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ORIGINAL ARTICLE

Investigation of Scapular Resting Position and Shoulder Range of Motion, and the Relationship Between Them in Athletes and Non-Athletes with Spinal Cord Injury

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Abstract: The present study aimed to examine the scapular resting position and shoulder range of motion (ROM) in flexion, abduction, internal rotation, and external rotation, as well as the relationships among these variables in athletic and non-athletic individuals with spinal cord injury. The target population consisted of wheelchair-bound athletes with spinal cord injury (SCI) active in sports clubs in Mashhad, Iran, as well as non-athletic individuals with SCI. Using a purposive sampling method, 45 men with SCI were recruited and categorized into three groups: wheelchair basketball players (n=15), wheelchair table tennis players (n=15), and non-athlete group (n=15). The primary outcomes of this study included the measurement of scapular protraction and rotation at rest position, as well as shoulder range of motion (ROM) in flexion, abduction, internal (medial) rotation, and external rotation. To evaluate resting scapular position, participants were positioned in an upright seated position and instructed to protract and retract their shoulders several times before sting into a fully relaxed posture. Shoulder ROM for flexion, abduction, medial (internal) rotation, and external rotation was measured and recorded using a standard universal goniometer. The study concludes that wheelchair athletes present distinct resting scapular kinematic profiles (specifically regarding protraction and rotation) compared to non-athletes, which correlates significantly with their shoulder range of motion. Differences also exist between the dominant and non-dominant limbs in both scapular resting position and shoulder ROM, highlighting potential asymmetries induced by sport-specific demands.

Keywords: Scapular Resting Position, Shoulder Range of Motion, Athletes, Spinal Cord Injury

Introduction

Proper upper limb function is vital for individuals with spinal cord injury (SCI) to perform activities of daily living (ADLs), including dressing, washing, and combing one's hair (Magermans et al 2005, Rundquist et al 2009). Particularly for wheelchair-dependent individuals, optimal shoulder range of motion

(ROM) is essential for achieving independence in transfers (gagnon2008) and performing activities such as toileting, bed mobility, driving, and participation in sports and recreational activities. Unfortunately, wheelchair users with SCI are at a high risk of developing shoulder disorders, characterized by pain (Ballinger et al 2000, Salisbury et al 2003, Sie et al 1992) or joint ROM limitations (Ballinger et al 2000, Salisbury et al 2003, Eriks-hoogland et al 2009) which are observed during both initial rehabilitation and the chronic stages of the condition. Shoulder ROM restrictions in this population have been reported as a fundamental issue even in the early stages of clinical rehabilitation and following discharge (Ballinger et al 2000). Due to immobility and spasticity (Eriks-hoogland et al 2009), individuals with SCI are more susceptible to shoulder ROM limitations, which can lead to complications such as "frozen shoulder."

Since the 1960s, medical advancements and surgical techniques, coupled with the increased production of adaptive equipment, have expanded athletic opportunities for people with disabilities. Individuals with physical impairments now participate in high-level disciplines such as track and field, basketball, swimming, and table tennis. These sports are often integrated into adaptive rehabilitation programs, helping individuals assume more active societal roles, overcome their disabilities, and enhance their motivation and functional levels (Nicholas and Hershman 1995).

Furthermore, exercise—as a result of continuous physical and cognitive training—exerts a positive impact on wheelchair users (Ferrara et al 2021). Specifically, exercise increases bone and muscle mass, counters disuse atrophy, and protects skeletal muscles against oxidative stress and proteolysis (Ferrara et al 2021). It also possesses neuroprotective and rehabilitative properties at both biochemical and physical levels (Invernizzi et al 2021) Despite these benefits, wheelchair users participating in overhead sports are twice as likely to suffer from rotator cuff injuries compared to their non-athletic counterparts (Wilroy et al 2018). Given the often-sedentary lifestyle of wheelchair users, exercise is essential for maintaining their health (Blauwet C and Willick SE 2012, Sánchez-Pay A, Sanz-Rivas D2004, Flank et al 2012). However, in addition to the demands of ADLs, athletic activity increases stress on the shoulder complex (Warner et al 2018, Burnham et al 1993). The prevalence of shoulder problems in wheelchair athletes has been reported to range from 16% to 76% (Chung et al 2012, Akbar et al 2015), a situation comparable to able-bodied tennis, where the shoulder is the most common site of upper limb injury (Gescheit et al 2019).

