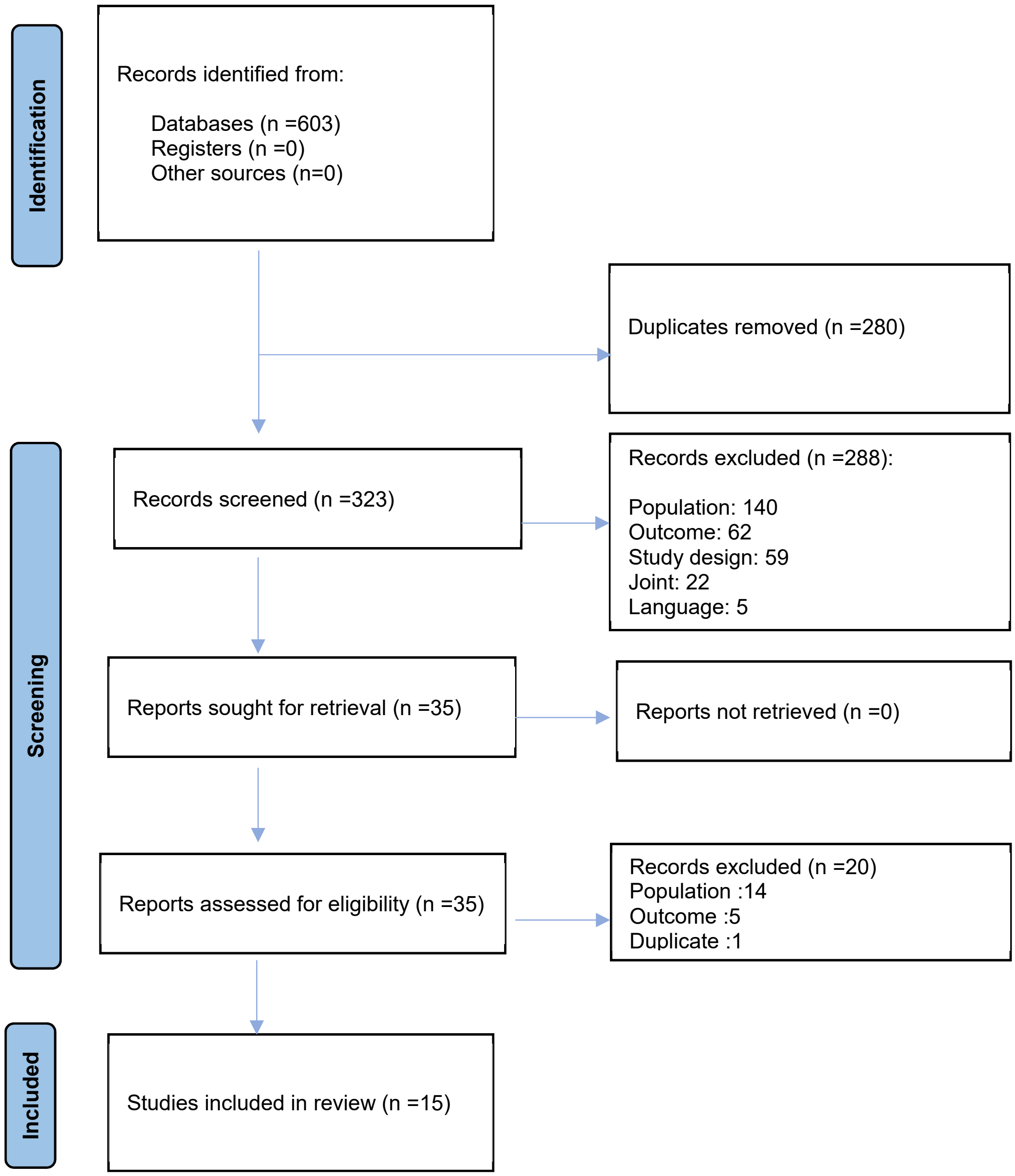

Figure 1 Systematic review of inclusion according to PRISMA guidelines. *PRISMA*, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

