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Comparing shoulder proprioception, upper extremity dynamic stability, and hand grip strength in overhead athletes with and without scapular dyskinesis

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ABSTRACT

Introduction: Scapular dyskinesis is prevalent among asymptomatic athletes, particularly those involved in overhead activities, and can significantly impact their neuromuscular control. These changes may impair upper extremity function and strength, elevating the risk of injury. Therefore, it is imperative to investigate how scapular dyskinesis affects shoulder proprioception, upper extremity dynamic stability, and hand grip strength in overhead athletes. This study compared these parameters between overhead athletes with and without scapular dyskinesis.

Methods: The study included twenty asymptomatic professional overhead athletes with scapular dyskinesis and twenty without scapular dyskinesis, identified using the lateral scapular slide test. In this cross-sectional study, shoulder active joint position sense, serving as shoulder proprioception, was measured using an isokinetic dynamometer. Upper extremity dynamic stability and hand grip strength were evaluated using an upper quarter modified star excursion balance test (UQ-mSEBT) and a handheld dynamometer.

Results: The study found that the shoulder active joint position sense was significantly lower in the scapular dyskinesis group compared to the group without scapular dyskinesis ($P_{\text{External Rotation}} = 0.003$, $P_{\text{Internal Rotation}} < 0.001$, and $P_{\text{Forward Flexion}} = 0.002$). However, the two groups had no significant differences in UQ-mSEBT and hand grip strength scores.

Conclusions: The results showed that scapular dyskinesis could affect the sense of shoulder active joint position among asymptomatic overhead athletes. However, it did not affect their upper extremity dynamic stability and hand grip strength.

1. Introduction

The scapula is a crucial link in the upper extremity (UE) kinetic chain, facilitating movement across the shoulder, forearm, and hand by connecting the trunk to the hands. Consequently, any disruption in the scapular function, such as scapular dyskinesis, can adversely affect UE function. Scapular dyskinesis is characterized by observable scapular position and movement alterations, including excessive protraction, anterior tilt, and downward rotation (Sciascia and Kibler, 2015). Research has shown that asymptomatic athletes with scapular dyskinesis have a 43% higher likelihood of experiencing shoulder pain over a 9–24 month follow-up period compared to those without scapular dyskinesis (Hickey et al., 2018). Moreover, scapular dyskinesis is prevalent in sports communities, affecting 65% of asymptomatic athletes and 61% of overhead athletes, highlighting its significance in athletic populations (Burn et al., 2016).

Proprioception is crucial in coordinating the muscles around the shoulder and scapula, particularly during intense and repetitive overhead throwing activities. Any disruptions in the structures responsible for joint stabilization can reduce proprioceptive input, resulting in impaired neuromuscular control and joint dysfunction, especially in high-demand activities. Therefore, maintaining effective proprioception is essential for preventing joint injuries among overhead athletes (Aarseth et al., 2015; Salles et al., 2015).

Previous research suggests dysfunctional kinematic chains during overhead throwing are associated with distal injuries (Ellenbecker and

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Aoki, 2020). Scapular dyskinesis alters UE kinematics and muscle activity, highlighting the significance of proximal muscle function in influencing distal muscle strength and function (Karagiannakis et al., 2018). Reduced proximal muscular strength may lead to diminished distal muscle function and strength, essential components of hand grip strength (HGS) (Ahmadi and Gutierrez). While decreased HGS has been observed in cases of asymptomatic wrist issues originating from proximal areas such as the elbow or shoulder, there is a lack of studies addressing this issue in the context of scapular dyskinesis. These findings underscore the importance of evaluating UE function and strength in individuals with scapular dyskinesis (Calvo Lobo et al., 2017; Pienimäki et al., 2002).

