Journal of Rehabilitation Sciences and Research

Journal Home Page: jrsr.sums.ac.ir

Original Article

Comparison of Strength, Muscle Length, and Shoulder Position Sense Between Dominant and Non-Dominant Sides in Individuals With and Without Uneven Shoulders

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ARTICLE INFO

Article History:
Received: 31/12/2024
Revised: 20/01/2025
Accepted: 25/01/2025

Keywords:
Uneven Shoulders
Muscle Strength
Muscle Length
Proprioception

Please cite this article as:
Feizi B, Norasteh A, Hosseini SH. Comparison of Strength, Muscle Length, and Shoulder Position Sense Between Dominant and Non-Dominant Sides in Individuals With and Without Uneven Shoulders. JRSR. 2026;13(2):137-144. doi:

ABSTRACT

Background: The present study aimed to evaluate differences in shoulder strength, muscle length, and proprioception between the dominant and non-dominant limbs of individuals with and without uneven shoulders.

Methods: This cross-sectional comparative study included 20 females with uneven shoulders and 20 age-matched controls (aged 20–30 years), selected through purposive sampling. Shoulder asymmetry was assessed using digital photography and analyzed with AutoCAD 2020. Muscle strength was measured using a manual dynamometer, proprioception was evaluated via joint angle reconstruction errors using a goniometer, and muscle length was assessed with standardized tests. Data were analyzed using SPSS version 22.

Results: Significant differences were observed between the groups in mean error of shoulder flexion angle reconstruction ($p = 0.049$, $d = 0.56$) and internal rotation ($p = 0.037$, $d = 0.61$), as well as in the lengths of the pectoralis minor ($p = 0.036$, $d = 0.58$) and levator scapulae muscles ($p = 0.021$, $d = 0.64$). Participants with uneven shoulders exhibited greater side-to-side differences compared to the control group. No statistically significant differences were found between groups regarding shoulder strength or upper trapezius muscle length.

Conclusion: Individuals with uneven shoulders demonstrated greater errors in joint position sense and asymmetries in specific muscle lengths. These findings suggest that uneven shoulders may be associated with impaired proprioception and altered muscle length, particularly in the pectoralis minor and levator scapulae muscles.

Introduction

The shoulder demonstrates the greatest mobility of any joint in the body. This capability depends on the efficient function of the scapular stabilizing muscles and the rotator cuff, which provide dynamic stability to the glenohumeral joint during a wide range of functional activities. Disruptions in the coordination and balance of scapular and humeral movements can adversely affect rotator cuff biomechanics, thereby increasing the risk of shoulder injuries. The scapula

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serves as a critical foundation for muscle attachment; consequently, alterations in scapular positioning can significantly influence the functionality and force generation of the shoulder girdle, particularly impacting muscles responsible for shoulder stabilization [1].

In a normal anatomical state, the scapula lies flat against the upper back, typically spanning from the second to the seventh thoracic vertebra, with both scapulae exhibiting symmetry. The medial border of each scapula aligns parallel to the vertebral column and is oriented approximately 30 degrees anteriorly relative to the frontal plane [2]. When assessing shoulder alignment using a horizontal reference line, both shoulders should ideally maintain equal distances from this line. A deviation in which one shoulder is positioned more than 2 degrees farther from the horizontal reference line is classified as an "uneven shoulder" [3, 4]. Recent studies in Iran indicate a rising prevalence of shoulder asymmetry [5–7].

A significant contributing factor to this asymmetry is the performance of improper exercises and the overuse of specific muscle groups, which can lead to muscular imbalances [8]. Weakness of the scapulothoracic muscles may result in abnormal shoulder positioning and disrupt the scapulohumeral rhythm, thereby impairing normal shoulder function [2, 9]. Musculoskeletal disorders frequently present with imbalances in muscle strength, with some individuals exhibiting limb dominance or non-dominance, whereas others exhibit habitual postural abnormalities. These imbalances may arise from occupational, athletic, or recreational activities that repeatedly engage certain muscle groups while leaving opposing muscles underactivated [10]. Repetitive movements of this nature can lead to shortening of tendon-muscle units, thereby reducing the joint's natural range of motion. Negative musculoskeletal adaptations at the affected site can further result in decreased range of motion, altered biomechanical patterns, diminished force production, and an increased risk of musculoskeletal injuries [11].