Despite the proven benefits of sports, long training hours and intensive competition schedules increase injury rates among athletes (Curtis 1996). Unfortunately, there is limited evidence regarding the etiology of shoulder injuries in sports such as wheelchair basketball, amputee football, and para-table tennis. It appears that abnormal biomechanics and overuse injuries occurring in the shoulder girdle are associated with dysfunction of the scapular stabilizing muscles (Moseley et al 1992, Kuhn et al 1995). This functional impairment in scapular biomechanics can predispose the shoulder to injury (Glusman et al 1986, Kibler1998), although it is not always correlated with shoulder pain (Tate et al 2009).

Pain is of particular significance for wheelchair athletes, as 72% to 76% of these individuals experience shoulder issues at least once in their lifetime (Riccio 2015). The most common injuries associated with shoulder pain in this group include subacromial impingement syndrome, bicipital tendinitis, rotator cuff tears, and glenohumeral instability. These injuries involve a dynamic component that is highlighted by clinical examinations and dynamic tests, rather than conventional imaging techniques which are primarily static (Lefèvre-Colau et al 2018, Riccio 2015).

Wheelchair athletes are at a high risk of overuse injuries due to the repetitive use of the upper limbs for mobility. The repetitive mechanics of wheelchair propulsion, including frequent scapular protraction, can lead to postural changes, weakness of the scapular stabilizers, and tightness of the anterior muscles. Additionally, compensatory muscle imbalances resulting from prolonged wheelchair use or incomplete training programs—specifically those lacking rotator cuff and scapular stabilizer strengthening—can predispose athletes to musculoskeletal injuries in sports with diverse movement patterns, such as swimming, throwing, or racquet sports (Dec et al 2000).

A high prevalence of shoulder problems has been reported in wheelchair tennis (Sánchez-Pay et al 2017, Chung KC, Lark ME 2017, Jeon et al 2010, Matsuwaka ST, Latzka EW2019). Unilateral striking movements, similar to conventional tennis, involve repetitive activation of the anterior muscle chain. The seated position, inherent to this sport, affects shoulder alignment and trunk rotation, thereby influencing shoulder mechanics and, consequently, force production during serves and groundstrokes (Chung KC, Lark ME 2017, Fairbairn JR, Bliven 2019, Reid et al 2007).

The combination of wheelchair dependency, overhead activities, and high training intensity imposes a heavy load on the shoulder, making it a potential risk factor for overuse injuries (Heyward et al 2017, Aytar et al 2015). Upper limb injuries significantly impact not only athletic performance but also the individual's activities and participation in daily life (Churton E, Keogh JWL 2013).

In the context of para-table tennis, while specific studies on shoulder injury mechanisms are lacking, statistics indicate that 12% of all shoulder injuries in Paralympic athletes are observed in this discipline (Vital et al 2007). Generally, despite the growth of adaptive sports, scientific literature in this field remains limited (Aytar et al 2012, Vital et al 2007).

Wheelchair basketball and para-table tennis are two major Paralympic disciplines; both associated with a high risk of shoulder and scapular injuries that can halt participation. The consequences of injury for an adaptive athlete can extend beyond exclusion from sports, potentially limiting functional independence and the ability to perform ADLs, thus requiring appropriate treatment (Lefèvre-Colau et al 2018, de Sire et al 2021). However, shoulder disorders in wheelchair athletes have multifactorial causes, including ROM limitations and strength imbalances, which can be difficult to identify (Heyward et al 2017, Wilroy, J.; Hibberd, E 2018). In fact, alterations in shoulder kinematics, overuse, and inefficient propulsion can all contribute to the onset of shoulder pain (Requejo et al 2008). To date, there is sparse evidence regarding shoulder function specifically in wheelchair basketball players, and no consensus exists on shoulder injury prevention programs for these athletes.

Wheelchair dependency shifts the role of the shoulder complex from providing ROM for fine motor tasks to serving as the primary power source for daily mobility (Churton E, Keogh JWL 2013). Although wheelchair propulsion alone exerts relatively low joint forces on the shoulder (Van Drongelen et al 2005, Briley et al 2020), the high frequency of movement and heavy loading during specific activities, such as wheelchair transfers, place the shoulder joint at extreme risk of repetitive overuse (Van Drongelen et al 2005). This shift necessitates increased force production in the upper limbs, which can lead to muscle imbalances and affect the position of the scapula relative to the humerus and thorax (Ballinger et al 2000). These altered conditions likely contribute to subacromial space impingement and increased joint wear (Van Der Hoeven H, Kibler WB 2006, Burnham et al 1993).