Based on these findings, scapular dyskinesis may affect shoulder proprioception and UE function in overhead athletes, potentially leading to shoulder problems and increased vulnerability to injury. However, despite the significance of these issues, there remains a lack of comprehensive studies examining changes in shoulder proprioception among asymptomatic overhead athletes with scapular dyskinesis. Only one recent study has examined active proprioception of shoulder abduction in adolescent athletes with and without scapular dyskinesis (Akınoğlu et al., 2020). A notable aspect of the present study is its complementarity to this prior research, as it explores joint position sense in internal and external rotation and flexion. Therefore, the primary aim of this study was to compare the shoulder active joint position sense (AJPS), representing shoulder proprioception, between overhead athletes with and without scapular dyskinesis. Additionally, changes in proprioception throughout the entire UE can result in kinematic and neuromuscular alterations, ultimately affecting the UE function. Given the absence of studies investigating the UE function of asymptomatic overhead athletes, the secondary objective was to compare the UE function between asymptomatic overhead athletes with and without scapular dyskinesis using functional tests such as the upper quarter modified star excursion balance test (UQ-mSEBT) and hand grip strength (HGS). It was hypothesized that shoulder AJPS and UE function scores would be lower in overhead athletes with scapular dyskinesis than those without scapular dyskinesis.

2. Methods

2.1. Setting and design

This cross-sectional study received approval from the local Ethics Committee of Shiraz University of Medical Sciences (SUMS) (Approval Number: IR.SUMS.REHAB.REC.1400.025). Sample sizes for each group were determined using MedCalc software, considering %90 power and the active shoulder proprioception variable reported by (Salles et al., 2018). The study comprised 20 asymptomatic professional overhead athletes with scapular dyskinesis and 20 without scapular dyskinesis, who were matched based on age, gender, BMI, type of sport, sports experience, and frequency of sports activity per week. Data collection took place in the biomechanics laboratory of the Faculty of Rehabilitation Sciences at Shiraz University of Medical Sciences.

2.2. Inclusion and exclusion criteria

The inclusion criteria were as follows: 1. Professional overhead athletes aged between 18 and 40 years old are defined as athletes whose upper body and shoulder repeatedly pass above the head (Asker et al., 2018); 2. Sports experience ranging from 2 to 8 years with regular sports activities, comprising at least three sessions per week), 3. shoulder internal rotation range of motion (ROM) between 60° and 80° (Norkin and White, 2016); as adaptations in overhead athletes can lead to altered dominant shoulder ROM, particularly reducing internal rotation ROM. Impairment in the internal rotation range can disrupt shoulder and scapula kinematics and neuromuscular control (Kalo et al., 2020). The exclusion criteria were: 1. Presence of pain in the dominant UE, 2. history of injury or surgery in the dominant UE, chest, or spine within the last six months, including shoulder labrum injury, dislocation, fracture, etc., 3. Diagnosis of systemic diseases such as diabetes and rheumatoid arthritis, 4. Presence of neurological diseases, and 5. Diagnosis of pathological conditions such as internal shoulder impingement syndrome, thoracic outlet syndrome, shoulder tendinopathy, and instability within the last six months. Criteria 1 to 4 were assessed based on the self-report by the participants, while an experienced examiner evaluated criterion 5.

2.3. Data collection and measures

Asymptomatic professional overhead athletes, both men and women, were recruited for this study using a convenient sampling technique. Athletes were approached through online and paper-based bulletins and in-person communication by the examiner at gym and sports centers. Prior to participation, athletes were required to complete an informed consent form. Once familiarized with the tests and materials, the main assessments were conducted.

This study employed the lateral scapular slide test (LSST) to assess scapular dyskinesis. This test is widely recognized as a valid and reliable two-dimensional method for diagnosing scapular dyskinesis (Paraskevopoulos et al., 2020). One notable advantage of the LSST is its practical utility, making it a valuable tool in clinical settings. According to the methodology, overhead athletes were categorized based on the presence of scapular dyskinesis in their dominant UE. The LSST assessed scapular asymmetry bilaterally at three positions, measuring the interval between the scapular inferior angle and the T7 spinous process. These positions included: 1) 0° abduction with neutral arms, 2) 45° abduction with hands at the waist and thumbs facing backward, and 3) 90° abduction with arms maximally internally rotated. A positive LSST result, indicating the presence of scapular dyskinesis, was defined by a difference of ≥1.5 cm in scapular inferior angles at any of these positions (Kibler, 1998) (Fig. 1).