The dynamic stability of the shoulder joint is closely linked to position sense, a complex neuromuscular process involving both afferent input and efferent responses. This process is essential for optimizing trunk stability and the positioning of body segments relative to one another during both dynamic and static activities [12]. Increased pressure within the capsular-ligamentous structures at the extremes of the range of motion activates joint receptors [13]. Furthermore, joint damage can alter the input generated by mechanoreceptors, both directly and indirectly [12]. Research indicates that heightened afferent signals from pain receptors surrounding the shoulder may reduce the effectiveness of position sense afferents [14].

Daneshjo and Hosseini reported that individuals with uneven shoulders exhibited notable asymmetry in the strength of internal and external rotator muscles when comparing their dominant and non-dominant sides. In contrast, this side-to-side strength disparity was not observed in participants with symmetrical shoulders. Interestingly, volleyball players with uneven shoulders demonstrated greater muscle strength in both internal and external rotation [1].

Similarly, Akin and colleagues examined shoulder muscle strength, proprioceptive accuracy, and flexibility of internal and external rotation among adolescent athletes, comparing those with scapular asymmetry to peers with normal scapular alignment. Their results indicated no significant differences in shoulder strength or proprioception between the two groups, suggesting that scapular asymmetry may not affect these parameters in adolescent athletes [15]. Rahmani assessed the biomechanical properties of the shoulder girdle muscles in adolescent girls with uneven (dropped) shoulders and found that muscle activity on the dropped (right) side was comparable to that of the unaffected side [2]. In contrast, a study by Dabulkar et al. reported a significant difference in proprioception between the injured and uninjured shoulders of patients [16].

The present study aims to compare muscle strength, muscle length, and proprioception between the superior and non-superior sides in individuals with and without asymmetric shoulders. Given the critical role of the shoulder joint in both daily functioning and athletic performance—particularly among youth—understanding the effects of skeletal structural disorders is essential for early identification and targeted intervention.

Methods

This study employed a cross-sectional comparative design. Participants were selected through a non-random, field-based sampling method. The statistical population comprised young female students aged 20 to 30 years residing in Sanandaj city, both with and without uneven shoulders. Initially, shoulder assessments were conducted for 80 students, of whom 22 were identified as having uneven shoulders.

Power analysis using G*Power indicated that at least 36 participants per group were necessary to detect an effect size of 0.80 with 80% statistical power at a significance level of 0.05. Accordingly, 40 participants were purposively selected: 20 with uneven shoulders and 20 with even shoulders.

Inclusion criteria were as follows: age between 20 and 30 years; presence of uneven shoulder symptoms (for the uneven shoulder group); absence of uneven shoulder signs (for the control group); absence of menstruation at the time of assessment; no history of shoulder surgery; no neurological disorders; no history of fractures in the upper quarter or spine; and absence of other significant medical conditions. Exclusion criteria included scoliosis; history of surgical interventions; onset of pain or discomfort during measurements following traumatic injuries; dislocation of the glenohumeral or acromioclavicular joints; history of surgery, fractures, or previous instability; as well as reluctance to continue participation or development of health issues after enrollment.

All participants provided written informed consent and completed forms collecting personal data and information on prior injuries and athletic history. Anthropometric measurements, including height and weight, were recorded to calculate each participant's body mass index (BMI). Before testing, participants performed a 5–10-minute warm-up.

