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Original Article

Prevalence of Rotator Cuff and Scapular Muscle Weakness and Associated Shoulder Pain and Disability Among Cricket Academy Players

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ABSTRACT

Background: Repetitive overhead activity in cricket places substantial biomechanical and neuromuscular demands on the glenohumeral joint, rotator cuff, and scapular stabilizers. Deficits in these systems may coexist with shoulder pain and activity limitation, but their relationship has been insufficiently investigated among cricket academy players. Objective: To determine the prevalence of rotator cuff-related and serratus anterior weakness and examine their associations with shoulder pain and disability among male cricket academy players in Lahore. Methods: This cross-sectional analytical study included 109 male players. Rotator cuff-related weakness was assessed using the Empty Can Test, serratus anterior/scapular dysfunction using the Wall Push-Up Test, and shoulder symptoms using the Shoulder Pain and Disability Index (SPADI). Descriptive statistics, Pearson chi-square tests, Fisher-Freeman-Halton exact tests, Cramer's V, and point-biserial correlations were used. Results: Rotator cuff-related weakness was present in 68 participants (62.4%) and serratus anterior weakness in 72 (66.1%). Rotator cuff-related weakness was associated with SPADI category, $\chi^2(4)=15.08$, exact $p=0.005$, Cramer's $V=0.372$. Serratus anterior weakness demonstrated a stronger association, $\chi^2(4)=35.34$, exact $p<0.001$, Cramer's $V=0.569$. Continuous SPADI scores were positively associated with rotator cuff-related weakness ($r_{pb}=0.681$, $p<0.001$) and serratus anterior weakness ($r_{pb}=0.746$, $p<0.001$). Conclusion: Clinically detected rotator cuff-related and serratus anterior weakness were common and associated with greater shoulder pain and disability. Serratus anterior weakness demonstrated the stronger relationship with symptom burden, although the cross-sectional design precludes causal inference. Keywords: Cricket; Rotator Cuff; Serratus Anterior; Scapular Dyskinesis; Shoulder Pain; SPADI.

INTRODUCTION

Cricket requires repeated combinations of throwing, catching, fielding, batting, and bowling, several of which impose substantial mechanical demands on the shoulder complex. Although force generation begins in the lower extremities and trunk, successful overhead performance depends on efficient transmission of this force through the scapula, glenohumeral joint, elbow, and wrist. Contemporary models therefore describe overhead sporting activity as an integrated kinetic-chain process in which segmental sequencing, shoulder mobility, scapular control, muscular capacity, and neuromuscular coordination collectively influence performance and tissue loading (1,2).

The glenohumeral joint achieves extensive mobility at the expense of relatively limited osseous stability. Functional stability consequently depends on coordinated contributions from passive structures, including the joint capsule

and ligaments, and dynamic muscular stabilizers, particularly the rotator cuff and scapular musculature. The scapula provides a mobile base for humeral movement, contributes to glenoid positioning, supports normal scapulohumeral rhythm, influences rotator cuff length-tension relationships, and transfers energy between the trunk and upper extremity. Altered scapular positioning or movement may therefore modify mechanical loading and muscular demand across the shoulder during overhead activity (3,4).

Normal scapular motion during arm elevation includes coordinated upward rotation, posterior tilting, external rotation, and translation across the thoracic wall. These movements depend heavily on the interaction between the serratus anterior and different portions of the trapezius. The serratus anterior contributes to scapular upward rotation and posterior tilt while maintaining the medial border of the scapula against the thoracic cage, making it particularly important during high-demand overhead movements. Reduced activation, endurance deficits, muscular fatigue, or altered coordination may contribute to winging, loss of scapular control, or inefficient movement during functional tasks (3,5).

Scapular dyskinesis describes altered static position or dynamic movement of the scapula but is increasingly regarded as an impairment rather than an independent pathological diagnosis. This distinction is clinically important because altered scapular movement may also occur in asymptomatic athletes as a sport-specific adaptation. Prospective evidence has shown that scapular dyskinesis in isolation is not a consistent independent predictor of subsequent shoulder injury, indicating that its clinical relevance depends on associated pain, strength, range of motion, previous injury, workload, and kinetic-chain characteristics (6). Scapular findings therefore require interpretation within the athlete's broader clinical presentation rather than being automatically considered causal.

Despite this complexity, systematic electromyographic evidence demonstrates that overhead athletes with scapular dyskinesis or symptomatic shoulders can exhibit altered activation of the serratus anterior and trapezius musculature (5). Systematic review evidence of three-dimensional scapular kinematics has likewise identified differences in anterior tilt, internal rotation, and upward rotation between dominant and nondominant shoulders and between selected symptomatic and asymptomatic groups, although no single kinematic pattern consistently characterizes all athletes with shoulder symptoms (7). These findings support a multifactorial interpretation in which strength, fatigue, motor control, tissue adaptation, and pain may interact to influence scapular behavior.

