Comparison of Joint Position Sense and Force-Reproduction in Female Racquet Athletes with and Without Scapular Dyskinesia

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Abstract

Background: Scapular dyskinesia (SD) is a common condition that affects racquet athletes, impacting their performance and predisposing them to injuries.

Objectives: This study aimed to compare joint position sense (JPS) and force reproduction in racquet athletes with and without SD.

Methods: This study was conducted as a cross-sectional study. The statistical population consisted of female student-athletes aged 18 to 30 who were engaged in badminton, tennis, and ping pong in Quchan city, both with and without shoulder dyskinesia. The sample included thirty athletes with shoulder dyskinesia and thirty without it, who were randomly selected. Joint Position Sense was assessed at 45 and 135 degrees of abduction. The tools employed in this research encompassed a consent form, an inclinometer (goniometer), the Kibler test, force-reproduction testing, and the McClure test. Data analysis was performed using the Shapiro-Wilk test and an independent t-test in SPSS version 23, with a significance level set at \( P < 0.05 \).

Results: The results revealed a statistically significant difference in JPS of the shoulder joint between athletes with and without SD at angles of 45 and 135 degrees (\( P < 0.05 \)). Similarly, the independent \( t \)-test analysis demonstrated a significant difference in force reproduction of the shoulder joint between athletes with and without dyskinesia (\( P < 0.05 \)).

Conclusions: These findings underscore the importance of addressing SD and its associated sensory impairments in racquet athletes to optimize performance and reduce the risk of injuries.

Keywords: Shoulder Joint, Dyskinesia, Scapula, Athletes

1. Background

Throughout their lifetime, 67% of adults will experience shoulder pain (1). Several factors contribute to the development of shoulder pain, and one possible cause is scapular dyskinesia (SD) (2). Scapular dyskinesia involves alterations in the position of the scapula, both at rest and during movement, which can include increased superior scapular translation and decreased posterior tilt, upward rotation, and internal rotation (3). It is commonly observed in individuals engaged in sports or physical activities that involve repetitive overhead motions or muscle imbalances. Scapular dyskinesia can lead to functional limitations, reduced performance, and an elevated risk of shoulder injuries (4). Scapular dyskinesia, or changes in dynamic scapular control, is present in 67 to 100% of athletes with shoulder injuries. However, it is also present in many asymptomatic individuals (5). The prevalence of SD varies among tennis players, ranging from 40 to 70% (2), and volleyball players, ranging from 20 to 35% (6). It remains unclear whether SD is a cause or a consequence of shoulder injuries (7, 8). Previous research has indicated that abnormal scapular movements can adversely affect shoulder function (9, 10), and correcting these movements can alleviate symptoms associated with shoulder injuries, such as full-thickness rotator cuff tears (9).

McClure et al. (2009) introduced the scapular dyskinesia test (SDT) as a widely used method for detecting SD and categorizing individuals into three levels: normal motion, subtle dyskinesia, and obvious dyskinesia (11). Despite the reliability and validity of the SDT (11, 12), only a limited number of clinicians are trained to administer it, and there is a need for greater consistency in assessment methods (11). Moreover, there is insufficient evidence to support the idea that identifying...
and correcting SD can prevent or treat shoulder pathology. Nevertheless, screening for SD is common in symptomatic and asymptomatic individuals, particularly in predicting or preventing injuries in overhead athletes (13). However, there is conflicting evidence regarding the relationship between SD and injuries in this population, and clinicians often focus on correcting SD even when it may be a normal variation in movement (14, 15).

Proprioception is a topic that straddles the fields of neurophysiology and neuropsychology. The term "proprioception" was initially introduced by Sir Charles Sherrington, who defined it as the perception of movement and body position in space without relying on visual feedback (16). Perception involves experiencing the external environment, while proprioception involves sharing one’s body (17). Proprioception results from multiple neural feedback systems within the human body, playing a critical role in motor control and adaptation (18, 19). Joint Position Sense (JPS) in the shoulder refers to an individual’s ability to accurately perceive and reproduce joint angles and movements within the shoulder joint. This proprioceptive skill is crucial for maintaining joint stability and ensuring correct movement patterns during physical activities (20). Proprioception, or JPS, is essential for motor control, coordination, and injury prevention. It provides valuable neural feedback that allows athletes to accurately sense the position and movement of their limbs during dynamic sporting activities. Force reproduction, another sensory function, is vital for maintaining grip force and optimizing racquet control during various strokes. Several studies have examined JPS in athletes participating in various sports, including tennis, badminton, ping pong, and volleyball.