In this study, shoulder AJPS, represented by the active repositioning absolute error (ARAE), served as an indicator of proprioception. The assessment was conducted using the Isokinetic Pro 4 System Biodex dynamometer (Biodex Medical Systems, Inc., Shirley, NY, USA). No warm-up exercises were performed before the assessment, as warm-up routines have enhanced joint proprioception (Magalhães et al., 2010).

Participants were seated on the isokinetic chair, blindfolded, and instructed to hold the "hold" button with their non-dominant hand. They were required to stop the dynamometer's lever arm upon perceiving the target angle. Prior to the three training trials in each movement direction, participants completed three training trials. Shoulder ARAE was assessed at 60° of external rotation (ER), 60° of internal rotation (IR), and 120° of forward flexion (FF) at a speed of 5°/s in a random order.

The starting angles of shoulder 60° ER and 60° IR were set at 0° and 90° ER, respectively. During ER, the forearm was positioned parallel to the earth's axis, while during internal rotation, it was perpendicular to its axis. In addition, the starting angle for the 120° flexion was determined as 0°, corresponding to the arm parallel to the body. Rest intervals of 15 s were provided between trials, and a 5-min break was observed between movement directions. The average absolute angular error (AAE) was calculated for the statistical analysis of the shoulder ARAEs. AAE is the difference between the target and repositioning angles (Ager et al., 2017) (Fig. 2).

This study evaluated the UE dynamic stability using UQ-mSEBT, a closed kinetic chain functional test. The UQ-mSEBT involved placing three tapes, each with a 0.5 cm scale, on a flat surface. The length of the non-dominant UE, measured between the C7 vertebra spinous process and the middle fingertip, was recorded with the arm positioned in 90° shoulder abduction, full elbow extension, and thumb upward.