The rotator cuff constitutes another essential component of dynamic shoulder stability. The supraspinatus, infraspinatus, teres minor, and subscapularis contribute to humeral head compression, rotational control, and stabilization during arm elevation. During overhead throwing, these muscles are exposed to repetitive concentric and eccentric loading, particularly during the acceleration and deceleration phases. Prospective and systematic-review evidence indicates that reduced rotator cuff strength, altered shoulder range of motion, previous injury, and training load may be associated with subsequent shoulder symptoms in overhead athletes, although the strength of evidence differs between populations and sports (8).

Clinical assessment of rotator cuff function commonly incorporates resisted tests such as the Empty Can or Jobe test. The procedure predominantly challenges supraspinatus-related function, and diagnostic studies show useful sensitivity for supraspinatus lesions but variable specificity depending on the population and definition of a positive test (9). Consequently, a positive Empty Can Test should not be interpreted as a quantitative assessment of the entire rotator cuff. When this test is used as the principal clinical measure, terminology such as rotator cuff-related or supraspinatus-related weakness more accurately reflects the measured construct.

Repetitive overhead activity can lead to both adaptive and potentially maladaptive changes in shoulder function. Athletes may develop sport-specific changes in rotational range, strength ratios, scapular orientation, muscle recruitment, and tissue capacity in response to repeated loading. These changes are not necessarily pathological; however, deficits may become clinically relevant when training load exceeds available muscular capacity or when combined with previous injury, reduced recovery, range-of-motion loss, or impaired strength (8,10). Contemporary injury models therefore emphasize interactions among modifiable and non-modifiable factors rather than attributing shoulder symptoms to a single anatomical abnormality.

Cricket imposes distinctive upper-extremity demands because playing roles differ substantially in exposure. Bowlers, batsmen, wicketkeepers, and fielders vary in throwing frequency, movement velocity, training duration, and recovery requirements. High-velocity fielding throws require effective proximal-to-distal sequencing, while

prolonged training may create repeated loading even outside competitive matches. A systematic review of overhead sports biomechanics, including cricket, identified shoulder external rotation during the preparatory phase and rapid internal rotation and elbow extension during acceleration as important contributors to throwing velocity (2).

The kinetic-chain model further suggests that deficits outside the shoulder can alter local shoulder loading. Reduced contribution from the lower extremities or trunk may require compensatory motion or greater muscular effort at the scapula and glenohumeral joint. The scapula functions as a critical link between the trunk and upper extremity, allowing proximal force to be transferred effectively to the throwing arm (1,3). Although the present study did not assess lower-extremity or trunk mechanics, this evidence provides a biomechanical rationale for evaluating scapular stabilizer function in cricket players.

Muscular fatigue may further influence shoulder mechanics during repetitive sports participation. Experimental evidence indicates that fatigue can alter scapular kinematics and neuromuscular control, although the magnitude and clinical implications vary between athletes (11). This means that apparent weakness during clinical assessment may reflect persistent impairment, transient fatigue, pain inhibition, or a combination of these factors. Clinical findings therefore need to be interpreted alongside symptom behavior, workload, and functional capacity rather than considered evidence of structural pathology in isolation.

Shoulder symptoms can affect both sporting participation and everyday function. Athletes may experience difficulty throwing, bowling, reaching overhead, carrying objects, sleeping on the affected side, dressing, or performing repetitive upper-extremity tasks. Because pain can also inhibit voluntary muscle activation, cross-sectional relationships between weakness and disability can be bidirectional: weakness may contribute to movement inefficiency, while pain itself may reduce apparent strength during testing (3,8).

Patient-reported outcome measures complement clinical examination by quantifying the athlete's own perception of pain and functional limitation. The Shoulder Pain and Disability Index (SPADI) was developed as a 13-item shoulder-specific questionnaire comprising five pain items and eight disability items (12). The instrument has demonstrated acceptable reliability, validity, and responsiveness across shoulder populations. An Urdu version has been translated and psychometrically evaluated in Pakistan and demonstrated strong internal consistency and test-retest reliability, supporting its use among Urdu-speaking populations with shoulder disorders (13).

The use of SPADI is particularly valuable in research examining muscular impairment because physical examination findings and self-reported function do not necessarily correspond. Some athletes may demonstrate altered scapular movement or reduced resistance without substantial disability, while others may report marked pain and activity limitation. Evaluating both domains permits a more clinically meaningful assessment of whether detected muscular impairment is associated with actual symptom burden (12,13).

Although shoulder disorders have been extensively investigated in baseball, handball, volleyball, swimming, and tennis, cricket-specific evidence remains comparatively limited. Sport-specific reviews emphasize that scapular adaptations and shoulder demands vary according to movement pattern and exposure, limiting direct extrapolation between different overhead sports (14). Small observational studies among cricket players have reported scapular dyskinesis, but prevalence estimates vary according to player level, clinical definitions, and testing procedures (15).