A recent systematic review rated the quality of existing studies as low and emphasized the need for biomechanical investigation of various sporting tasks (Riccio et al 2015). In this regard, surface electromyography (sEMG) and kinematic analysis can serve as valid and reliable tools for analyzing shoulder function (Warner et al 2018, de Sire et al 2019), providing useful data on ROM and muscle activation (Vigotsky et al 2017). Therefore, longitudinal observational studies are essential to better investigate the effects of rehabilitation on improving upper limb function in this population (Heyward et al 2017).

Consequently, a detailed assessment of scapular status and shoulder ROM in wheelchair athletes is of paramount importance, especially considering the significance of post-SCI exercise for maintaining physical and mental health. These individuals are prone to occupational and athletic injuries due to repetitive movements and excessive loading on upper body structures. However, the lack of sufficient research in this area has created a gap in understanding the precise mechanisms of injury, making it difficult to rely on generic preventive protocols. Therefore, the regular and targeted evaluation of ROM and scapular stability is vital and urgent, not only to prevent secondary injuries in the shoulder and scapula—which can threaten quality of life and athletic continuity—but also to formulate evidence-based rehabilitation strategies.

Methods

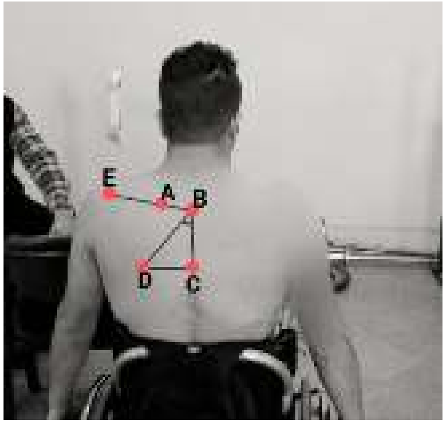
Study Design and Participants. The present study is semi-experimental, descriptive, and comparative, utilizing a cross-sectional design. The target population consisted of wheelchair-bound athletes with spinal cord injury (SCI) active in sports clubs in Mashhad, Iran, as well as non-athletic individuals with SCI. Using a purposive sampling method, 45 men with SCI were recruited and categorized into three groups: wheelchair basketball players (n=15), wheelchair table tennis players (n=15), and non-athlete group (n=15). The athletes included in the study participated in at least three training sessions per week and were professional players in the Mashhad city league. To ensure homogeneity across groups, participants were stratified based on the Stoke Mandeville classification into three neurological levels: upper thoracic (T1–T7), mid-thoracic (T8–T11), and thoracolumbar (T12–L3). Consequently, each of the three groups (non-athletes, table tennis, and basketball) contained an equal number of participants from each injury level. Demographic characteristics of the participants are summarized in Table 1.

Inclusion and Exclusion Criteria. The dominant hand, defined as the limb used for throwing the ball or holding the racquet, was used for assessments. To control for potential gender-related physiological differences, only male participants were included. Exclusion criteria consisted of a history of shoulder surgery, traumatic injuries (such as dislocation, subluxation, or acromioclavicular joint sprains), and reports of shoulder pain within the six months preceding the study.

Procedure and Ethical Considerations. Following the acquisition of necessary institutional approvals, participants were briefed on the study’s objectives, the assessment protocols, and potential risks. Written informed consent was obtained from all volunteers, and all queries regarding the testing procedures were addressed by the researchers.

Assessments and Measurements. The primary outcomes of this study included the measurement of scapular protraction and rotation at rest position, as well as shoulder range of motion (ROM) in flexion, abduction, internal (medial) rotation, and external rotation.

To evaluate resting scapular position, participants were positioned in an upright seated position and instructed to protract and retract their shoulders several times before seating into a fully relaxed posture. The examiner then identified the spinous process of the seventh cervical vertebra (C7) as a reference point to locate and mark the spinous process of the third thoracic vertebra (T3) using a clinical marker. All anatomical landmarks were identified and marked via palpation to ensure the accurate drawing of reference lines for subsequent measurements.