Scapular dyskinesis is a prevalent condition among racquet athletes that can impact their performance and predispose them to musculoskeletal injuries. It is characterized by abnormal scapular movement and positioning, which can disrupt the dynamic stability of the shoulder joint. Previous research has highlighted the negative effects of SD on shoulder function and overall athletic performance (20). However, there is limited understanding of how SD may influence proprioception and sensory perception in racquet athletes.

This study investigates the comparison of JPS and force reproduction (FR) between racquet athletes with and without SD. By examining these sensory aspects, we aim to shed light on potential impairments in proprioceptive and FR abilities in athletes with SD. Understanding these differences will contribute to our knowledge of the impact of SD on sensorimotor function in racquet athletes. It may inform the development of targeted interventions and training strategies to optimize performance and reduce the risk of injury. We hypothesize that racquet athletes with SD will exhibit impaired JPS and altered FR compared to athletes without SD.

Additionally, we anticipate these sensory impairments may be associated with reduced performance, increased vulnerability to injuries, and compromised racquet control during various strokes. The findings from this study will provide valuable insights into the specific sensory deficits related to SD in racquet athletes. Such knowledge may guide the development of evidence-based interventions to improve proprioception and pressure perception abilities in athletes with SD, ultimately optimizing their performance and reducing the risk of musculoskeletal injuries. For example, research by Hübischer et al. highlighted the significant relationship between reduced proprioception and increased susceptibility to sports injuries, particularly in activities requiring rapid changes in direction and agility (21). Our study stands out for its comprehensive evaluation of JPS and force reproduction, specifically in female racquet athletes with and without scapular dyskinesia (SD). While previous research may have investigated similar measures in other athlete populations or focused solely on either JPS or force reproduction (2, 4, 8, 22-25), our study uniquely combines these assessments in the context of female racquet sports athletes.

Moreover, our study explores the intricate relationship between these parameters and SD, an area that has yet to be explored within the context of JPS and force reproduction in female racquet athletes. This unique focus enables us to gain potential insights tailored to this specific group, contributing to a deeper understanding of the impact of SD on JPS and force reproduction within the context of racquet sports. No studies have compared JPS and force reproduction in racquet athletes with and without SD, despite previous research on the relationship between proprioceptive deficits and sports injuries (20, 23, 24).

2. Objectives

This study aimed to compare JPS and force reproduction in racquet athletes with and without SD.

3. Methods

3.1. Study Design and Participants

This research received approval from the Ethics Committee of the Sport Sciences Research Institute in Tehran, Iran (approval number: IR.SSRC.REC.1402.013). It was a cross-sectional study that involved female
student-athletes aged 18 to 30 years participating in badminton, tennis, and ping pong in Khorasan Razavi province, specifically Qochan city. The study aimed to investigate SD in this population. Initially, all 302 female students regularly involved in racket sports were screened, and 64 students with scapular dyskinesia were identified based on inclusion and exclusion criteria. Among these, 30 students with SD were randomly selected as the experimental group. Also, among the students who did not have shoulder dyskinesia (238 students), 30 athletes were randomly selected as the control group.

3.2. Inclusion Criteria
- Gender and age: The study focused exclusively on female racquet athletes aged 18 to 30 to ensure a homogeneous age group.
- Scapular dyskinesia (for the dyskinesia group): Participants with a diagnosed SD were included. This allowed for the comparison between athletes with and without the condition (26).
- Engagement in racquet sports: Participants needed to have experience in racquet sports such as tennis, badminton, ping pong, or racquetball. This ensured that the athletes had a relevant background for the study's objectives.
- Three-year history in racquet athletes: Participants were included if they had at least 3 years of continuous experience in racquet sports. This criterion aimed to select athletes with sufficient experience and skill level within the specific sports.
- Absence of significant abnormalities: Individuals with significant abnormalities like kyphosis, scoliosis, swayback, or uneven shoulders were excluded. This criterion aimed to minimize the potential impact of pre-existing conditions that could confound the study results.