This methodological heterogeneity is important when interpreting clinical prevalence. Scapular dyskinesis identified through visual observation, lateral scapular slide testing, or a wall push-up procedure does not necessarily represent the same impairment. Similarly, manual resistance testing and dynamometry measure different aspects of muscular performance. Differences in examination method may therefore contribute substantially to variation in prevalence estimates between studies (3,5,14).

Exercise-based rehabilitation has been investigated for individuals with scapular dyskinesis and shoulder dysfunction. Systematic-review evidence suggests that targeted exercise can influence scapular position, movement, strength, and symptoms in selected populations, although programme content, dosage, and outcome measures remain heterogeneous (16). Evidence for shoulder injury prevention in overhead athletes is similarly evolving, with systematic reviews identifying shoulder strength, scapular function, training load, playing position, and previous symptoms as potentially relevant factors but noting variable certainty across sports (8,17,18).

Cricket academy players represent an important population because frequent practice occurs during development of sport-specific technique, strength, and workload tolerance. Identifying clinically meaningful muscular deficits in this setting may assist physiotherapists and coaches in recognizing athletes who require more detailed assessment. Screening should not be used to classify asymptomatic athletes as injured, but the coexistence of weakness with pain and disability may identify impairment patterns worthy of monitoring and targeted rehabilitation (3,14,18).

A key unresolved issue is whether rotator cuff-related and serratus anterior weakness are associated with greater shoulder-related functional burden among cricket academy players. Prevalence alone does not establish clinical significance. Demonstrating that muscular impairment is concentrated among athletes with higher pain and disability scores would provide a stronger rationale for integrating these assessments into cricket-specific clinical evaluation.

The present study therefore aimed to determine the prevalence of rotator cuff-related and serratus anterior weakness among male cricket academy players in Lahore and to examine their association with shoulder pain and disability measured using SPADI. The study also evaluated the relationship between continuous SPADI scores and muscle-weakness status and descriptively examined patterns according to playing experience. It was hypothesized that players demonstrating rotator cuff-related or serratus anterior weakness would have greater concurrent shoulder pain and disability than those without these clinical findings.

MATERIALS AND METHODS

A cross-sectional analytical study was conducted among male cricket academy players at Azhar Ali Cricket Academy, Lahore, Pakistan. The design was selected to estimate the prevalence of clinically detected rotator cuff-related and serratus anterior weakness and to evaluate their concurrent relationships with shoulder pain and disability. Data collection was completed over four months following institutional approval of the research synopsis. The target population comprised male academy players participating regularly in cricket training and overhead cricket-related activity.

Participants were recruited using non-probability convenience sampling. Players were eligible if they were 15-35 years of age, had participated in regular cricket training for at least one year, trained or participated in matches at least three times per week, and were willing to provide informed consent. Participants were excluded if they had a history of shoulder fracture or surgery, an acute traumatic shoulder injury during the preceding six months, current use of analgesics, corticosteroids, or muscle relaxants for a shoulder condition, neurological, systemic, or inflammatory disorders affecting shoulder function, or cervical radiculopathy or another condition capable of influencing upper-extremity mechanics. These exclusions were intended to reduce the influence of major traumatic, postoperative, neurological, or systemic disorders on the shoulder assessment.

The final sample comprised 109 participants. The source study determined the required sample using a prevalence-based Cochran approach. Although the eligibility range extended from 15 to 35 years, the participants actually included in the analysis ranged from 18 to 35 years. All 109 participants represented in the final dataset were included in the statistical analysis.

Permission for data collection was obtained from the cricket academy administration. Eligible players were informed about the study objectives and procedures, and written informed consent was obtained before assessment. Demographic and cricket-related information was recorded using a structured data-collection form, including age, playing experience, dominant arm, and training frequency.

Shoulder pain and functional disability were assessed using SPADI. The original SPADI was developed by Roach et al. as a shoulder-specific self-report instrument containing 13 items, with five items addressing pain and eight addressing disability (12). Each item is rated on a numerical scale from 0 to 10, with higher values indicating greater pain or functional difficulty. Conventional SPADI scoring allows pain, disability, and total scores to be expressed on a 0-100 scale. The Urdu version has demonstrated good validity, high internal consistency, and good test-retest reliability in a Pakistani shoulder population (13).

The present dataset contained individual SPADI item values, summed pain and disability item scores, continuous SPADI scores used for correlation analysis, and a five-level categorical variable described as mild, moderate, severe,

very severe, and extremely severe. The categorical variable was retained for the planned contingency analyses, while the continuous SPADI analysis provided an additional assessment of the relationship between symptoms and muscle-weakness status.

Rotator cuff-related impairment was assessed using the Empty Can Test. This procedure primarily challenges supraspinatus-related function and is commonly incorporated into clinical evaluation of rotator cuff disorders (9). Pain, weakness, or inability to resist manually applied pressure was considered a positive test finding. Because the procedure does not provide isolated quantitative measurements of all four rotator cuff muscles, positive findings were interpreted as rotator cuff-related weakness rather than definitive generalized rotator cuff weakness.