PA for the CG, with differences of 19% at 45°, 25% at 60°,[28] and 22% at 75°.[44] However, Hung et al found no significant differences at 45° and 75°. For internal rotation, two studies on TAINS participants also reported mixed results: 1 observed a 11% higher PA for the CG at 30°,[28] whereas Hung et al[21] reported no differences at 45°. Angle-specific variations were noted in flexion, where PA was 35% lower at angles below 60° and 41% lower at angles above 120° in TAINS participants.[28] In abduction, PA was reduced by 34%, 41%, 35%, and 34% at 45°, 60°, 120°, and 135° respectively, compared to 90°.[21,28] Following surgery, PA showed significant improvements, with gains of 22% at 6 and 12 months and 23% at 36 months at 75° in external rotation.[44]

Affected vs. Unaffected

Two studies reported conflicting findings regarding abduction, flexion, and external rotation in TAINS participants. Zuckerman et al[48] observed better PA in the unaffected upper limb, with differences of 53% at 40° flexion, a 55% at 40° abduction, and 49% at 20° external rotation. In contrast, Lubiatowski et al[28] found no significant differences at 60°, 90°, or 120° in flexion and abduction, nor at 30° and 45° in external rotation. For internal rotation, Lubiatowski et al reported a 42% difference favoring the unaffected side at 30°.[28]

In TAIS participants, Zuckerman et al[48] reported that the unaffected side outperformed the affected side, showing a 31% difference at 40° flexion and a 37% difference at 40° abduction six months post-urgery. Conflicting results were noted for external rotation. Zuckerman et al[48] reported a 27% difference favoring the affected side at 20° external rotation at six months postsurgery. However, Aydin et al[7] found no significant differences at 10° and 30° external rotation at 10 months postsurgery. Although post-surgical improvements in PA were observed, deficits persisted in

Table II
Joanna Briggs Institute critical appraisal tools for risk of bias.

Observational: Cross-sectional study	Total (/8)	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Aydin Yavuz Yildiz et al, 2001[7]	4	U	Y	Y	U	N	N	Y	Y
Edmonds et al, 2003[12]	5	Y	Y	Y	U	U	U	Y	Y
Eshoj et al, 2019[13]	6	Y	Y	Y	Y	U	U	Y	Y
Fremerey et al, 2006[15]	4	Y	U	Y	U	N	N	Y	Y
Hung et al, 2012[21]	5	Y	Y	Y	U	N	N	Y	Y
Lubiatowski et al, 2018[28]	4	Y	Y	Y	U	N	N	U	Y
Balke et al, 2011[8]	5	Y	Y	Y	U	N	N	Y	Y
MORNIEUX et al, 2018[30]	5	Y	Y	Y	U	N	N	Y	Y
Sayaka et al, 2021[39]	4	Y	U	Y	U	N	N	Y	Y
Smith et al, 1989[42]	4	Y	Y	Y	U	N	N	U	Y
Sullivan et al, 2008[43]	5	Y	Y	Y	U	N	N	Y	Y
Observational: prospective study									
Lephart et al, 1994[27]	5	Y	Y	Y	U	N	N	Y	Y
Rokito et al, 2010[38]	5	Y	Y	Y	U	N	N	Y	Y
Tsuda et al, 2020[44]	5	Y	Y	Y	U	N	N	Y	Y
Zuckerman JD et al, 2003[48]	5	Y	Y	Y	U	N	N	Y	Y

N, no; *Q*, question; *U*, unknown; *Y*, yes.