3.3. Exclusion Criteria
- Age: Participants outside the specified age range (below 18 or above 30) were excluded to ensure a consistent age group for comparison purposes.
- Gender: The study focused exclusively on female racquet athletes, so male participants were excluded. Previous injuries could potentially interfere with joint position sense and force-reproduction, which could confound the study results (26).
- Previous or current injuries: Individuals with a history of shoulder or scapular injuries were excluded.
- Other medical conditions: Participants with pre-existing medical conditions that could impact JPS or force reproduction, such as neurological disorders or musculoskeletal abnormalities, were excluded.

- Pregnancy or postpartum: Female participants who were pregnant or in the postpartum period were excluded due to potential influences on JPS and forced reproduction.

Our study focuses on the exposure of being a racquet athlete. The 2 main predictors we examine are SD and JPS. Participants are grouped based on whether they possess SD or not. Additionally, JPS plays a crucial role in determining the outcome. Confounding variables like age, training level, and previous injuries can affect the relationship between SD, JPS, and force reproduction.

3.4. Measuring Instruments
The research utilized several tools, including a consent form, a stadiometer for measuring height, a digital scale for measuring weight, the Kibler test to assess shoulder lateral slide, the McClure test to diagnose SD, an inclinometer for measuring shoulder JPS, a Baseline bubble inclinometer (model 12-1056, Fabrication Enterprises, White Plains, NY) for measuring range of motion (ROM) in the shoulder. The inclinometer resembles a flat goniometer with 360 degrees (marked in single-degree increments on the circumference). The inclinometer's intratester reliability was high (ICC = 0.98) (26). We employed a Kinetic Communicator (Kin Com) 125 AP isokinetic dynamometer (Chattanooga Group, Chattanooga, TN) integrated with a computer and suitable software to evaluate the reliability of FR. This instrument was reliable (26). The measurements in this study were done by one examiner.

3.5. Ethical Considerations
All participants provided informed consent, and their confidentiality and anonymity were strictly maintained throughout the study.

3.6. Procedure
The research began with participants completing informed consent forms. The scapular dyskinesis test (McClure test) (11, 12) was performed at the gym. The researcher placed 2 dumbbells (1.4 for individuals under 68 kg and 2.3 for over 68 kg) in both hands of the participants and asked them to raise their hands from zero degrees' flexion angle to 180 degrees' extension and then return their hands to the initial position after a 3-second pause. The researcher stood behind the participant at this time and observed the athlete's shoulder movement (the athlete did not wear any clothes on their shoulders). If the athlete had shoulder dysfunction, the inner edge of the scapular would separate from the torso, and the scapular would experience internal rotation. Now, the Kibler test (27) was performed on athletes to
measure scapular rhythm. The test was performed in 3 positions: 0, 45, and 90 degrees of arm abduction. At each angle of arm abduction, the distance between the inferior angle of the scapula and the closest spinous process was measured using a modified method. By subtracting the measurements at 45 and 90 degrees from the measurement at 0 degrees, differences greater than 1.5 mm were considered external rotation, and differences less than 1 mm were considered internal rotation (27).

3.6.1. Joint Position Sense Assessment
An inclinometer was used to measure the participants’ shoulder JPS. During the JPS assessment, we provided active assistance to the subject’s arm to reach the target angle, which was set at 45 and 135 degrees of abduction. The subject was instructed to hold the arm in that position for 3 s before returning it to the original position. This duration was (28) long enough for the subject to accurately identify position without fatigue. The subject was blindfolded to eliminate visual cues and was asked to concentrate on the arm’s position in space at the target angle. Upon returning to the starting point, the subject was asked to immediately reposition the arm back to the target angle abduction (45 and 135 degrees) and indicate when they felt the position had been achieved. At this point, we recorded the angle observed on the inclinometer. This measurement was repeated twice, with a 30 s rest period separating each trial into 3 trials. We then calculated the error score by averaging all 3 trials’ absolute differences between the target and observed angles.