This study adhered to all relevant ethical guidelines. Written informed consent was obtained from all participants, and participant information was handled confidentially. Participants were free to withdraw from the study at any time without consequence. The study protocol was approved by the Ethics Committee of the Research Institute of Sports Sciences (IR.SSRI.REC.1399.985).

Measurement of Uneven Shoulders

Uneven shoulders were evaluated from a frontal view using a digital camera, with subsequent angle measurements performed in AutoCAD 2020 software. Participants were instructed to stand on a designated mark, with their arms resting naturally at their sides, feet together, and gaze directed straight ahead, maintaining a stationary posture. The examiner identified the acromion processes of each shoulder as anatomical landmarks and captured images from a fixed distance of 265 cm, with the camera aligned at shoulder height.

In AutoCAD 2020, the angle between the two acromion processes and a horizontal reference line was measured to quantify differences in shoulder height. Participants exhibiting a shoulder height difference greater than 2 degrees were classified as having uneven shoulders [1, 17–19] (Figure 1).

Shoulder elevation or depression was assessed using two anatomical landmarks: the superior angle of the scapula, typically aligned with the T2 vertebra, and the inferior angle of the scapula, generally located between the T7 and T9 vertebrae. Positions above or below these reference points were considered indicative of shoulder elevation or depression, respectively [20–22]. Shoulder positioning in a standing posture was analyzed using digital photographs and AutoCAD software [23].

Measurement of Isometric Strength of Shoulder Muscles

Flexion Strength Measurement: To assess flexion strength, the participant was positioned supine on a treatment table, with the shoulder extending beyond the edge of the table and the palm facing downward. A hand-held dynamometer was secured at the distal end of the arm, and the participant was instructed to exert an upward force while maintaining full elbow extension. The reliability coefficient of the hand-held dynamometer used for this measurement ranged from 0.79 to 0.92 [20].

Extension Strength Measurement: To assess shoulder extension strength, the participant lay prone on the treatment table, with the shoulder extending beyond the table edge and the palm facing upward. The hand-held dynamometer was positioned at the distal end of the arm, and the participant was instructed to exert an upward force while maintaining elbow flexion [19].

Measurement of Shoulder Abduction Strength: To assess shoulder abduction strength, the participant was seated upright in a chair, with the shoulder tested at 75 degrees of abduction in the frontal plane. The hand-held dynamometer was placed on the lower-lateral aspect of the arm, and the participant was instructed to exert maximal force against the device in the direction of abduction [10, 20, 24].

Measurement of Internal and External Rotation Strength: Participants were positioned prone on a treatment table to assess the isometric strength of shoulder internal and external rotation. The shoulder was placed at 90° abduction and the elbow at 90° flexion, allowing the forearm to hang vertically off the edge of the table. For internal rotation testing, the hand-held dynamometer was positioned on the anterior forearm just above the wrist, while for external rotation, it was placed on the dorsal forearm. Participants were instructed to exert maximal force against the examiner-held dynamometer, and the peak isometric force was recorded on the device's digital display [10, 20, 24]. Each test included two contractions of 5 seconds each, with a 1-minute rest interval between repetitions. The average force from these trials was used to estimate the maximum isometric strength of the shoulder rotator muscles [25]. To express strength relative to body weight, the average force was divided by the participant's weight and multiplied by 100.

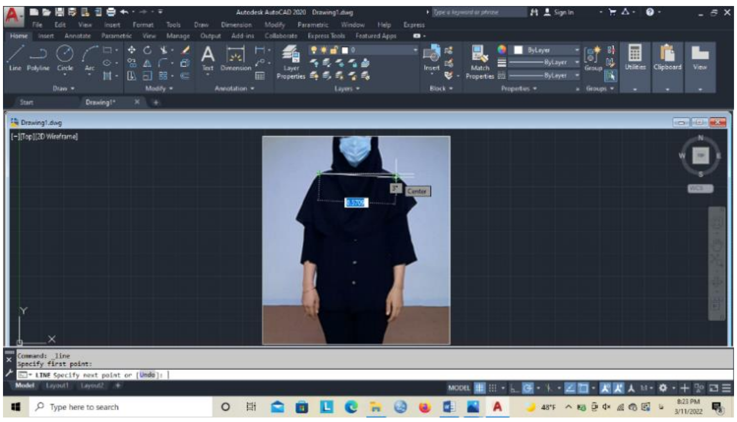

Figure 1: Measurement of Uneven Shoulder Using AutoCAD 2020 Software
Note: Figure 1 is original and created by the authors.