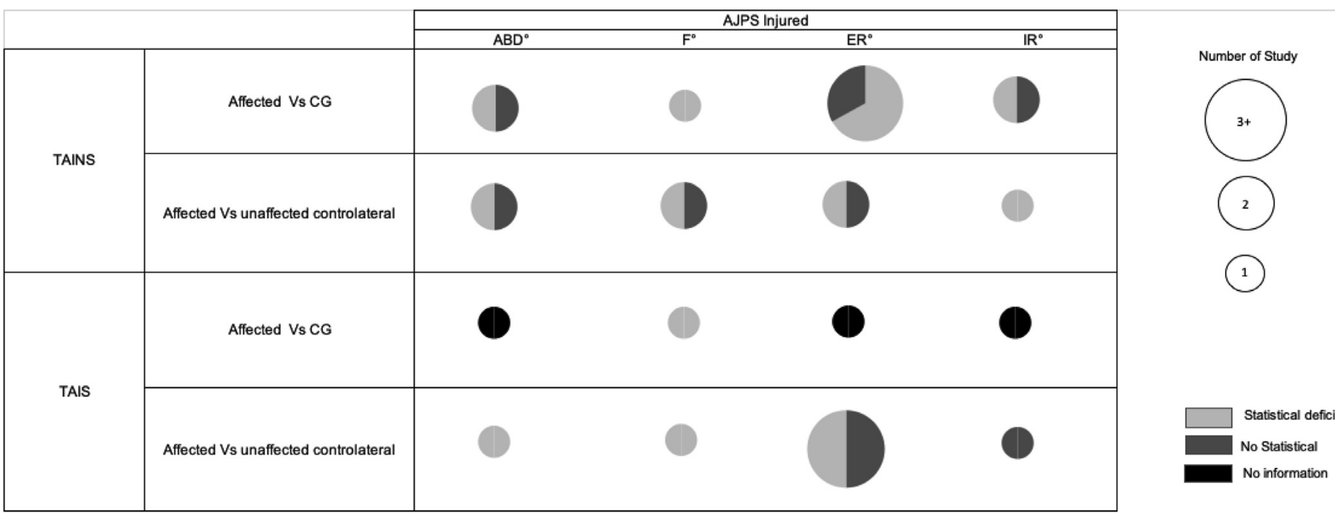

Figure 2 Evidence on AJPS deficits after traumatic anterior instability. *ABD*, abduction; *AJPS*, active joint position sense; *CG*, control group; *ER*, external rotation; *F*, flexion; *IR*, internal rotation; *TAINS*, traumatic anterior instability without surgery; *TAIS*, traumatic anterior instability with surgery.

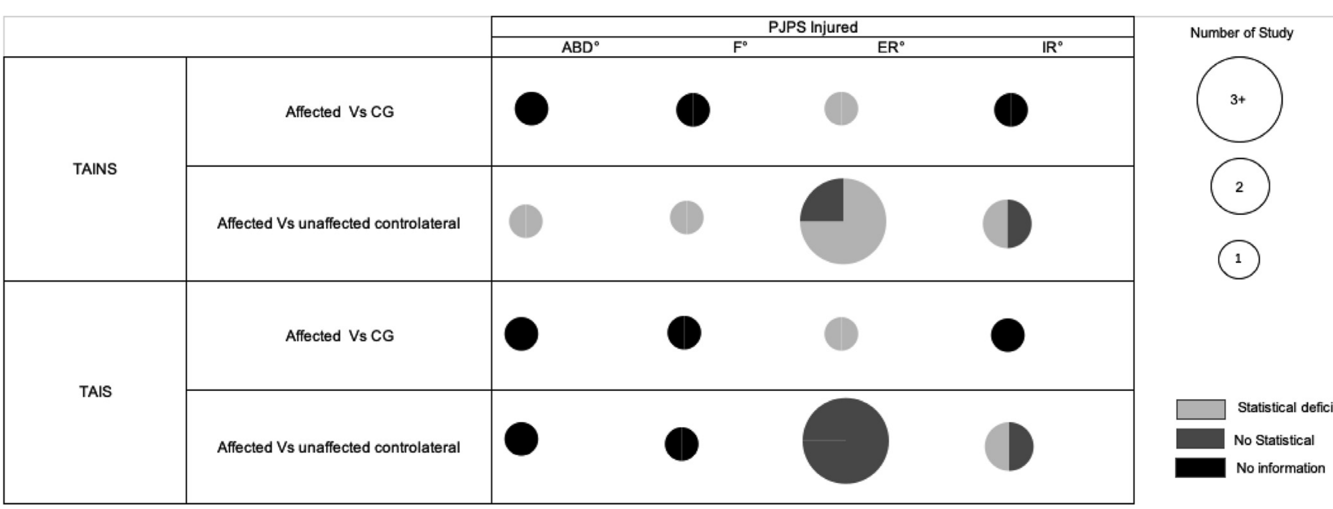

Figure 3 Evidence on PJPS deficits after traumatic anterior instability. *TAINS*, traumatic anterior instability no surgery; *ABD*, abduction; *CG*, control group; *ER*, external rotation; *F*, flexion; *IR*, internal rotation; *PJPS*, passive joint position sense; *TAIS*, traumatic anterior instability with surgery.