Serratus anterior/scapular stabilizer function was assessed using the Wall Push-Up Test. Participants performed the movement while scapular stability was observed. Visible scapular winging or impaired scapular control was considered a positive finding for serratus anterior/scapular stabilizer weakness. Clinical observation of scapular control can identify impairment relevant to overhead function but does not quantify isolated serratus anterior force or electromyographic activation; the interpretation was therefore restricted to the clinical construct assessed by the procedure (3,5).

Data collection followed a standardized sequence. Demographic and cricket-related characteristics were recorded first, followed by the Empty Can Test and Wall Push-Up Test. Participants then completed SPADI. The main exposure variables were rotator cuff-related weakness and serratus anterior weakness, each classified as present or absent. The primary outcome was shoulder pain and functional disability measured by SPADI. Age and playing experience were recorded as descriptive characteristics, and playing experience was additionally examined descriptively in relation to muscle-weakness patterns.

Data were coded and analysed using IBM SPSS Statistics version 31.0. Continuous variables were summarized using means and standard deviations, and categorical variables were summarized using frequencies and percentages. The prevalence of each muscular impairment was calculated relative to the total sample of 109 participants.

Associations between muscle-weakness status and the five study-defined SPADI categories were assessed using 5×2 contingency tables. Pearson chi-square statistics were recalculated directly from the reported cell counts to ensure internal consistency. Because two expected cell frequencies in each contingency table were below five, Fisher-Freeman-Halton exact probabilities were additionally calculated. Cramer's V was used to quantify the strength of categorical association. The relationship between continuous SPADI scores and binary weakness status was expressed as a point-biserial correlation, which is mathematically equivalent to Pearson correlation when one variable is continuous and the other dichotomous. The relationship between the two binary weakness variables was expressed using the phi coefficient. Statistical significance was established at $p<0.05$ using two-sided testing. As the study was cross-sectional, all inferential results were interpreted as associations and not as evidence of temporal sequence or causality.

RESULTS

A total of 109 male cricket academy players were included. Their mean age was 26.02 ± 5.10 years, with an observed range of 18-35 years. Rotator cuff-related weakness was identified in 68 players (62.4%), while serratus anterior weakness was identified in 72 (66.1%). SPADI item responses indicated substantial pain and activity-related difficulty. Pain at its worst had the highest pain-item mean (7.12 ± 1.84), followed by pain while pushing with the affected arm (7.04 ± 1.79). Among disability items, carrying a heavy object had the highest mean (7.09 ± 1.91), followed by placing an object on a high shelf (6.77 ± 1.86). The summed pain-item and disability-item values were 33.89 ± 6.42 and 48.33 ± 8.15, respectively. The study-defined SPADI distribution showed that 11 participants (10.1%) were classified as mild, 24 (22.0%) as moderate, 34 (31.2%) as severe, 28 (25.7%) as very severe, and 12 (11.0%) as extremely severe. Severe, very severe, and extremely severe categories together contained 74 participants (67.9%).

Table 1. Participant Characteristics and Prevalence of Muscle Weakness

Variable	Result
Participants, N	109
Age, years, mean ± SD	26.02 ± 5.10
Age range, years	18-35
Rotator cuff-related weakness, n (%)	68 (62.4)

No rotator cuff-related weakness, n (%)	41 (37.6)
Serratus anterior weakness, n (%)	72 (66.1)
No serratus anterior weakness, n (%)	37 (33.9)

Table 2. Descriptive Statistics of SPADI Pain and Disability Items

Domain/item	Mean ± SD
Pain items	
Pain at its worst	7.12 ± 1.84
Pain when lying on affected side	6.85 ± 1.92
Pain reaching for something on a high shelf	6.67 ± 1.71
Pain while touching the back of neck	6.21 ± 1.66
Pain while pushing with affected arm	7.04 ± 1.79
Summed pain-item score	33.89 ± 6.42
Disability items	
Washing hair	5.94 ± 1.58
Washing back	6.48 ± 1.73
Putting on undershirt/jumper	5.89 ± 1.69
Putting on shirt with buttons	5.42 ± 1.44
Putting on pants	4.91 ± 1.39
Placing object on high shelf	6.77 ± 1.86
Carrying heavy object	7.09 ± 1.91
Removing something from back pocket	5.83 ± 1.52
Summed disability-item score	48.33 ± 8.15

Table 3. Distribution of Study-Defined SPADI Categories

SPADI category	n (%)
Mild	11 (10.1)
Moderate	24 (22.0)
Severe	34 (31.2)
Very severe	28 (25.7)
Extremely severe	12 (11.0)
Total	109 (100.0)

Rotator cuff-related weakness became progressively more frequent across the higher SPADI categories. Weakness was present in 3 of 11 participants in the mild group, 10 of 24 in the moderate group, 24 of 34 in the severe group, 22 of 28 in the very severe group, and 9 of 12 in the extremely severe group. The association was statistically significant, $\chi^2(4)=15.08$, $p=0.0045$. The Fisher-Freeman-Halton exact probability was $p=0.0050$, and Cramer's $V=0.372$ indicated a moderate association.