To quantify scapular positioning, the following anatomical landmarks were identified and marked using colored circular stickers:

- **Point A:** Root of the spine of the scapula.
- **Point B:** Spinous process of the third thoracic vertebra (T3).
- **Point C:** Spinous process of the thoracic vertebra at the level of the inferior angle of the scapula.
- **Point D:** Inferior angle of the scapula.
- **Point E:** Posterior surface of the tip of the acromion.

Distances between these points, specifically BC, CD, AE, and BAE, were measured using a standard centimeter tape measure.

Scapular Protraction and Rotation. Scapular protraction was calculated using the following ratio:

$$\textbf{Scapular Protraction} = BAE/AE$$

Scapular rotation was determined by calculating the tangent of angle θ\thetaθ (the angle formed between lines BCBCBC and BDBDBD):

$$\textbf{Scapular rotation} = \tan\theta = CD/BC$$

The validity of this palpation-based method was previously established by Greenfield et al., who demonstrated no statistically significant difference between measurements obtained through physical examination markers and those obtained via radiographic imaging.

Scapular Symmetry. Scapular symmetry for each participant was determined using the following formula:

Symmetry=L/R

Where L represents the ratio of protraction to rotation for the left scapula, and R represents the same ratio for the right scapula.

Range of Motion (ROM). Shoulder ROM for flexion, abduction, medial (internal) rotation, and external rotation was measured and recorded using a standard universal goniometer. For each movement, three trials were performed, and the mean value of these repetitions was recorded as the final ROM for the joint.

Statistical Analysis. Data distribution normality was assessed using the Shapiro-Wilk test. Inter-group differences were analyzed using independent t-tests and One-way Analysis of Variance (ANOVA). The relationship between variables was examined using the Pearson correlation coefficient. The level of statistical significance was set at $p \leq 0.05$. All statistical analyses were performed using SPSS software (Version 23.0).

Results

Table 1 presents the demographic information of the subjects. Tables 2 show the Analysis of variance test results in resting Scapular position and Shoulder ROM Among Groups. Table 3 show Results of the independent t-test in in resting Scapular position and Shoulder ROM between the dominant and non-dominant shoulder. Table 4 show the Pearson Correlation Coefficients Between Resting Scapular position and Shoulder ROM. Figure 1 show ANOVA test results in resting Scapular position and Shoulder ROM Among Groups based on SCI level.

Table 1. Demographic information of the subjects

Group	Number	Mean±SD		
		Age (y)	Weight (kg)	Sitting Height (cm)
Wheelchair Table Tennis (WCTT)	15	٤٥,٤٠ ± ٤,٥٩	٦١,٠٠ ± ٧,١٠	٧٦,٩٣ ± ٣,١٢
Wheelchair Basketball (WCB)	15	٤٩,٣٣ ± ١٠,٦٢	٧١,٦٦ ± ٩,٥٤	٧٨,٢٠ ± ٣,٧٦
Non-Athletes (NA)	15	٤٧,٠٠ ± ٨,٨١	٦٦,٩٣ ± ١١,١١	٨٠,٥٣ ± ٥,١٦
General	45	٤٧,٢٤ ± ٨,٣٦	٦٦,٥٣ ± ١٠,١٨	٧٨,٥٥ ± ٤,٢٨

Table 2. Analysis of variance test results in resting Scapular position and Shoulder ROM Among Groups

	Shoulder	df	F	sig	Post Hoc Test Results between Groups	sig
Scapular Protraction	Dominant	2	17/25	٠/001	WCTT with WCB	٠/94
					WCTT with NA	٠/001
					WCB with NA	0/001
	Non-Dominant	2	14/08	٠/001	WCTT with WCB	٠/23
					WCTT with NA	٠/003
					WCB with NA	٠/001
Scapular rotation	Dominant	2	9/68	٠/001	WCTT with WCB	٠/38
					WCTT with NA	٠/01
					WCB with NA	0/001