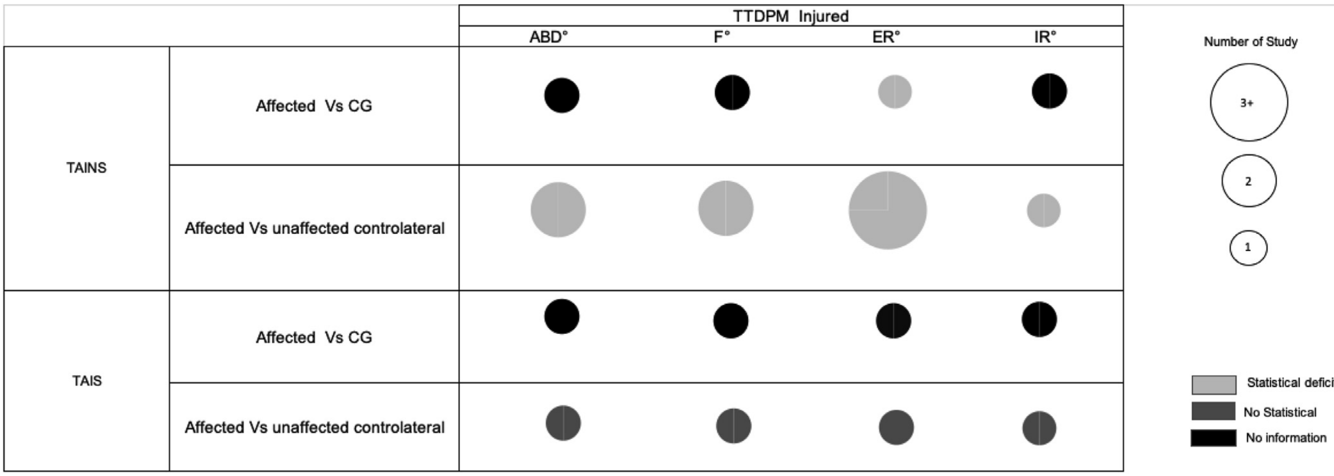

Figure 4 Evidence on TTDPM deficits after traumatic anterior instability. *ABD*, abduction; *CG*, control group; *ER*, external rotation; *F*, flexion; *IR*, internal rotation; *TAINS*, traumatic anterior instability without surgery; *TAIS*, traumatic anterior instability with surgery; *TTDPM*, threshold to detection of passive movement.

the affected upper limb at six months for flexion, abduction, and external rotation.[48] By 12 months, no significant differences were noted between the affected and unaffected upper limbs, indicating recovery in PA over time.[48]

Passive joint position sense

Affected vs. control group

The CG exhibited superior PA, particularly in internal rotation at 45°, with a 43% difference for TAINS participants.[21] Conflicting results were observed in external rotation. One study reported better PA for the CG at mid-range (45% difference) and at end-range (53% difference) in the nondominant upper limb compared to the injured side.[42] However, Hung et al[21] found no statistical differences at 45° and 90° external rotation in TAINS participants. For TAIS participants, 1 study found improved PA for the CG in external rotation at mid-range with a 33% difference.[43] Despite this, no significant differences were observed in external rotation testing angles for both TAINS[21] and TAIS participants across multiple studies.[12,43]

Affected vs. unaffected

The comparison between the affected upper limb and the unaffected contralateral limb revealed consistently better PA in in the unaffected upper limb among TAINS participants. Specifically, in flexion, the unaffected upper limb demonstrated a 61% higher PA difference at an unspecified angle,[38] whereas in abduction, the difference reached 67%.[38] For external rotation, conflicting results were reported. Three studies reported superior PA in the unaffected upper limb, with differences of 56% at an unspecified angle,[38] 21% at 40°,[27] 61% at mid-range, and 67% at end-range.[42] However, 1 study found no significant difference at 20° of external rotation.[30] Similarly, for internal rotation, two studies produced mixed findings. While 1 study identified a 20% difference favoring the unaffected side at 20°,[27] another study reported no difference at the same angle.[30]