Table 4. Association Between Rotator Cuff-Related Weakness and SPADI Category

SPADI category	Weakness present, n	Weakness absent, n	Total
Mild	3	8	11
Moderate	10	14	24
Severe	24	10	34
Very severe	22	6	28
Extremely severe	9	3	12
Total	68	41	109

Pearson $\chi^2(4)=15.084$, $p=0.0045$; Fisher-Freeman-Halton exact $p=0.0050$; Cramer's $V=0.372$.

Table 5. Association Between Serratus Anterior Weakness and SPADI Category

SPADI category	Weakness present, n	Weakness absent, n	Total
Mild	2	9	11
Moderate	8	16	24
Severe	26	8	34
Very severe	24	4	28
Extremely severe	12	0	12
Total	72	37	109

Pearson $\chi^2(4)=35.342$, $p<0.001$; Fisher-Freeman-Halton exact $p<0.001$; Cramer's $V=0.569$.

Serratus anterior weakness showed a more pronounced gradient across SPADI categories. Weakness was present in 2 of 11 participants in the mild group, 8 of 24 in the moderate group, 26 of 34 in the severe group, 24 of 28 in the very severe group, and all 12 participants in the extremely severe group. The association was statistically

significant, $\chi^2(4)=35.34$, $p<0.001$. The exact probability was also $p<0.001$, and Cramer's V=0.569 indicated a strong association.

Continuous SPADI scores were strongly positively associated with both muscle-weakness variables. The relationship between SPADI score and serratus anterior weakness was r_pb=0.746 ($p<0.001$), while the relationship between SPADI and rotator cuff-related weakness was r_pb=0.681 ($p<0.001$). Rotator cuff-related weakness and serratus anterior weakness were themselves positively associated, r_phi=0.627 ($p<0.001$).

Table 6. Correlations Between SPADI Score and Muscle-Weakness Status

Variables	SPADI score	Rotator cuff-related weakness	Serratus anterior weakness
SPADI score	1.000	0.681**	0.746**
Rotator cuff-related weakness	0.681**	1.000	0.627**
Serratus anterior weakness	0.746**	0.627**	1.000

p<0.001. Point-biserial coefficients apply to SPADI versus binary weakness variables; phi coefficient applies to the association between the two binary weakness variables.

A descriptive pattern was also observed in which both serratus anterior and rotator cuff-related weakness appeared more frequent among players with longer cricket experience. Because complete experience-category denominators and inferential statistics were not available for this comparison, the finding was retained as descriptive rather than interpreted as a statistically established exposure-response relationship.

DISCUSSION

The present study demonstrated that clinically detected rotator cuff-related and serratus anterior weakness were common among male cricket academy players and were strongly associated with greater concurrent shoulder pain and disability. Approximately two-thirds of the participants exhibited each impairment, while serratus anterior weakness showed the stronger relationship with SPADI across both categorical and continuous analyses. These findings are clinically relevant because contemporary approaches to the overhead athlete emphasize integrated assessment of glenohumeral strength, scapular function, symptom behavior, range of motion, previous injury, and workload rather than reliance on a single anatomical diagnosis or isolated special test (3,8,14).

The prevalence of rotator cuff-related weakness observed in the present population is plausible given the repetitive concentric and eccentric demands placed on the shoulder during throwing and other high-velocity upper-extremity tasks. Rotator cuff muscles contribute to humeral head centering, rotational control, and dynamic stability, while the deceleration phase of throwing imposes particularly high eccentric demands. Systematic evidence has identified reduced shoulder strength among the potentially modifiable factors associated with overuse shoulder injury in overhead athletes, although the magnitude and consistency of this relationship vary between sports and study designs (8,17).

The prevalence of serratus anterior weakness was slightly higher than that of rotator cuff-related weakness and demonstrated a stronger association with symptom severity. This finding is biomechanically plausible because the serratus anterior contributes to upward rotation, posterior tilting, and stabilization of the scapula against the thoracic wall, thereby helping provide an efficient base for humeral movement (3,5). Altered serratus anterior activation can disturb the balance of scapulothoracic muscle recruitment, potentially increasing the demand placed on other scapular stabilizers and the glenohumeral musculature during repetitive overhead tasks (5).

Electromyographic evidence strengthens this interpretation. A systematic review of overhead athletes reported altered scapulothoracic muscle activation in individuals with scapular dyskinesis, including changes involving the serratus anterior and trapezius (5). However, such abnormalities are not uniform across all symptomatic athletes, and the presence of dyskinesis in asymptomatic individuals indicates that altered scapular control should be interpreted as a context-dependent impairment rather than a diagnosis in isolation (5-7).