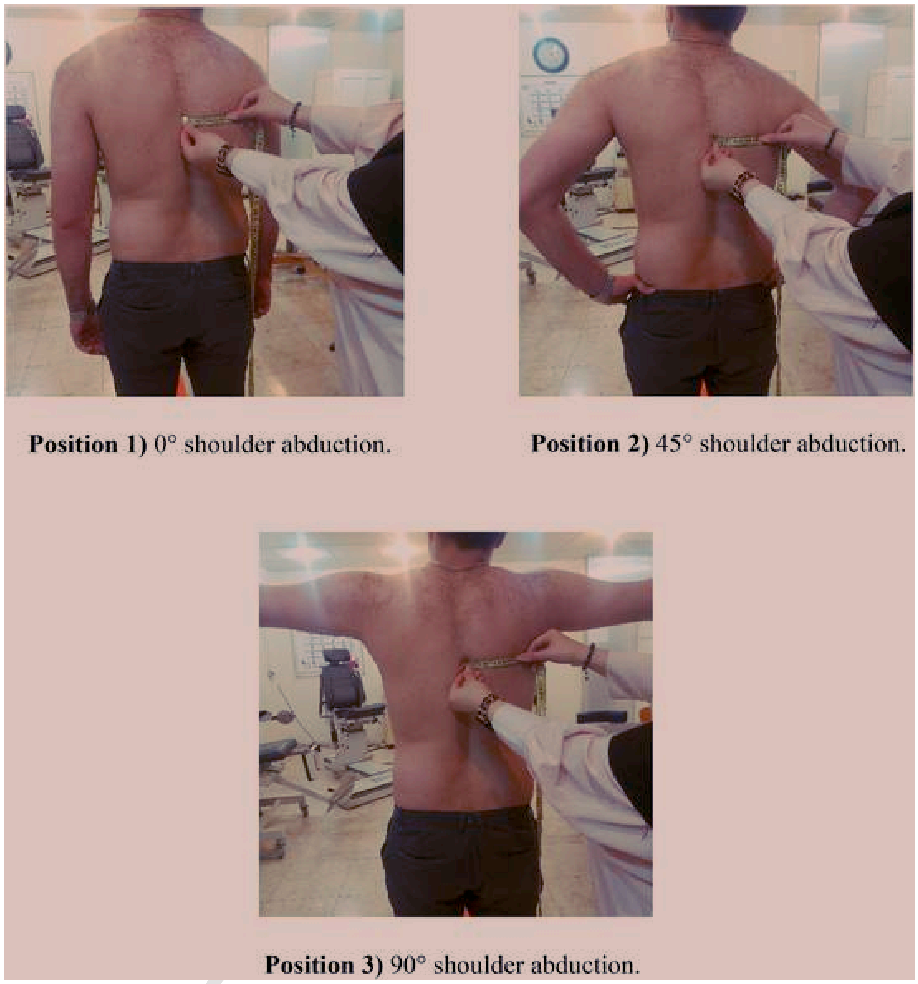

Fig. 1. Lateral scapular slide test (LSST).

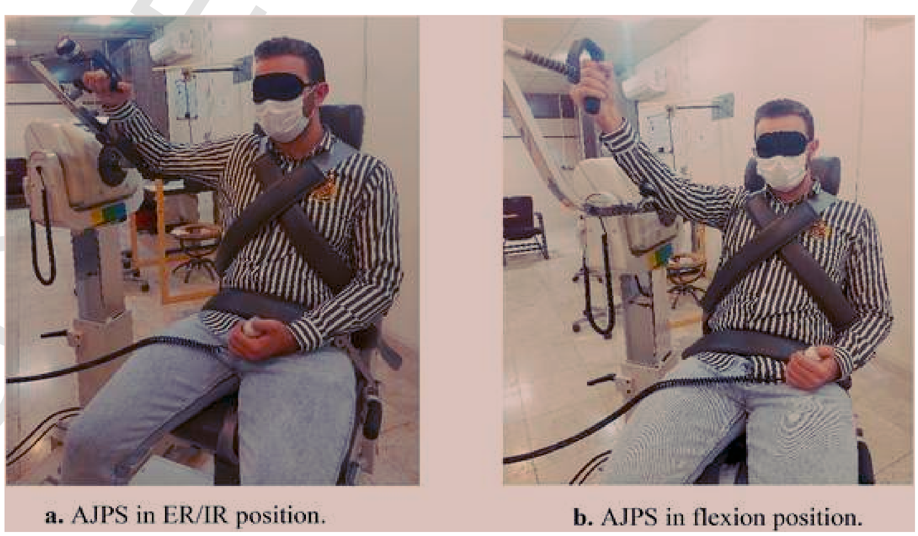

Fig. 2. Shoulder active joint position sense (AJPS).

The UQ-mSEBT was performed on the dominant UE, corresponding to the overhead athletes' throwing extremities. Participants assumed a push-up position, and the non-dominant UE reached out as far as possible in the medial (M), superolateral (SL), and inferolateral (IL) directions before returning to the starting position in a controlled manner. Each participant completed three trials on the dominant UE, with 60 s of rest between each trial. Prior to the test, participants completed three practice trials, and any failed attempts to maintain the plank position resulted in the trial being repeated.

The maximum scores for each direction and composite score were normalized for analysis. Normalization involved dividing the maximum distance reached in each direction by the length of the non-dominant UE and then multiplying by 100. The composite score was calculated by summing the maximum distances for all directions, dividing by three times the length of the non-dominant UE, and multiplying by 100 (Borms et al., 2016) (Fig. 3).

This study measured HGS using the Korea SEHAN dynamometer with athletes seated upright. The HGS test was conducted following the guidelines set by the American Society of Hand Therapists (MacDermid et al., 2015). Athletes were positioned with their shoulders at 0° abduction, in a neutral rotation, and their elbows flexed at 90°.