In TAIS participants, the findings were more consistent. For external rotation, three studies reported no significant differences at 10°,[27] 45°,[15] mid-range, and end-range.[43] However, in internal rotation, conflicting results were noted. One study reported a 36% higher PA in the unaffected upper limb at 45°,[15] whereas another study found no difference at 10°.[27]

Postsurgical outcomes demonstrated persistent deficits with the affected upper limb at six months. The unaffected upper limb continued to perform better, with a 53% higher PA in flexion, 55% in adduction, and 49% in external rotation.[38] The type of surgery also appeared to influence PA outcomes. Open surgeries showed a 41% improvement, whereas thermal surgeries demonstrated a 39% improvement, both of which outperformed arthroscopic surgery in mid-range external rotation at 50°.[43] Furthermore, patients who underwent inferior capsular shift surgery exhibited better PA than those who had anterior capsulolabral reconstruction, with differences of 55% in abduction, 53% in flexion, and 49% in external rotation.[38] No significant differences in external rotation PA were observed between TAINS and TAIS participants.[12]

Threshold to detection of passive motion

Affected vs. control group

When comparing TTDPM, significant differences were found favoring the CG, particularly in external rotation. Specifically, TAINS participants exhibited a 54% lower PA at mid-range and a 59% lower PA at end-range compared to the CG.[42]

Affected vs. unaffected

For TAINS participants, the unaffected side demonstrated superior PA in flexion and abduction, particularly at 40° and an unspecified angle, with differences of 21% and 13%, respectively.[38,48] In external rotation, four studies showed superior PA in the unaffected side at 10°,[27] 20°,[27,48] and an unspecified angle,[38,42] with reported differences ranging from 24%[38] to 65%.[42] For internal rotation, a 31% difference favoring the unaffected side was observed at 10°.[27] In contrast, for TAIS participants, no significant differences in PA were reported across all movement types. Furthermore, no differences were found between TAINS and TAIS participants in external rotation[12] or over time in abduction, flexion, and external rotation.[38]

Discussion

This review aimed to investigate the suspected proprioceptive deficits across the different subcategories of proprioception following a TAI of the shoulder. Proprioceptive deficits were identified among TAINS participants when comparing the affected side to both a CG and the unaffected contralateral upper limb in abduction, flexion, external rotation, and internal rotation for AJPS. During passive testing (PJPS) and kinesthetic testing (TTDPM), deficits were observed in external rotation when compared to a CG, as well as in abduction, flexion, external rotation, and internal rotation when compared to the contralateral unaffected upper limb. Few significant differences were reported among AJPS, PJPS, and TTDPM outcomes among TAIS participants, with only 1 study reporting a persistent deficit beyond six months with AJPS repositioning in shoulder flexion.[39]

These findings partially align with those from a previous systematic review and meta-analysis by Fyhr et al[16] which included 15 studies summarizing the effects of shoulder injuries on kinesthesia (sense of movement). Fyhr et al[16] found moderate evidence of worse PA with TTDPM when comparing patients to a CG. Moreover, they also found a reduced PA in JPS, both AJPS and PJPS, when comparing the affected shoulder to the unaffected contralateral side. However, no significant differences were observed in JPS between patients and controls overall. When analyzed individually, specific movements, particularly abduction and external rotation, showed significant deficits, as also observed in this review.