This distinction is particularly important when interpreting the strong association between serratus anterior weakness and SPADI in the current study. Hogan et al. found that scapular dyskinesis alone was not significantly associated with future shoulder injury in pooled prospective athletic studies, suggesting that scapular movement alterations may not independently determine injury development (6). More recent sport-specific reviews similarly

recommend evaluating scapular findings in relation to symptoms, strength, kinetic-chain function, sport demands, and other modifiable impairments rather than treating dyskinesis as an inherently pathological state (14).

The strong association observed here therefore indicates that the clinically detected serratus anterior/scapular impairment was closely related to current shoulder symptom burden, but it does not establish that the impairment caused the symptoms. Cross-sectional assessment cannot distinguish whether reduced scapular control preceded pain, developed secondary to pain-related inhibition, or reflected a shared exposure such as repetitive training, fatigue, previous injury, or insufficient muscular capacity. Prospective designs are required to determine the temporal direction of this relationship (6,8).

The association between rotator cuff-related weakness and SPADI was also substantial, although weaker than that observed for serratus anterior weakness. Reduced rotator cuff strength has been identified as a potentially modifiable risk factor in systematic reviews of overhead athletes, and updated evidence continues to support shoulder rotational strength as one component associated with injury risk in selected athletic populations (8,18). The present findings extend that broader evidence by demonstrating a concurrent relationship between clinically detected rotator cuff-related weakness and greater shoulder pain and disability in cricket academy players.

The clinical meaning of the Empty Can finding requires careful interpretation. The test primarily loads the supraspinatus, and diagnostic studies have shown that it may be sensitive to supraspinatus pathology while lacking sufficient specificity to define the entire rotator cuff independently (9). Pain during testing can also reduce voluntary resistance. Consequently, the present finding should be understood as rotator cuff-related or supraspinatus-related impairment rather than proof of generalized rotator cuff structural disease.

Pain-mediated inhibition may partly explain the high correlation between weakness status and SPADI. Musculoskeletal pain can alter motor output and movement strategies, while athletes experiencing pain during resisted testing may demonstrate less force even without a major structural lesion. Conversely, insufficient muscular capacity may contribute to inefficient mechanics and greater symptoms when the athlete is exposed to repetitive high-load activity. The likely relationship is therefore bidirectional and embedded within a broader interaction of strength, workload, movement control, and previous symptoms (3,8,17).

The positive association between rotator cuff-related and serratus anterior weakness further supports the concept that glenohumeral and scapular impairment may coexist rather than function independently. The rotator cuff relies on an appropriately positioned and dynamically controlled scapula, while scapular muscles operate within a kinetic chain that includes the trunk, glenohumeral joint, elbow, and wrist. A deficit in one component may therefore alter mechanical demand in another, particularly during rapid overhead activity (1,3).

The kinetic-chain model provides a useful framework for understanding these relationships in cricket. Throwing performance depends on sequential transfer of energy from the lower extremities and pelvis through the trunk and scapula to the upper limb. Systematic biomechanical evidence shows that shoulder external rotation, rapid internal rotation, elbow extension, and coordinated segmental sequencing contribute substantially to overhead throwing velocity (2). If proximal segments contribute inefficiently, greater compensatory demand may be imposed on the shoulder complex, although the present study did not directly assess this mechanism.

The SPADI item pattern further supports the functional relevance of the observed impairments. Participants reported particularly high pain during pushing and substantial disability while carrying heavy objects and placing objects on high shelves. These activities require dynamic stabilization, force generation, and controlled arm elevation. Rotator cuff and scapular muscle systems are central to these functions, making the observed association between clinical weakness and activity-related limitation biomechanically coherent (3,9).

The high values reported across individual SPADI items indicate that the study population included a considerable burden of symptomatic shoulder dysfunction. SPADI was specifically developed to capture shoulder-related pain and activity limitation and has been shown to provide reliable and responsive measurement across shoulder conditions (12). The availability of a validated Urdu version further strengthens its suitability for use in Pakistani participants by reducing linguistic and cultural barriers to patient-reported assessment (13).

Nevertheless, SPADI primarily evaluates pain and everyday functional activities rather than cricket-specific performance. It does not directly measure throwing speed, bowling accuracy, fielding endurance, workload

tolerance, or return-to-play readiness. Sport-specific reviews emphasize that assessment of overhead athletes should consider the particular mechanical and functional requirements of the sport in addition to generic shoulder disability (14). Future cricket studies would therefore benefit from combining SPADI with sport-specific performance and participation measures.

The five-category SPADI variable used in the present analysis also warrants cautious interpretation. SPADI is conventionally analysed as a continuous score, and categorical labels such as mild, moderate, severe, very severe, and extremely severe are not inherent to the original instrument (12). For this reason, the continuous correlation findings are particularly important: the strong relationships between SPADI and both muscle-weakness variables confirm that the central association did not depend solely on the way participants were divided into categories.