					WCTT with WCB	0/65
	Non-Dominant	2	۳/33	۰/04	WCTT with NA	۰/23
					WCB with NA	۰/04
Scapular Symmetry		2	۰/57	۰/55		
					WCTT with WCB	۰/۲۷
	Dominant	2	۵/۲۹	۰/۰۰۹	WCTT with NA	۰/۴۱
Shoulder Flexion					WCB with NA	۰/۰۰۷
					WCTT with WCB	۱/۰۰
	Non-Dominant	2	۷/۹۶	۰/۰۰۱	WCTT with NA	۰/۰۰۳
					WCB with NA	۰/۰۰۵
					WCTT with WCB	۰/۰۰۱
	Dominant	2	۴۸/۱۹	۰/۰۰۱	WCTT with NA	۰/۰۰۱
Shoulder Abduction					WCB with NA	۰/۰۰۱
					WCTT with WCB	۰/۰۰۳
	Non-Dominant	2	۴۳/۸۵	۰/۰۰۱	WCTT with NA	۰/۰۰۱
					WCB with NA	۰/۰۰۱
					WCTT with WCB	۰/۱۳
	Dominant	2	۶۸/۱۱	۰/۰۰۱	WCTT with NA	۰/۰۰۱
Shoulder Internal Rotation					WCB with NA	۰/۰۰۱
					WCTT with WCB	۰/۴۷
	Non-Dominant	2	۸۴/۴۷	۰/۰۰۱	WCTT with NA	۰/۰۰۱
					WCB with NA	۰/۰۰۱
					WCTT with WCB	۰/۰۲
	Dominant	2	۴۹/۷	۰/۰۰۱	WCTT with NA	۰/۰۰۱
Shoulder External Rotation					WCB with NA	۰/۰۰۱
					WCTT with WCB	۱/۰۰
	Non-Dominant	2	۳۴/۰۳	۰/۰۰۱	WCTT with NA	۰/۰۰۱
					WCB with NA	۰/۰۰۱

WCTT wheelchair tennis table, WCB wheelchair basketball and NA Non-athlete

Table 3. Results of the independent t-test in in resting Scapular position and Shoulder ROM between dominant and non-dominant shoulder

Shoulder	Dominant	Non-Dominant
Scapular Protraction	۱/64 ± ۰/1	۱/71 ± ۰/1
p	۰/002	
Scapular rotation	36/47 ± ۳/47	۳۵/67 ± 4/2
p	۰/33	

Shoulder Flexion	١٧٧/٢٢ ± ٣/٥٦	١٧٤/٧٥ ± ٣/٢١
p	٠/٠٠١	
Shoulder Abduction	١٦٦/٤٢ ± ٥/٠٥	١٦٤/٦٢ ± ٤/٩٠
p	٠/٠٩	
Shoulder Internal Rotation	٥٩/٤ ± ٤/٢١	٥٦/٨٤ ± ٤/٤٣
p	٠/٠٠٦	
Shoulder External Rotation	٨٧/٧٥ ± ٤/٢٤	٨٥/٤٦ ± ٤/٧٨
p	٠/٠٢	

Table 4. Pearson Correlation Coefficients Between Resting Scapular position and Shoulder ROM

	Shoulder Flexion		Shoulder Abduction		Shoulder Internal Rotation		Shoulder External Rotation	
	D	ND	D	ND	D	ND	D	ND
Scapular Protraction	r = - 0.41 p = 0.001	r = - 0.52 p = 0.001	r = - 0.51 p = 0.001	r = - 0.58 p = 0.001	r = - 0.71 p = 0.001	r = - 0.70 p = 0.001	r = - 0.55 p = 0.001	r = - 0.58 p = 0.001
Scapular rotation	r = 0.19 p = 0.21	r = 0.25 p = 0.09	r = 0.46 p = 0.002	r = 0.31 p = 0.04	r = 0.50 p = 0.001	r = 0.39 p = 0.009	r = 0.36 p = 0.01	r = 0.30 p = 0.04

D: Dominant ND: Non-Dominant

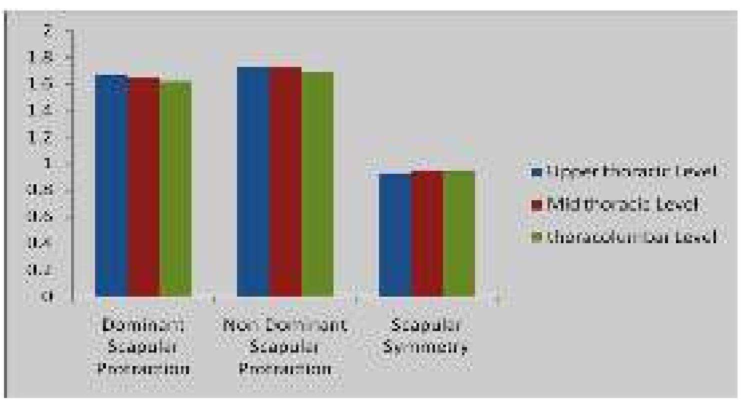


Figure 1. ***ANOVA*** **results in resting Scapular position and Shoulder ROM Among Groups** ***based on SCI level***