Pectoralis Minor Length Assessment

The reliability coefficient for the pectoralis minor length test has been reported as 0.94. The assessment is performed with the participant lying supine, arms positioned alongside the body, and palms facing downward. The therapist marks the posterior border of the acromion and measures the vertical distance from this mark to the treatment table, viewing the mark from above. This measurement evaluates the distance between the lateral edge of the scapula and the table, which should correspond to the participant's anthropometric proportions. An elevated acromion may indicate potential tightness of the pectoralis minor muscle. The normative vertical distance between the acromion and the table is approximately 2 cm (1 inch). Additionally, horizontal alignment of the acromions can be assessed from the anterior view, with the inter-acromial distance ideally not exceeding 5 cm (2 inches) [26-28]

Levator Scapulae Muscle Length Measurement

Measurements of the levator scapulae muscle length were performed with participants seated in a chair, arms positioned at their sides, and legs shoulder-width apart. Participants were instructed to maintain a neutral gaze and remain still throughout the assessment. To minimize the influence of respiration on the measurements, participants were instructed to exhale, hold their breath briefly, and then inhale before measurement. Before assessment, spinal alignment was confirmed in the frontal, sagittal, and transverse planes. Muscle length was quantified by measuring the linear distance between the transverse process of the second cervical vertebra and the superomedial angle of the scapula using a ruler. The Levator Scapulae Index (LSI) was calculated by dividing the resting muscle length (cm) by the participant's height (cm) and multiplying by 100. Each participant underwent two measurements to ensure accuracy. The intra-test reliability was reported as 0.99, while the inter-test reliability was 0.72 [29-31].

Upper Trapezius Muscle Length Measurement

To assess the length of the upper trapezius muscle, participants were seated in a chair with their feet comfortably positioned on the floor and their elbows resting on a table. Positioned behind the participant, the examiner supported the arm on the side of the targeted muscle and passively moved the participant's head into contralateral lateral flexion and ipsilateral rotation relative to the assessed muscle. An upward displacement of the shoulder on the assessed side was considered indicative of potential shortening of the upper trapezius. Simultaneously, a second examiner measured the vertical distance from the table to the participant's elbow, which was elevated from the table, using a ruler. This measurement was repeated three times for both the right and left sides, and the average distance was calculated and recorded for each side. Any increase in neck range of motion resulting from shoulder elevation was taken into account [32]. If the participant's elbow remained on the table and there was no alteration in neck range of motion, the upper trapezius muscle length was considered normal [27].

Measurement of Shoulder Position Sense

Shoulder position sense was evaluated using the active shoulder angular reconstruction test, facilitated by a goniometer. To eliminate visual input, participants were instructed to keep their eyes closed throughout the assessment. Before testing, the active range of motion of each shoulder joint was assessed in flexion, extension, abduction, and internal and external rotation. The arm naturally hanging at the side of the body was designated as the neutral starting position. The examiner passively moved the participant's arm to a predetermined target angle and held it for 5 seconds to allow the participant to focus on the angle. The arm was then returned to the neutral position. With eyes closed, participants were instructed to reproduce the target angle and actively maintain it. This procedure was performed three times for each shoulder, and the mean of the three trials was calculated. The difference between this mean and the target angle was used to calculate the participant's shoulder position sense score [33, 34]. All steps were performed for both the dominant and non-dominant shoulders.