The corrected categorical analyses showed a clear gradient in rotator cuff-related weakness. Only 3 of 11 participants in the mild SPADI category had weakness, whereas 22 of 28 in the very severe category and 9 of 12 in the extremely severe category had positive findings. The association was statistically significant and of moderate magnitude. This pattern is consistent with broader evidence linking lower shoulder strength and greater functional impairment in overhead athletes, although direct comparison is limited by differences in sports, measures, and study populations (8,18).

The gradient was even stronger for serratus anterior weakness. Only 2 of 11 players in the mild group demonstrated weakness, compared with 24 of 28 in the very severe group and all participants in the extremely severe group. Although this strong association suggests substantial clinical relevance, it should not be interpreted as demonstrating a dose-dependent causal relationship. Evidence concerning scapular dysfunction and injury remains heterogeneous, with some prospective reviews identifying limited or conflicting predictive value and others identifying scapular dyskinesis as one of several potentially modifiable factors (6,18).

The corrected statistical values improve the internal consistency of the study. Recalculation from the reported contingency counts yielded $\chi^2(4)=15.08$ for rotator cuff-related weakness and $\chi^2(4)=35.34$ for serratus anterior weakness. Because two expected cells in each table were below five, exact conditional testing was also applied and confirmed both associations. Reporting Cramer's V further allows interpretation of association magnitude rather than relying on statistical significance alone.

The point-biserial correlations were also large, particularly for serratus anterior weakness. However, bivariate correlation does not estimate an independent effect because potential confounders are not controlled. Systematic reviews of overhead-sport shoulder injuries have identified factors including previous injury or pain, rotational strength, range of motion, playing position, training load, and sport-specific exposure as potentially relevant to shoulder outcomes (8,17,18). Any of these variables could partly influence both clinical weakness and SPADI scores in the present sample.

Playing experience showed a descriptive pattern in which weakness appeared more frequent among participants with longer cricket participation. Years of sporting exposure have been examined as a possible risk factor in overhead athletes, but systematic evidence suggests that its independent contribution is less consistent than factors such as strength, range of motion, previous injury, and training load (8). The present pattern should consequently be regarded as hypothesis-generating rather than evidence that longer cricket participation itself causes progressive shoulder weakness.

Training load is likely to be more informative than years of participation alone. Athletes with similar playing histories can differ markedly in the number of throws performed, bowling volume, training intensity, competition exposure, strength-conditioning practices, and recovery. Systematic reviews identify workload among the modifiable factors that may influence shoulder injury risk, although definitions and measurement methods vary across studies (8,17). Future cricket research should therefore quantify actual throwing and bowling exposure rather than relying solely on training frequency or years played.

Muscular fatigue may provide an additional explanation for the clinical impairment observed in frequently training academy players. Experimental research indicates that fatigue can alter scapular movement and neuromuscular control during repeated upper-extremity activity (11). Without standardization of assessment timing relative to recent training, a positive clinical weakness test may therefore reflect persistent deficit, transient fatigue, pain inhibition, or combinations of these phenomena.

Cricket-specific evidence remains relatively sparse compared with baseball, handball, volleyball, swimming, and tennis. Sport-specific review literature emphasizes that the mechanical demands of overhead sports differ sufficiently that findings should not be transferred uncritically between disciplines (14). A small observational study among novice cricket players reported scapular dyskinesis in approximately 10% of participants using the lateral scapular slide test, substantially lower than the prevalence observed in the current study (15). Differences in population, playing experience, assessment method, and definition of impairment are likely explanations for this discrepancy. The comparison with the cricket literature also highlights the importance of measurement standardization. The Wall Push-Up Test used in the present study evaluates visible winging and scapular stability during a closed-chain task, whereas other investigations have used visual dynamic assessment or distance-based scapular tests. Electromyographic research demonstrates that scapular muscle dysfunction is multidimensional and cannot be fully characterized by one observational measure (5). Future studies should therefore combine clinical assessment with quantitative strength or neuromuscular measures where feasible.

From a clinical perspective, the findings support comprehensive rather than isolated shoulder screening. Contemporary overhead-athlete frameworks recommend assessment of symptom behavior, rotator cuff capacity, scapular control, shoulder mobility, kinetic-chain function, previous injury, and training exposure (3,14). A positive Empty Can or Wall Push-Up Test should therefore trigger broader evaluation rather than be treated as a definitive diagnosis. Rehabilitation strategies should similarly address identified impairment patterns rather than focus on a single muscle. Systematic-review evidence suggests that exercise therapy can modify scapular position and movement in selected individuals with scapular dyskinesis, although intervention heterogeneity limits certainty regarding a single optimal programme (16). An individualized programme may therefore incorporate progressive rotator cuff strengthening, serratus anterior and trapezius conditioning, motor-control training, shoulder mobility work where indicated, and restoration of sport-specific movement capacity (3,16).