After receiving a clear command, athletes were instructed to exert maximal force on the dynamometer for 5 s. To familiarize themselves with the test procedure, each athlete performed two submaximal contractions before the main test. Subsequently, athletes performed three maximum-effort trials of the HGS test. A 1-min rest period separated each contraction. The highest recorded score from the three trials was used for subsequent statistical analysis (Cronin et al., 2017) (Fig. 4).

2.4. Statistical analysis

Statistical analysis was conducted using SPSS 25.0 (Statistical Package for Social Sciences Inc., Chicago, IL, USA). The normality of the data was assessed using the Shapiro–Wilk test. Descriptive statistics are the mean ± standard deviation (μ ± SD). Independent samples were compared using either the *t*-test or the Mann–Whitney *U* test, depending on the normality of the data. The significance level was set at $P < 0.05$ for all analyses. The sample size of 20 overhead athletes in each group was determined to achieve a statistical power of 90% and a confidence level of 95% for the study.

3. Results

The data were collected from forty asymptomatic professional overhead athletes participating in various sports, including volleyball (n = 20), basketball (n = 6), tennis (n = 2), badminton (n = 6), water polo (n = 4), and discus throw (n = 2). They were divided into scapular dyskinesis and non-scapular dyskinesis groups. Table 1 demonstrates that both groups had similar demographic characteristics at baseline ($P > 0.05$). In addition, their internal rotation ROM fell within the normal range (60°–100°), as reported in previous studies (Reese and Bandy, 2017). Each group comprised ten men and ten women.

The measurements of scapular asymmetry at 45° and 90° shoulder abduction positions in the LSST showed significant differences between the two groups. Furthermore, there was a significant difference in dominant shoulder ARAE between the groups at 60° ER, 60° IR, and 120° FF ($P_{ER} = 0.003$, $P_{IR} < 0.01$, $P_{FF} = 0.002$). However, there were no sig-

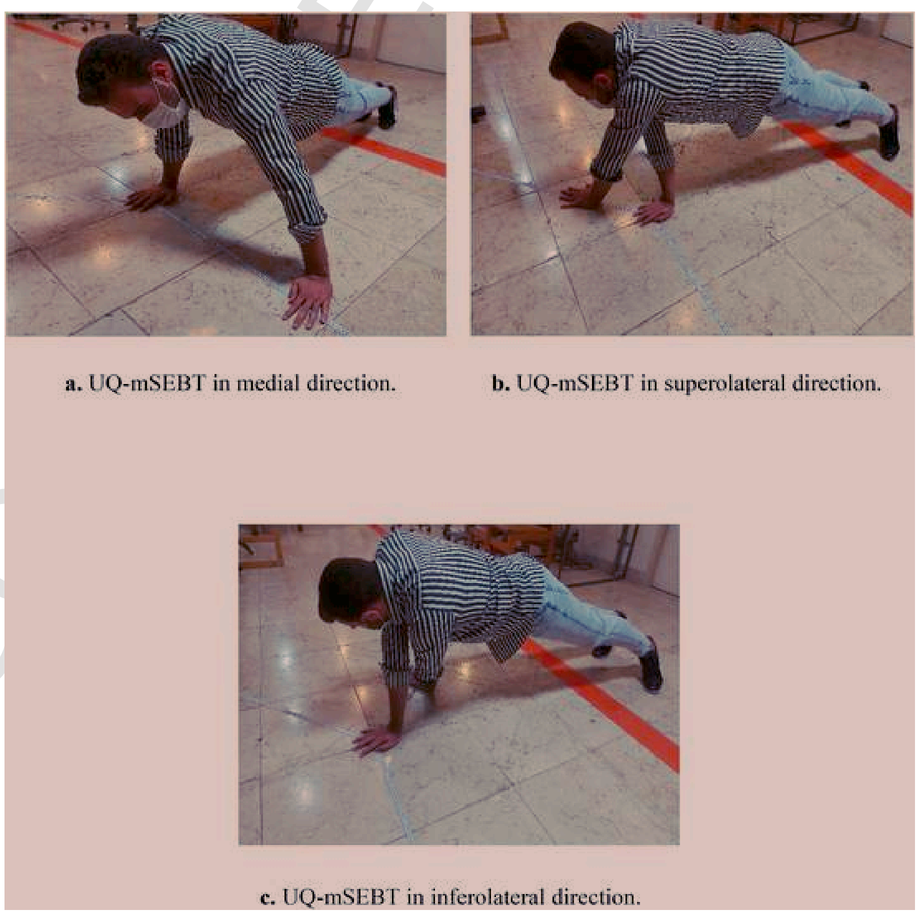

Fig. 3. Upper quarter modified star excursion balance test (UQ-mSEBT).