Measurement of Shoulder Flexion and Extension

Participants were seated in a chair with the arm positioned at the side of the body and the elbow fully extended. The central axis of the goniometer was placed beneath the acromion, the fixed arm was aligned with the midline of the trunk, and the movable arm was aligned along the long axis of the humerus. The examiner passively moved the participant's arm to an angle of 60° in either flexion or extension. The participant was then instructed to actively reproduce the specified angle.

Measurement of Shoulder Abduction

The participant was seated with the arm at the side of the body and the elbow fully extended. The central axis of the goniometer was positioned over the center of the shoulder joint, with the fixed arm aligned parallel to the midline of the trunk and the movable arm aligned along the long axis of the humerus. The examiner passively abducted the participant's arm to an angle of 60°. The participant was then instructed to actively reproduce this angle.

Measurement of Shoulder Internal and External Rotation

The participant lay supine on a treatment table with the shoulder abducted to 90° and the elbow flexed at 90°. Anatomical landmarks, including the ulnar styloid process and the olecranon, were marked for reference. The central axis of the goniometer was positioned along the ulnar process, with the fixed arm perpendicular to the floor and the movable arm aligned with the longitudinal axis of the ulna. For external rotation, the examiner passively rotated the participant's arm to 45°, while for internal rotation, the arm was passively rotated to 45° in the opposite direction [14, 33, 35].

Data Analysis Procedures

Data analysis began with the computation of descriptive statistics for participants' demographic and anthropometric characteristics, including means and standard deviations. Descriptive and inferential results of the study were subsequently presented in tables and graphs. Statistical analyses were conducted using SPSS version 22, while Microsoft Word and Excel were used to generate tables and figures.

The normality of all variables was assessed using the Shapiro–Wilk test. For variables that did not meet the assumption of normal distribution, group comparisons were performed using the Mann–Whitney U test. These non-normally distributed variables included shoulder strength (flexion, extension, abduction, and internal rotation), muscle length of the pectoralis minor, levator scapulae, and upper trapezius, as well as reconstruction error for shoulder angles (flexion, extension, abduction, internal rotation, and external rotation) between the superior and non-superior shoulders. The Mann–Whitney U test was employed as the non-parametric alternative to the independent t-test.

For variables meeting the assumption of normality, an independent t-test was applied to compare external rotation strength between the dominant and non-dominant shoulders. Statistical significance was set at $p < 0.05$ for all analyses.

Results

The general characteristics of the subjects, categorized into two groups based on the presence or absence of uneven shoulders, are presented in Table 1.

As shown in Tables 2 and 3, no statistically significant side-to-side differences were observed in shoulder strength measures—including flexion, extension, abduction, and internal and external rotation—within either the uneven-shoulder or control groups (Tables 2, 3).

Between-group comparisons indicated no significant difference in upper trapezius asymmetry ($p = 0.344$). In contrast, significant differences were identified for pectoralis minor and levator scapulae asymmetry ($p = 0.036$ and $p = 0.021$, respectively) (Table 3).

Regarding mean differences, individuals with uneven shoulders exhibited a mean pectoralis minor length difference (measured from the height of the acromion to the table surface) of 0.31 cm and a mean levator scapulae difference of 0.29 cm. These values exceeded the corresponding mean differences observed in individuals with symmetrical shoulders.

The analysis revealed no significant differences in shoulder reconstruction errors for extension, abduction, or external rotation between the dominant and non-dominant sides in either group (with or without uneven shoulders). However, significant differences were observed in the reconstruction errors for shoulder flexion and internal rotation between the dominant and non-dominant sides in both groups, with p-values of 0.049 and 0.037, respectively (Table 3).

Regarding mean differences, individuals with uneven shoulders demonstrated an average reconstruction error that was 2.6° higher for shoulder flexion and 2.25° higher for internal rotation on the superior side, compared to the corresponding errors in individuals with even shoulders.