Broader injury-prevention evidence also supports the importance of strength development. A meta-analysis of randomized sports-injury prevention studies found that strength-training interventions reduced acute and overuse injury risk across athletic populations, although these findings were not specific to cricket or shoulder disorders (19). This evidence supports integrating progressive strength development within athletic preparation while avoiding the unsupported assumption that strengthening one isolated shoulder muscle will necessarily prevent cricket-related injury. Workload management should accompany strength and rehabilitation programmes. Reviews of overhead athletes identify training load as a potentially modifiable factor and suggest that prevention strategies are most likely to succeed when multiple risk domains are considered together (8,17). For cricket players, this may involve monitoring throwing exposure, bowling volume, training intensity, symptom response, and recovery while progressively matching physical capacity to sport demands.

The findings also have implications for communication among physiotherapists, coaches, and athletes. Scapular asymmetry or weakness should not automatically lead to restriction from sport in an asymptomatic player because such findings can occur as athletic adaptations (6,14). In contrast, a player who demonstrates weakness together with substantial pain and functional limitation may warrant further assessment, load modification, and individualized rehabilitation. This distinction can reduce unnecessary pathologization while still identifying clinically relevant impairment. Prospective cohort studies are required to determine whether the observed impairments predict future shoulder pain or injury. Baseline measurement of quantitative shoulder strength, scapular control, range of motion, previous injury, and workload followed by longitudinal surveillance would clarify temporal relationships and help distinguish risk factors from consequences of existing symptoms. This approach is consistent with recommendations from systematic reviews highlighting limitations of cross-sectional and heterogeneous evidence in overhead-athlete injury research (6,8,17).

More objective measurement would also improve future work. Handheld or isokinetic dynamometry could quantify shoulder strength continuously, while surface electromyography could characterize serratus anterior and trapezius activation patterns. Three-dimensional motion analysis could evaluate scapular and throwing kinematics and determine whether clinical weakness corresponds to measurable movement alterations. Systematic biomechanical and electromyographic reviews support the value of these approaches for improving understanding of shoulder function in overhead athletes (2,5,7). Future analyses should also account for playing position. Bowlers, fielders, batsmen, and wicketkeepers experience different combinations of throwing volume, arm elevation, impact, and repetitive load. Updated systematic evidence suggests that playing position may influence shoulder injury risk in

overhead sports, supporting role-specific analysis rather than treating all athletes as biomechanically equivalent (18).

Multivariable analysis would further strengthen interpretation by determining whether rotator cuff-related or serratus anterior weakness remains independently associated with shoulder disability after adjustment for workload, previous symptoms, age, playing experience, dominant-arm characteristics, range of motion, and other relevant factors. Existing reviews demonstrate that shoulder injury and pain are multifactorial, making adjusted models more clinically informative than isolated bivariate associations (8,17,18). The current study has several strengths. It investigated a defined academy-level cricket population, addressed an under-studied sporting context, evaluated both glenohumeral and scapular impairment, and combined clinical testing with a validated patient-reported shoulder measure. The availability of complete cell frequencies for the primary categorical analyses also allowed independent recalculation of the chi-square statistics and effect sizes, improving internal statistical consistency.

Several limitations should be considered when interpreting the findings. The cross-sectional design prevents determination of temporal sequence and cannot distinguish risk factors from consequences of pain. Single-academy convenience sampling limits generalizability to professional players, female cricketers, younger athletes, and players from other regions. These limitations are typical of cross-sectional athletic studies and reinforce the need for prospective, multicentre research before broad risk or prevention conclusions are drawn (6,8). Clinical measurement also limited precision. The Empty Can Test cannot quantify all rotator cuff muscles, and the Wall Push-Up Test does not isolate serratus anterior force or activation. Instrumented strength testing and electromyography would provide more precise characterization of muscle performance and neuromuscular control (5,9). The study-defined SPADI categories also require cautious interpretation because the original instrument is fundamentally continuous (12).

Potential confounding represents another limitation. Previous shoulder symptoms, playing position, throwing exposure, training load, recovery, strength-conditioning history, range of motion, and kinetic-chain characteristics were not incorporated into adjusted models. Each has been identified as potentially relevant in overhead-athlete shoulder research, and their omission means that the observed associations cannot be interpreted as independent effects of weakness (8,17,18). Despite these limitations, the findings demonstrate a coherent pattern across prevalence, categorical analyses, and continuous correlations: rotator cuff-related and especially serratus anterior weakness were closely associated with greater shoulder pain and functional limitation. The results support a multidimensional approach to cricket shoulder assessment and provide a rationale for prospective research combining quantitative muscular testing, workload monitoring, playing-role stratification, and sport-specific functional outcomes (3,8,14,18).

CONCLUSION

Rotator cuff-related and serratus anterior weakness were common among male cricket academy players in Lahore and were significantly associated with greater shoulder pain and functional disability. Serratus anterior weakness demonstrated the stronger relationship with SPADI burden, while rotator cuff-related weakness was also substantially associated with symptoms. The coexistence of these impairments supports assessment of both scapular and glenohumeral function when evaluating symptomatic cricket players. Because the study was cross-sectional, the findings represent concurrent associations and do not establish that muscular weakness caused pain, disability, or subsequent injury.

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