3.6.2. Force-Reproduction Test
The Force-reproduction testing (FRT) was conducted while the subject was in a standing position, and the limb was positioned similarly to the JPS testing. The dynamometer’s axis of rotation was aligned with the shoulder’s frontal axis of rotation, with the limb placed at 90° of shoulder abduction and 90° of elbow flexion. The subject’s wrist was securely fastened to the force transducer on the dynamometer arm using a wrist attachment. All tests were conducted in isometric mode, with the dynamometer set to record data accordingly (22, 26).

3.7. Statistical Analysis
Descriptive statistics, including mean and standard deviation, were calculated for demographic variables. The normality of the data was assessed using the Shapiro-Wilk test, and an independent t-test was employed to compare means between groups in SPSS version 23. The significance level was set at P < 0.05.

4. Results
The descriptive information regarding the participants’ age, height, and weight is presented in Table 1.

The Kolmogorov-Smirnov test was employed to assess the normality of the data distribution. The results of this test indicated that the distribution of all research variables was normal.

Table 2 displays the mean and standard deviation of JPS and FR variables in athletes with and without SD.

To compare JPS and FR of the shoulder joint in athletes with and without SD, an independent t-test was conducted, and the results are presented in Table 3.

The results of the independent t-test demonstrated a significant difference in the JPS of the shoulder joint at angles of 45 and 135 degrees between athletes with and without SD (P < 0.05). Furthermore, the results of the independent t-test indicated a significant difference in the FR of the shoulder joint between athletes with and without dyskinesis (P < 0.05).

5. Discussion
This study aimed to compare JPS and FR between racquet athletes with and without SD. The study included 30 female participants with SD and 30 female participants without SD, randomly selected as the sample. The results of the independent t-test revealed a statistically significant difference in JPS of the shoulder joint between athletes with and without SD at angles of 45 and 135 degrees (P < 0.05). Similarly, the independent t-test analysis demonstrated a significant difference in FR of the shoulder joint between athletes with and without SD (P < 0.05). This study showed that racquet athletes with SD had significantly poorer JPS and FR compared to those without SD, indicating reduced accuracy in perceiving joint position and pressure applied to their shoulders. Scapular dyskinesis commonly affects racquet athletes, leading to shoulder pain, instability, and decreased performance. It is caused by abnormal movement patterns of the scapula, which can disrupt the normal mechanics of the shoulder joint (20).

The independent t-test results indicated a significant difference in JPS of the shoulder joint at angles of 45 and 135 degrees between athletes with and without SD (P < 0.05). Notably, individuals with better proprioceptive sense tend to have lower JPS errors in their shoulder joint (26). Joint position sense is vital for optimal performance in racquet sports, enabling athletes to position their limbs and apply appropriate force during movements accurately. A study by Sood et al. investigated the impact of
Table 1. Distribution of Mean and SD of Age, Height, and Weight in Athletes with and Without Scapular Dyskinesia

<table>
<thead>
<tr>
<th>Variables and Athletes</th>
<th>N</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Without dyskinesia</td>
<td>30</td>
<td>22.80 ± 3.39</td>
</tr>
<tr>
<td>With dyskinesia</td>
<td>30</td>
<td>24.10 ± 3.85</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Without dyskinesia</td>
<td>30</td>
<td>59.16 ± 7.69</td>
</tr>
<tr>
<td>With dyskinesia</td>
<td>30</td>
<td>59.73 ± 7.43</td>
</tr>
<tr>
<td><strong>Height</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Without dyskinesia</td>
<td>30</td>
<td>165.30 ± 10.39</td>
</tr>
<tr>
<td>With dyskinesia</td>
<td>30</td>
<td>164.23 ± 10.17</td>
</tr>
</tbody>
</table>

Table 2. Mean and Standard Deviation of JPS and FR Variables in Athletes with and Without SD