Table 1: Descriptive Statistics (Mean ± SD) of Participants' Characteristics (n = 40)

	Even Shoulder Group (n=20)	**Uneven Shoulder Group (n=20)**	**Total (n=40)**	
Variable	M ± S.D	M ± S.D	M ± S.D	P
Age (years)	26.80 ± 2.35	26.50 ± 1.70	26.65 ± 2.03	0.655
Height (cm)	159.77 ± 7.49	164.17 ± 6.72	161.97 ± 7.37	0.058
Weight (kg)	58.10 ± 9.32	60.27 ± 11.84	59.18 ± 10.58	0.523
BMI (kg/m²)	22.85 ± 3.67	22.29 ± 3.83	22.57 ± 3.71	0.640

Significance Level: P<0.05.

Table 2: Independent T-Test Results Comparing External Rotation Strength Between Groups (Dominant vs. Non-Dominant Side, n = 40)

Variable	Levene's F	Sig. (F).	t	Mean	Difference	df	P
External Rotation Strength		2.241	0.143	0.636	0.222	38	0.529

Significance Level: P<0.05.

Table 3: Mann–Whitney U Test Results Comparing Muscle Strength, Muscle Length, and Proprioception Between Groups (Dominant vs. Non-Dominant Side, n = 40)

Variable	Group	Mean Rank	Z	P
Flexion Strength (N)	Even / Uneven shoulder	20.35 / 20.65	-0.081	0.935
Extension Strength (N)	Even / Uneven shoulder	18.70 / 22.30	-0.974	0.330
Abduction Strength (% Body Weight)	Even / Uneven shoulder	23.48 / 17.53	-1.610	0.107
Internal Rotation Strength (% Body Weight)	Even / Uneven shoulder	20.80 / 20.20	-0.162	0.871
Pectoralis Minor Muscle Length (cm)	Even / Uneven shoulder	16.83 / 24.18	-2.094	0.036*
Levator Scapulae Muscle Length (cm)	Even / Uneven shoulder	16.50 / 24.50	-2.314	0.021*
Upper Trapezius Muscle Length (cm)	Even / Uneven shoulder	21.78 / 19.23	-0.947	0.344
Flexion Angle Reconstruction Error (°)	Even / Uneven shoulder	16.95 / 24.05	-1.960	0.049*
Extension Angle Reconstruction Error (°)	Even / Uneven shoulder	19.63 / 21.38	-0.483	0.629
Abduction Angle Reconstruction Error (°)	Even / Uneven shoulder	21.40 / 19.60	-0.516	0.606
Internal Rotation Angle Reconstruction Error (°)	Even / Uneven shoulder	16.73 / 24.28	-2.081	0.037*
External Rotation Angle Reconstruction Error (°)	Even / Uneven shoulder	20.55 / 20.45	-0.027	0.978

*Significance Level: P<0.05.

Discussion

The purpose of this study was to examine shoulder strength, muscle length, and proprioceptive position sense with respect to side-to-side differences in individuals with and without uneven shoulders.

The results indicated that shoulder strength—including flexion, extension, abduction, and rotational movements—did not differ significantly between the dominant and non-dominant sides in either group. These findings are consistent with those reported by Karagianakis et al., Heshmati, and Rahmani. Karagianakis et al. investigated shoulder muscle activity in female volleyball players exhibiting shoulder asymmetry at rest. Their results demonstrated that electromyographic (EMG) activity of the upper trapezius (UT), serratus anterior (SA), and middle trapezius (MT) muscles was not significantly affected during closed-chain exercises, despite the dominant shoulder being positioned more distally and lower at rest [36]. Similarly, Heshmati compared the electrical activity of the serratus anterior and upper trapezius muscles across three shooting disciplines and found no significant differences in upper trapezius activity among the groups. The distinct hand and shoulder postures adopted by shooters during training and competition may substantially contribute to the observed variations in muscle electrical activity and scapular symmetry [37]. Rahmani evaluated the biomechanical properties of shoulder girdle muscles in adolescent girls with uneven (dropped) shoulders and reported that muscle activity on the dropped (right) side was comparable to that of the unaffected side, which aligns with the findings of the present study [2].