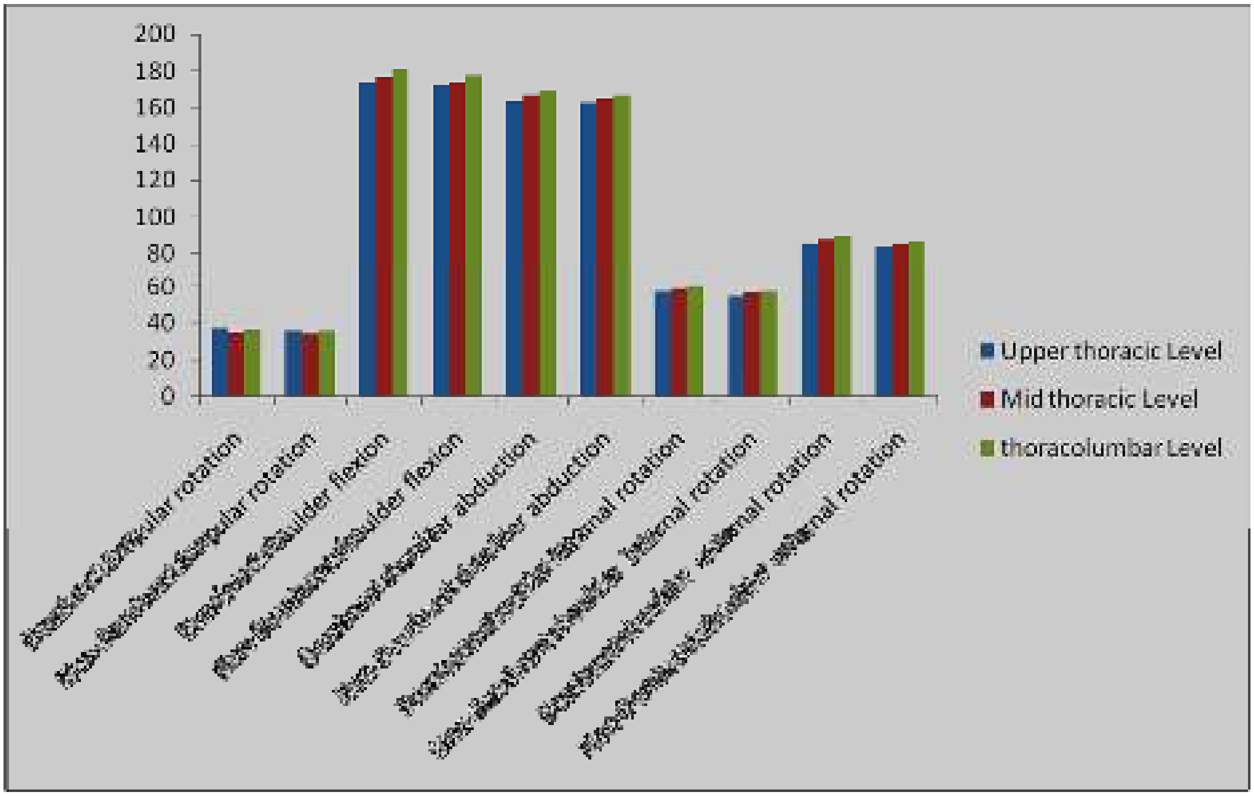


Figure 2. The horizontal axis represents the various movements at the joints, while the vertical axis indicates the range of motion in degrees

Discussion

The present study aimed to examine the scapular resting position and shoulder range of motion (ROM) in flexion, abduction, internal rotation, and external rotation, as well as the relationships among these variables in athletic and non-athletic individuals with spinal cord injury. The findings revealed significant differences in scapular position and shoulder ROM across the study groups. Specifically, scapular protraction was lower in athletes with spinal cord injury (wheelchair table tennis and wheelchair basketball players) compared to non-athletic individuals with spinal cord injury on both the dominant and non-dominant sides. No significant differences were observed between the two athletic groups. These results were consistent with the findings of Aytar (Aytar et al 2015). Furthermore, scapular rotation was greater in the athletic groups than in non-athletic participants on both sides. These results were consistent with the findings of Marouf et al. (Maarouf et al 2021). However, no significant group differences were found in scapular symmetry. Shoulder ROM in flexion, abduction, internal rotation, and external rotation differed significantly among the three groups, with non-athletic participants exhibiting reduced ROM in all movements compared to athletes.