It is worth noting that our findings differ from their results in several key ways. Unlike Fyhr el al,[16] we did not identify proprioceptive deficits through TTDPM testing. Also, we found distinct differences in AJPS and PJPS that were not fully reflected in their meta-analysis.[16] These discrepancies may be due to variations in the study design. Fyhr et al[16] included a broad range of shoulder pathologies—such as TAI, multidirectional glenohumeral instability, shoulder impingement syndrome, chronic rotator cuff pain, and nonspecific shoulder pain—and combined all movement directions in their analysis. By contrast, our study focused exclusively on TAI and presented results in clusters (injured/uninjured; with/without surgery; and contralateral limb/CG) without performing a meta-analysis, given the heterogeneity of the included studies. In addition, based on recent evidence,[20] we categorized proprioceptive submodalities (AJPS, PJPS, kinesthesia, SoF, and SoV) and performed analyses by two main comparison groups (affected vs. CG, affected vs. unaffected limbs). This approach provided more detailed patterns of proprioceptive deficits specific to TAI. Horváth et al[20] suggest that PA may not be universal. Instead, PA may vary according to the bodily location, proprioception outcome measure, or specific pathology or injury.[10,20] Instead, no consistent associations have been found between results from different proprioceptive outcomes across different body parts or joints,[20] meaning that there may not be a transferable proprioception ability across the body.

From an anatomical and physiological perspective, the senses of movement (kinesthesia) and position (JPS) are indeed distinct.[35] The sense of movement, as assessed through TTDPM, primarily relies on muscle spindle discharge. In contrast, the sense of position, as evaluated by AJPS, involves thixotropic changes in muscle spindles and other slowly adapting mechanoreceptors. Active motion, which involves both afferent (feedback from muscle spindles) and efferent (motor command) signals, has been shown to improve proprioception accuracy,[18] and are more representative of daily activities (better ecological validity).[9] Likewise, greater PA has been found with AJPS compared to PJPS testing.[45] Therefore, combining different proprioceptive categories, such as PJPS and AJPS, into a single score offers limited clinical values and may create confusion for both clinicians and researchers.

Recently, Horvath et al[20] identified the following eight aspects to proprioception: joint position, movement extent, trajectory, velocity, force, muscle tension, weight, and object shape or size (stereognosis). Each aspect can be assessed using psychophysics methods, such as the method of adjustment, the method of constant stimuli, and the method of limits.[19] However, our review only focused on joint position, movement detection, SoF, and SoV. Our review did not find any studies exploring the SoF or SoV, nor did we consider the proprioceptive aspects of trajectory, tension, weight, or object size—leaving many areas within the proprioceptive realm unexplored.

When compared to healthy CGs, the affected upper limb exhibited lower PA than both the dominant and nondominant upper limbs; highlighting the significant impact of TAI on PA.[28,38,48] These deficits have been observed up to 11 months postinjury in TAINS participants.[21] Before surgical intervention, injuries affecting the capsule, labrum, ligaments, and surrounding muscles can damage neural mechanoreceptors essential for proprioceptive sensation, potentially contributing to persistent shoulder joint instability. Moreover, restricted activity due to shoulder instability may reduce overall proprioceptive ability due to reconditioning, whereas anxiety and behavioral factors can further disrupt central neuromuscular control and adaptations on the injured side.[27,28] This disruption could partially explain the observed differences between the affected shoulder and the CGs.

In addition to the deficits observed in comparison with healthy CGs, analyzing proprioceptive differences between the affected and unaffected upper limbs reveals potential bilateral implications of unilateral shoulder injury. Recent theories suggest that TAI may impair the proprioception of the injured side and lead to deficits in the opposite, uninjured shoulder.[28] Some studies have identified increased bilateral brain connectivity in patients with unilateral shoulder apprehension, suggesting that cognitive processes related to apprehension may be generalized and not specific to the side of the shoulder instability.[18] It is interesting to consider evidence of a neural laterality effect, or sharing of proprioception information across cerebral hemispheres, ultimately affecting the motor performance of the contralateral limb.[9] Active testing might be particularly sensitive to this phenomenon due to the altered central coordination within the sensorimotor loop. Such bilateral deficits are well-documented within lower-limb injuries,[45] and emerging evidence supports their occurrence involving the shoulder complex as well.[41] Consequently, regarding AJPS testing, it may be more accurate for clinicians to rely on preinjury (whenever possible) or normative values, rather than comparing with the unaffected upper limb, and researchers are encouraged to include a CG when conducting active testing.