<table>
<thead>
<tr>
<th>Variables, AM, and Athletes</th>
<th>Mean ± SD</th>
</tr>
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<tbody>
<tr>
<td><strong>JPS</strong></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td></td>
</tr>
<tr>
<td>Without dyskinesia</td>
<td>3.76 ± 1.85</td>
</tr>
<tr>
<td>With dyskinesia</td>
<td>5.63 ± 2.20</td>
</tr>
<tr>
<td>135</td>
<td></td>
</tr>
<tr>
<td>Without dyskinesia</td>
<td>4.71 ± 2.06</td>
</tr>
<tr>
<td>With dyskinesia</td>
<td>6.70 ± 1.80</td>
</tr>
<tr>
<td><strong>FR</strong></td>
<td></td>
</tr>
<tr>
<td>Without dyskinesia</td>
<td>6.43 ± 2.73</td>
</tr>
<tr>
<td>With dyskinesia</td>
<td>8.93 ± 3.30</td>
</tr>
</tbody>
</table>

Additionally, the independent t-test results demonstrated a significant difference in FR of the shoulder joint between athletes with and without SD (P < 0.05). FR involves accurately perceiving the force applied to a joint or body part. Dover et al.’s study on the reliability of JPS and FR measures during internal and external shoulder rotation found that both JPS and FR were reliable measures of shoulder proprioception. Clinicians may find FR to be a better measure of shoulder proprioception due to its ability to provide more muscle activity and afferent information than JPS. However, further research is necessary to determine the significance of FR in an injured population or during rehabilitation. Clinical measurements of JPS and FR can be valuable for tracking rehabilitation progress and motivating athletes to improve proprioception between visits (26).

This study’s novelty lies in its comprehensive evaluation of JPS and force reproduction within the female racquet athlete population, with and without SD. While previous research may have explored similar measures in other athlete populations (2, 4, 8, 22-25) or focused exclusively on either JPS or force reproduction (26), our study uniquely combines these assessments within the specific context of female racquet sports athletes. Furthermore, our study delves into the nuanced relationship between these parameters and scapular dyskinesia, an area that has yet to be explored within the context of JPS and force reproduction in female racquet athletes. This unique focus allows us to uncover potential insights tailored to this specific population, ultimately contributing to a deeper understanding of the impact of scapular dyskinesia on JPS and force reproduction within the context of racquet sports.

These findings have important implications for the management of SD in racquet athletes. Improving scapular mechanics reduces pain and, enhances performance, and improves JPS and FR. This, in turn,
Table 3. The Results of the Independent t-test on JPS and FR of the Shoulder Joint in Racket Sports Athletes with and Without Dyskinesis

<table>
<thead>
<tr>
<th>Degree</th>
<th>Leven's Test</th>
<th>Independent t-test</th>
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<tbody>
<tr>
<td></td>
<td>F</td>
<td>P-Value</td>
</tr>
<tr>
<td>JPS</td>
<td>45</td>
<td>1.07</td>
</tr>
<tr>
<td></td>
<td>135</td>
<td>0.78</td>
</tr>
<tr>
<td>FR</td>
<td>90</td>
<td>0.78</td>
</tr>
</tbody>
</table>

Abbreviations: JPS, joint position sense; FR, force-reproduction; MD, mean difference; df, degrees of freedom.

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Footnotes

Authors' Contribution: TB and KK contributed to the study conception and design, and TB performed clinical examination and data collection. MS and KK participated in the methodological development and design of the statistical analysis. MS wrote the first draft of the manuscript and contributed to the comments and suggestions that greatly improved it. Finally, all the authors revised it critically for important intellectual content, agreed with the content, contributed to the current study's refinement, and approved the final manuscript.

Conflict of Interests: Authors declare no conflict of interest.

Data Availability: The datasets generated during and analyzed during the current study are available from the corresponding author upon reasonable request. The researchers interested in using the final dataset for scientific purposes may contact the corresponding author.

Ethical Approval: This research was approved by the ethics committee of Sport Sciences Research Institute, Tehran, Iran (approval number: IR.SSRC.REC.1402.013).

References