The findings of the current research indicated that the resting position of the scapula and the range of motion of the shoulder are affected by the level of physical activity in individuals with spinal cord injury. The results suggested that physically active individuals with spinal cord injury (wheelchair tennis, wheelchair basketball) possess a more stable scapular resting position and a wider range of motion compared to inactive individuals.

The reduction in scapular protraction in the active group compared to the inactive group indicates better modulation of scapular position and improved coordination between the shoulder girdle muscles, including the serratus anterior and upper trapezius. It appears that repetitive training related to pushing movements, wheelchair control, and the application of throwing force in sports like basketball and tennis may lead to enhanced function of the scapular stabilizing muscles, consequently reducing the protraction position (Ferrara et al 2021).

On the other hand, the increase in scapular rotation in active individuals compared to inactive ones suggests greater neuromuscular adaptation and shoulder joint flexibility in this population. This adaptation could be due to consistent training and repetitive movements at the end ranges of the upper body joints, which strengthens motor control and improves shoulder kinematic movement patterns (Warner et al 2018).

The absence of a significant difference in scapular symmetry between the groups indicates that regular sports activities in individuals with spinal cord injury, although improving motor function, do not necessarily lead to asymmetry between the dominant and non-dominant sides. This could be attributed to bilateral training and relatively similar use of both upper limbs in wheelchair sports activities.

Finally, the significant difference in the range of motion for flexion, abduction, internal, and external rotation across the three groups demonstrates that regular physical activity plays an effective role in maintaining and enhancing shoulder joint function. Inactive individuals, due to limited mobility, weakness of stabilizing muscles, and potentially greater reliance on a fixed sitting posture, exhibited a reduced range of motion (Maarouf et al 2021).

Based on injury level, scapular protraction and scapular symmetry did not differ significantly across groups. Nevertheless, shoulder ROM—except for internal rotation—showed significant variations across injury levels. These findings were consistent with those of Eriks-Hoogland et al. (Inge et al 2009). The results also demonstrated significant side-to-side differences in scapular resting position, protraction, and rotation, as well as in dominant and non-dominant shoulder movements. These results were consistent with the findings of Warner et al. and Marouf et al. (Maarouf et al 2021, Warner et al 2018).

The findings of this research, which investigated the scapular position and shoulder range of motion in individuals with varying levels of spinal cord injury, offer important insights into the impact of these injuries on upper extremity biomechanics.

One noteworthy point is the absence of a significant difference in scapular protraction and its symmetry across different groups based on the level of spinal cord injury (upper back, mid-back, and lower back). This finding may suggest that despite differences in injury level, and consequently, in muscle engagement and control patterns, compensatory mechanisms or fundamental patterns related to scapular forward movement (protraction) remain relatively stable. This relative stability could be attributed to factors such as scapular stabilization by trunk muscles (like pectoral muscles) or the preservation of the relative function of muscles such as the serratus anterior, even at different injury levels. However, this topic requires further investigation using more precise methods for assessing protraction and its symmetry.

In contrast, another key finding is the significant difference in shoulder range of motion (excluding internal rotation) across the three different levels of spinal cord injury. This strongly indicates that the level of spinal cord injury plays a crucial role in limiting or altering shoulder movements. For instance, injuries at higher levels (such as the upper back) may involve a broader engagement of muscles and nerves associated with the shoulder, leading to significant limitations in flexion (forward bending), abduction (moving the arm away from the body), and external rotation (outward rotation of the arm). The lack of a significant difference in internal rotation (inward rotation of the arm) might indicate the relative resistance of this movement or differences in the muscles involved, which are less affected by the injury level(Inge et al 2009).

The research results also emphasize the functional asymmetry between the dominant and non-dominant scapula in the resting position. The presence of a significant difference in scapular protraction and rotation at rest, even before active movements, indicates a baseline positional imbalance. This imbalance could stem from compensatory movement patterns, muscle spasticity, or long-term structural changes in the non-dominant limb (which is often the more injured or functionally limited limb).