Fig. 4. Hand grip strength.

Table 1
Comparison of the demographic characteristics of the groups.

	Scapular Dyskinesis Group *(N=20)*	non-Scapular Dyskinesis Group *(N=20)*	*P* value	95% Confidence Interval
	Mean ± SD	Mean ± SD		(Lower, Upper)
Age *(year)*	21.45 ± 1.76	21.25 ± 1.74	0.711	(-0.92, 1.32)
BMI *(kg/ m^2)*	22.20 ± 2.98	22.18 ± 3.10	0.850	(-1.92, 1.97)
Sports Experience *(year)*	5.60 ± 1.87	5.55 ± 1.93	0.923	(-1.16, 1.26)
Sport Activity Days per Week *(day)*	3.05 ± 0.22	3.10 ± 0.30	0.553	(-0.22, 0.12)
Internal Rotation ROM *(degree)*	78.75 ± 6.66	78.75 ± 6.46	0.978	(-4.20, 4.20)
Scapular Difference in Neutral Position *(cm)*	0.95 ± 0.68	0.65 ± 0.48	0.153	(-0.08, 0.68)
Scapular Difference in 45° Abduction Position *(cm)*	1.35 ± 0.87	0.65 ± 0.48	0.006*	(0.24, 1.15)
Scapular Distance in 90° Abduction Position *(cm)*	1.45 ± 0.75	0.65 ± 0.48	0.001*	(0.39, 1.20)

nificant differences in UQ-mSEBT and HGS scores between the groups ($P > 0.05$) (**Table 2**).

4. Discussion

This study aimed to explore the lasting impacts of scapular dyskinesis on active shoulder proprioception, UE dynamic stability, and HGS. The results indicated that the scapular dyskinesis group exhibited

Table 2
Comparison of the dominant shoulder ARAE, UQ-mSEBT, and HGS between the groups with and without SD.

		Scapular Dyskinesis Group *(N=20)*	non-Scapular Dyskinesis Group *(N=20)*	*P* value	95% Confidence Interval
		Mean ± SD	Mean ± SD		(Lower, Upper)
Shoulder ARAE *(degree)*	60° ER	7.82 ± 3.56	4.70 ± 2.65	0.003¥*	(1.10, 5.13)
	60° IR	8.87 ± 3.94	3.18 ± 1.37	<0.001£*	(3.79, 7.57)
	120 ° FF	9.47 ± 5.16	4.48 ± 2.39	0.002£*	(2.30, 7.68)
Normalized UQ-mSEBT *(%)*	Medial	103.40 ± 8.55	107.80 ± 6.98	0.083¥	(-9.39, 0.59)
	Sup. Lateral	52.20 ± 10.17	56.85 ± 9.46	0.143¥	(-10.93, 1.63)
	Inf. Lateral	76.05 ± 10.72	77.90 ± 9.80	0.572¥	(-8.42, 4.72)
	Composite score	77.15 ± 8.78	80.95 ± 6.77	0.134¥	(-8.81, 1.21)
Max HGS *(kg)*		37.32 ± 11.98	36.82 ± 11.66	0.894¥	(-7.07, 8.07)

higher mean shoulder ARAE scores at 60° ER, 60° IR, and 120° FF than the non-scapular dyskinesis group. However, the groups had no significant differences regarding UQ-mSEBT and maximum HGS scores. These results suggest that scapular dyskinesis may diminish active shoulder proprioception in asymptomatic overhead athletes.