These results suggest that asymmetrical shoulders may not significantly affect the magnitude of shoulder girdle muscle contraction but may instead influence the timing of muscle activation. The findings of the current study imply that observed differences may be attributable to neuromuscular control mechanisms of the shoulder girdle rather than to variations in muscle or tissue strength.

In contrast, Daneshjoo et al. examined upper-limb strength and range of motion in volleyball players with symmetrical and asymmetrical shoulders. They reported greater internal and external rotation strength in athletes with shoulder asymmetry, findings that differ from those of the present study [1]. Additionally, Gillette et al. [38] found that tennis players with a history of shoulder injuries exhibited lower glenohumeral external-to-internal rotator strength ratios on both sides and demonstrated stronger upper trapezius and more dominant serratus anterior activity than players without a history of shoulder problems, findings that contradict our findings. Hadzic et al. examined shoulder strength asymmetries in professional volleyball players. They reported that male athletes exhibited a reduced external-to-internal rotation strength ratio in the dominant shoulder, irrespective of playing position, competitive level, or injury history. In contrast, a similar reduction was observed in female athletes only at higher competitive levels [39]. Furthermore, Wang et al. reported that internal rotator strength on the dominant side of volleyball players with asymmetrical shoulders was significantly lower than in healthy individuals, which contrasts with the results of the present study [40].

Differences in the populations examined may explain the discrepancies between these studies and our findings. Many previous studies focused on individuals with various shoulder injuries or involved athletes with more uniform training regimens, which could result in differing degrees of shoulder asymmetry and influence strength measures.

Azarsa et al. examined the influence of loading on dynamic stability and scapular asymmetry, demonstrating that scapular stability is highly dependent on muscle function. Specifically, as muscular load increases, scapular asymmetry becomes more pronounced [41]. The study also revealed significant differences in muscle length between the dominant and non-dominant sides in both groups. In individuals with uneven shoulders, these asymmetries were particularly evident, with the pectoralis minor exhibiting reduced length and the levator scapulae showing increased length.

Sahrman suggests that repetitive movements or prolonged postures can lead to adaptations in muscle length and stiffness, which may contribute to movement disorders. Variations in sarcomere number can result in muscles becoming either elongated or shortened. Additionally, certain injuries may create muscle imbalances, whereas other imbalances may arise from pre-existing muscular asymmetries [42].

The muscular connections among the spine, scapula, clavicle, and arm directly influence the alignment of these bony structures. This alignment is critical because it affects muscle length, which in turn determines the muscle's capacity to generate tension [42]. Functionally, the pectoralis minor primarily contributes to scapular abduction and downward rotation, whereas the levator scapulae acts to elevate the scapula. Shortening of the pectoralis minor combined with elongation of the levator scapulae can lead to scapular and shoulder depression. When such alterations occur predominantly on one side, particularly the dominant side, they may result in observable shoulder asymmetry.

The results indicated a significant difference in the error of shoulder flexion angle reconstruction ($p = 0.049$) and internal rotation ($p = 0.037$) between subjects with uneven shoulders and those without. Dabulkar et al. assessed shoulder proprioception in patients experiencing shoulder pain. They found a significant difference in proprioception between injured and uninjured shoulders, as evidenced by the target angle derived from the subtraction of results. However, no significant difference in proprioception was observed between the dominant and non-dominant shoulders in healthy subjects [16]. Lubiatowski et al. investigated bilateral shoulder proprioception deficits among individuals with unilateral anterior shoulder instability. Their findings revealed a marked impairment in the accuracy of active joint position sense in unstable shoulders, with similar deficits in the contralateral, unaffected shoulders compared with controls [43].