Furthermore, the significant differences observed between the dominant and non-dominant shoulders in flexion, abduction, internal rotation, and external rotation movements highlight the importance of assessment and therapeutic intervention based on functional symmetry. This asymmetry in range of motion can lead to increased load on joint structures, reduced movement efficiency, and an increased risk of secondary shoulder injuries. This finding is consistent with studies that have reported upper limb functional imbalances in individuals with spinal cord injuries (Maarouf et al 2021).

Finally, the findings revealed a significant correlation between scapular protraction on both sides and all shoulder ROM measures, indicating that higher levels of scapular protraction were associated with reduced shoulder ROM. Additionally, scapular rotation was significantly correlated with flexion, abduction, internal rotation, and external rotation (except dominant-side flexion), such that increased scapular rotation was associated with greater ROM.

The findings of this research indicate a strong association between scapular position and movements and the range of motion of the shoulder joint in individuals with spinal cord injury. Specifically, two aspects of scapular movement, namely “protraction” and “rotation,” were examined and showed a significant correlation with the primary shoulder movements (flexion, abduction, internal, and external rotation) in this population.

A notable finding regarding scapular protraction is its inverse relationship with shoulder range of motion. This implies that the greater the anterior and lateral movement of the scapula (protraction), the more the shoulder joint’s range of motion in various directions decreases. This finding can be justified by several reasons in individuals with spinal cord injury. Spinal cord injury often leads to weakness, muscle imbalance, and impaired coordination between the muscles controlling the scapula and shoulder (van Drongelen et al 2005). Excessive scapular protraction may indicate an imbalance in the shoulder girdle muscles, where certain muscles are overactive and others are weak. This imbalance can alter the position of the scapula and restrict the glenohumeral joint space. The scapula serves as a base for shoulder movements. When the scapula is in an abnormal protraction position, the glenohumeral joint (the main shoulder joint) is not optimally positioned for full range movements. This can lead to relative impingement or mechanical restrictions that reduce the range of motion. Individuals with spinal cord injury may adopt alternative movement patterns to compensate for weakness or limitations in motion. Scapular protraction might be part of these compensatory patterns, which inadvertently reduce the actual shoulder range of motion (Riek et al 2008).

In contrast, the findings regarding scapular rotation (with the exception of dominant shoulder flexion) indicate a direct relationship; that is, as scapular rotation increases, the shoulder's range of motion also increases. This finding appears logical, as proper scapular rotation, especially in specific directions, is essential for correct glenohumeral positioning and allowing the humerus to move through its full range. Scapular rotation aids in better congruency of the glenoid fossa with the humeral head and prevents impingement with surrounding bony structures or soft tissues. This is particularly important in individuals with spinal cord injury who may have less voluntary control over scapular muscles (Maarouf et al 2021).

The observed exception in "dominant shoulder flexion" might be due to greater complexities in the interaction of muscles and the joint in this specific movement or individual differences in movement patterns that warrant deeper investigation.

Conclusion

The study concludes that wheelchair athletes present distinct resting scapular kinematic profiles (specifically regarding protraction and rotation) compared to non-athletes, which correlates significantly with their shoulder range of motion. Differences also exist between the dominant and non-dominant limbs in both scapular resting position and shoulder ROM, highlighting potential asymmetries induced by sport-specific demands.

Clinical Applications. Scapula has an essential role in shoulder movements, its' postural and movement disorders can cause secondary problems such as shoulder pain, shoulder entrapment syndrome, and limited motion range. So, physicians and trainers devote part of their training program to scapula stabilizers. Despite our results, more research and follow-up are needed to prepare an effective exercise therapy program for wheelchair athletes and identify its long-term effects in preventing injury and determining its benefits in wheelchair athletes, especially wheelchair basketball players.

Ethical Considerations. Necessary coordination was arranged with the head of the welfare department of Mashhad City and Imam Khomeini and Shahid Fayyaz Bakhsh rehabilitation centers. The participants were informed of the purpose of the research and its implementation sages. A written consent has been obtained from the subjects. They were also assured about the confidentiality of their information and were free to leave the study whenever they wished, and if desired, the research results would be available to them. The Helsinki Convention was also observed.

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*Conflict of Interest***.** There are no conflicts of interest in this study.

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