Previous research has reported a connection between scapular dyskinesis and shoulder muscle shortening, indirectly influencing shoulder kinematics and altering scapular stabilizer muscle function, leading to scapular dyskinesis (Yeşilyaprak et al., 2016). While direct investigations into this relationship are lacking, some research has suggested that interventions targeting shoulder proprioception, such as proprioceptive neuromuscular facilitation (PNF) exercises, may improve muscle activity and strength in the scapular and shoulder regions. (Ciğercioğlu et al., 2022; Kim et al., 2021). Additionally, studies have shown that correcting static and dynamic positioning of the scapula can alter muscle activity patterns and enhance shoulder proprioception (Lin et al., 2011). Therefore, it is plausible that the observed differences in the ARAE scores between the scapular dyskinesis and non-scapular dyskinesis groups may be attributed to the changes in muscle activity and kinematics induced by scapular dyskinesis.

There is only one study similar to the present research. In that study, the researchers reported no significant difference in shoulder AJPS between healthy athletes with and without scapular dyskinesis (Akınoğlu et al., 2020). However, the present study differs in several aspects. While Akinoglu et al. only assessed shoulder AJPS in the abduction direction, the present study evaluated it in three different directions: ER, IR, and FF. These movements are critical in overhead sports and can subject the shoulder joint to significant load, potentially leading to microtrauma (Asker et al., 2018). Therefore, the present study provided more comprehensive results. Additionally, the present study focused specifically on professional and competitive overhead athletes (Swann et al., 2015).

The UE kinetic position during overhead throwing exerts distinct stresses on the shoulder joint, particularly in professional athletes compared to nonprofessional athletes (Seroyer et al., 2010). Moreover, it is important to note differences between our study and a previous one: the average age of participants in the earlier study was 15.89 ± 2.17 years, and they engaged in various sports activities. In contrast, the current study focused solely on adult athletes with an average age of 21.35 ± 1.73, all actively participating in overhead sports. These methodological distinctions may account for the discrepancies observed in the findings between the two studies.

It is worth noting that the athletes involved in the current study did not experience any symptoms in their UEs. Research has shown that experiencing pain can reduce one's sense of proprioception (Sole et al., 2015). Additionally, previous studies have indicated that scapular dyskinesis may eventually lead to shoulder pain (Hickey et al., 2018). The present study's findings suggest that alterations in shoulder proprioception may manifest due to scapular dyskinesis alone, even in the absence of pain.

The mSEBT is a valuable tool in assessing dynamic stability and predicting sport-related injuries among athletes (Gribble et al., 2012). In cases of UE injuries, this test is crucial in determining an athlete's readiness to return to play while assessing their UE dynamic stability, speed, power, and trunk stability. Consequently, the UQ-mSEBT is particularly adept at evaluating the dynamic stability of the UE, unilateral mobility, and scapular stability in a closed kinetic chain position (Pires and Camargo, 2018).

Contrary to the findings of the current study, Haji-Hosseini et al. (Hajihosseini et al., 2019) observed reduced UE dynamic stability among female volleyball players with scapular dyskinesis compared to those without scapular dyskinesis. The present study participants consisted of male and female athletes in various overhead sports such as volleyball, basketball, badminton, tennis, and discus throwing. Previous research has illustrated variations in UQ-mSEBT results across different sports disciplines (Fatih et al., 2022). Therefore, the lack of significant differences in UQ-mSEBT results in our study, despite matching sport types and gender, could be attributed to the variability in athlete composition across different overhead sports.

As highlighted in previous research, the UQ-mSEBT is recognized for establishing a stable position for the scapula and UE in a closed kinetic chain configuration. Conversely, scapular dyskinesis is commonly associated with open kinetic chain movements (Pires and Camargo, 2018). As a result, the lack of significant differences in UQ-mSEBT scores between the two groups in this study could be attributed to the closed kinetic chain nature of the test. This closed chain setup may not adequately capture the specific challenges of scapular dyskinesis in open kinetic chain movements.