Several factors can influence proprioceptive testing and shape our understanding of PA deficits. It is important to consider one factor at a time. With the TAIS participants, deficits were present at six months postinjury but demonstrated improvement by eight months,[7,38,48] suggesting that PA recovery may be time dependent. Postsurgical interventions aimed at restoring shoulder stability, such as tightening the capsule and ligaments, likely enhance mechanotransduction of proprioceptive signals, leading to a gradual PA improvement, particularly when combined with an appropriate rehabilitation program.[1,47] Increasing evidence shows that training focused on specific proprioceptive aspects within a given injury context can improve the targeted motor function and may even transfer benefits to untrained motor tasks.[1,47] It is interesting to consider a transference of motor control ability through proprioception exercises.

Testing angles may also play a significant role, particularly for TAINS patients during AJPS assessments. Although PJPS and TTDPM studies found no differences between testing angles,[12,21,43] PA improved progressively with increased range of motion, peaking around 90° of flexion and abduction and decreasing below 60° and above 120°.[8,28] Involving rotation movements, angles did not appear to influence PA in either active or passive testing, especially in external rotation.[12,43] One possible explanation for the greater accurate of JPS around 90° of abduction and flexion is that, at this angle, the upper limb generates maximum gravitational torque, requiring higher muscle activation from the shoulder flexors and abductors to maintain the position, consequently soliciting a higher recruitment or mechanoreceptors and proprioceptors for feedback. Movements above the shoulder level engage not only the GH joint, but also the scapulothoracic and acromioclavicular joints. As more anatomical structures are recruited, conscious PA may decreases by conflicting information.[8]

Regarding rotational movements, supporting the elbow during testing minimizes gravitational influence. With passive testing, the proprioceptive feedback primarily originates from the stretching of passive structures near the end of the range of motion.[31] To avoid inducing apprehension in participants, passive tests are generally conducted in mid-range motion, which may explain the lack of significant differences between rotational angles. It is also worth considering whether healthy individuals display similar sensitivity to testing angles, suggesting that this characteristic is not specific to TAI participants.[8]

Strength and limitations

The strengths of this review include valuable guidance for future studies by emphasizing the importance of replication and methodological standardization.[4]

However, there are also limitations to consider. The included studies' clinical heterogeneity and observational nature present significant limitations, requiring cautious interpretation of the results. Furthermore, the small number of studies dedicated to each specific proprioception subcategory (JPS/kinesthesia/SoV/SoF) and the unexplored areas (trajectory/tension/weight/object size) highlight the need for further research. Proprioception was assessed using various devices and outcome measures, including inclinometers, motion analysis systems, and isokinetic dynamometers, without standardized procedures between studies. The variability in the ranges and directions of movements tested also likely influenced our findings.

Our review exclusively included methods requiring conscious awareness of proprioceptive information, which may limit the ecological validity of our findings, as movement regulation in daily life largely operates at both a conscious and unconscious level.[17] Proprioceptive signals are indeed processed through conscious pathways, such as the dorsal column/medial lemniscus system.[36] However, automatic processes do not rely on conscious perception. We focused on conscious proprioception to avoid conflating results, as well as there is currently a lack of understanding of the mechanisms and processes involved in unconscious proprioception. Also, there has yet to be a clear relationship established between conscious and unconscious proprioception; this is worth exploring in a separate review.[1,20]

Conclusion

This review highlights deficits in the following submodalities of proprioception: AJPS, PJPS, and kinesthesia in participants with a traumatic anterior shoulder instability, suggesting that the affected shoulder caries an impairment when compared to a CG or the unaffected upper limb before surgery. Although these deficits may persist up to six months postsurgery, our findings suggest that the proprioceptive differences dissipate by eight months postsurgery. However, further investigation is warranted to understand the underlying processes and mechanisms. Future research should build on these insights to standardize study designs, proprioception outcome measures, and enhance statistical analyses by incorporating multiple dimensions and aspects of the sense of proprioception within their evaluations.

Disclaimers:

Funding: No funding was disclosed by the authors.
Conflicts of interest: The authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

Supplementary Data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.xrrt.2025.08.001.

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