Muscle imbalance is indicative of neuromuscular dysfunction and often presents as a systemic response affecting the entire body. The Panjabi Spinal Stability Model (1992) delineates three subsystems: the skeletal system, the muscular system, and the central nervous system. Dysfunction within any of these subsystems can result in one of three outcomes: (1) successful compensation by other subsystems or natural maladaptation, (2) long-term adaptation within one or more subsystems, or (3) damage to one or more components, leading to pathological adaptation. Research suggests that increased afferent signals from pain receptors surrounding the shoulder can diminish proprioceptive feedback and motor afferents, disrupting the rhythm of shoulder movements and impairing shoulder muscle function [44].

Akin et al. examined shoulder muscle strength, proprioceptive acuity, and rotational range of motion in adolescent athletes with and without scapular asymmetry. They reported no significant differences between groups in either shoulder strength or proprioceptive measures [15]. The present study's results align with previous findings regarding muscle strength, showing no significant intergroup differences. However, our findings diverged with respect to proprioception: individuals with uneven shoulders exhibited poorer proprioceptive performance in shoulder flexion and internal rotation. Joint mobility limitations and pressure can degrade mechanoreceptor function, diminishing joint position sense. This impairment may perpetuate a cycle that exacerbates discrepancies in angle reconstruction errors. The nervous system plays a central role in the development and persistence of musculoskeletal pathologies, as muscle imbalances may arise from altered proprioceptive input or abnormal joint positioning and movement. These factors can lead to either muscle shortening (hypertonicity) or weakness (inhibition), ultimately fostering local muscle imbalances [42].

Conclusion

This study found no significant side-to-side differences in shoulder muscle strength or upper trapezius length. However, individuals with uneven shoulders demonstrated specific asymmetrical characteristics, including a shorter pectoralis minor and a longer levator scapulae on the superior side, as well as greater joint position reconstruction errors in shoulder flexion and internal rotation, indicating impaired proprioception.

These findings suggest that shoulder asymmetry may be more closely associated with neuromuscular control and muscle length adaptations rather than deficits in muscle strength.

Several limitations should be acknowledged. The relatively small sample size and inclusion of only young women limit the generalizability of the findings. Additionally, constraints related to measurement tools and testing procedures may have influenced the precision of the results. Despite these limitations, the findings provide valuable insights for the development of preventive and therapeutic strategies targeting shoulder dysfunction. The results underscore the importance of postural assessment and corrective interventions to address muscle-length imbalance and proprioceptive deficits.

Future research should include larger and more diverse populations and further investigate the influence of specific sports activities and training patterns on the development of shoulder asymmetry.

Ethical Considerations

This study was conducted in accordance with applicable ethical standards. Written informed consent was obtained from all participants before participation, and the confidentiality of participants' information was strictly maintained. Participants were informed of their right to withdraw from the study at any time without penalty. The study protocol was approved by the Ethics Committee of the Research Institute of Sports Sciences (IR.SSRI.REC.1399.985).

Author Contributions

AAN and SHH were responsible for conceptualization and methodology. AAN and SHH conducted a formal analysis. BF carried out the investigation and provided the necessary resources. AAN, SHH, and BF performed data curation. BF prepared the original draft of the manuscript. AAN and SHH contributed to manuscript review and editing. AAN and SHH undertook supervision and project administration. All authors have read and approved the final manuscript.

Funding

This research received no external funding.

Acknowledgments

This article is derived from the master's thesis in Sports Injury and Corrective Exercises by Ms. Bayan Feizi, conducted under the supervision of Dr. Ali Asghar Norasteh and Dr. Seyyed Hossein Hosseini. The authors sincerely thank all individuals who contributed to the successful completion of this research.

Conflict of Interest: The authors declare no conflicts of interest related to this study. The research was conducted without external financial support.

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