The primary objective of this study was to investigate the impact of scapular dyskinesis on dominant HGS in overhead athletes. The HGS assessment is widely acknowledged as reliable for evaluating UE function (Cronin et al., 2017). Studies have indicated that painful UE conditions, such as tennis elbow and wrist pain, can reduce HGS (Pienimäki et al., 2002). While previous research has established a correlation between HGS and scapular muscle strength (Ahmadi and Gutierrez), investigations specifically exploring the influence of scapular dyskinesis on HGS are lacking.

Prior studies consistently highlighted the significant association between painful UE conditions and HGS (Calvo Lobo et al., 2017; Pienimäki et al., 2002). Research by Srinivas et al. (Srinivas and Babu, 2022) demonstrated that treatments targeting pain reduction are more effective in improving hand grip strength than enhancing shoulder strength. Furthermore, Turabi et al. (2022), drawing on data from Horsley et al., reported no significant disparity in HGS between individuals with shoulder instability and those without. However, It is essential to recognize that scapular dyskinesis can contribute to shoulder joint instability (Zacharia et al., 2021).

The study's findings suggest that pain in the UEs exerts a greater influence on HGS than the stability and strength of the proximal muscles. In the current study, participants were pain-free and actively engaged in their respective sports. This context likely contributed to the similarity in HGS results observed between the groups with and without scapular dyskinesis.

4.1. Limitations

A notable limitation of this study was the influence of the COVID-19 pandemic, which disrupted access to athletes and prolonged the data collection process. The closure of gyms during the pandemic posed a challenge in recruiting a consistent number of athletes from various sports, resulting in an uneven distribution across different types of overhead sports. Moreover, the study's cross-sectional design presents inherent limitations in establishing a causal relationship between scapular dyskinesis and joint proprioception. Cross-sectional studies provide valuable insights into associations between variables at a single point in time but cannot elucidate causal relationships.

4.2. Research implications

Additional research, especially prospective studies, is warranted to validate the impact of scapular dyskinesis on shoulder proprioception. Future investigations could explore the efficacy of corrective exercises in modifying shoulder proprioception among asymptomatic overhead athletes with scapular dyskinesis. Additionally, incorporating other upper extremity (UE) functional tests alongside proprioceptive assessments could provide a more comprehensive understanding of the impact of scapular dyskinesis on UE function and stability.

5. Conclusion

This study represents the initial endeavor to contrast active shoulder proprioception, evaluated through ARAE, with UE functions assessed via UQ-mSEBT and HGS in healthy overhead athletes with and without scapular dyskinesis. Results indicate that compared to their counterparts without scapular dyskinesis, healthy overhead athletes with scapular dyskinesis manifest indications of compromised active proprioception in their dominant UE. Thus, this study underscores the potential negative impact of scapular dyskinesis on active shoulder proprioception among healthy overhead athletes. Nevertheless, no significant differences emerged between the groups concerning UE dynamic stability and hand grip strength.

6. Clinical relevance

- The results of the present study revealed a significant association between scapular dyskinesis and diminished active shoulder proprioception in asymptomatic overhead athletes.
- These findings offer valuable insights for future research endeavors investigating the effects of scapular dyskinesis on upper extremity function and proprioception.
- The utilization of the LSST as a reliable two-dimensional assessment tool for scapular dyskinesis represents a notable strength of the present study, given its practical applicability in clinical settings.

***P* value**: comparison of the scapular dyskinesis and non-scapular dyskinesis groups (Mann–Whitney *U* test and independent samples *t*-test). A ***P* value** $<$ **0.05** is significant, which is marked with *.

***P* value**: comparison of the scapular dyskinesis and non-scapular dyskinesis groups (£ Mann–Whitney *U* Test and ¥ Independent Samples *t*-test). A ***P* value** $<$ **0.05** is significant, which is marked with *.

CRediT authorship contribution statement

Fatemeh Reyhani: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Narges Meftahi:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization. **Zahra Rojhani-Shirazi:** Validation, Supervision, Project administration, Methodology, Conceptualization.

Declaration of competing interest

Declarations of interest: none.

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