

Surface electromyography assessment of infraspinatus injuries in competitive volleyball players

DHAYALAN K¹, AKSHAY K², AKASH TOM MATTAKOTTIL³, BABU SUBBIAH⁴,
MOHANAKRISHNAN JAGADEVAN⁵, S JAYARAMAN^{6*}

^{1,3,6} Department of Physical Education and Sports, Central University of Tamil Nadu, INDIA

^{2,4} Department of Physical Education, NIT Puducherry, Karaikal, INDIA

⁵ Department of Neuro-Surgery, JIPMER, Puducherry, INDIA

⁶ Department of Physical Education and Sports, Central University of Tamil Nadu, INDIA

Published online: July 31, 2025

Accepted for publication: July 15, 2025

DOI:10.7752/jpes.2025.07161

Abstract:

Problem Statement: In volleyball, effective blocking is essential for successful defense, but due to specific sports dynamic demands, the risk of shoulder injury is higher. The infraspinatus muscle, crucial for shoulder stability, is particularly prone to strain, which can compromise blocking performance. Despite this, there is limited research on how infraspinatus injuries influence muscle activation during volleyball-specific movements.

Purpose: This study assesses the impact of previous infraspinatus strain (IS) on muscle activation during a volleyball blocking task and focuses on asymmetries that could affect performance and increase injury risk.

Approach: Muscle activation patterns were examined using surface electromyography (sEMG) in collegiate male volleyball players, comparing those with and without a history of IS. The analysis aimed to determine whether infraspinatus injuries lead to persistent neuromuscular imbalances during blocking movements.

Materials and Methods: Twenty-four right-hand dominant male players were divided into two groups: (I) With Grade I/II IS (WGIS), and (II) Without IS (WtGIS). sEMG electrodes were placed bilaterally to record muscle activity during a standardized blocking maneuver set-up. Statistical comparison between groups and muscles has been analysed. **Results:** Players in the WGIS group demonstrated significantly reduced infraspinatus activation (57.6 ± 12.99) compared to the WtGIS group (82.3 ± 11.75). Notable differences were found in the right medial infraspinatus (RMI) ($p = 0.031$, $p = 0.034$) and right inferior infraspinatus (RII) ($p = 0.015$, $p = 0.028$), indicating an apparent asymmetry ($p < 0.001$) in muscle engagement. **Conclusions:** Volleyball players with a history of infraspinatus injury exhibit significant muscle activation asymmetries and persistent weakness in the affected shoulder during blocking movements. These findings underscore the importance of targeted rehabilitation and conditioning strategies to enhance shoulder function and prevent recurrent injuries.

Keywords: Infraspinatus, Electromyography, Asymmetry, Volleyball, Injury.

Introduction

The infraspinatus muscle is an integral part of the rotator cuff. It helps keep the shoulder joint stable and allows for external rotation movements. In volleyball, repetitive overhead actions, especially during skills like blocking, lead to excessive loads on the rotator cuff muscles, with the infraspinatus as a stabilizer. This vulnerability arises because external rotation is vital for preparing the shoulder for high-speed arm movements, especially when the arm is elevated, as in blocking (Challoumas & Dimitrakakis, 2017). Deficits in external rotator strength led to muscle imbalances, reduced athletic performance, and overuse injuries.

The growing participation and professionalization of volleyball have significantly improved the training intensities, loads, and match demands, consequently elevating the incidence of shoulder injuries in players. Despite the critical importance of the rotator cuff, especially the infraspinatus, there is limited understanding of how repetitive blocking impacts this muscle group functionally and structurally. This research was needed to bridge the gap in understanding the neuromuscular consequences of infraspinatus injuries, particularly in collegiate volleyball players at higher risk of such injuries. The importance of the infraspinatus in overhead sports like volleyball increases its susceptibility to overuse injuries, progressive weakness, and neuromuscular problems, leading to uneven activation patterns. This issue may make players more likely to get injured again (Walker et al., 2021). Repetitive shoulder movements, especially at extreme angles, can strain the suprascapular nerve significantly. This strain can cause nerve compression injuries and muscle atrophy.

In volleyball, blocking is an important defensive skill that puts much strain on the shoulder complex. Players must jump and reach their arms above the net to block the opponent's attack. This specific movement requires careful coordination and strong use of the rotator cuff muscles to keep the shoulder joint stable and achieve success in competition (Ficklin et al., 2014). Blocking plays a big role in a team's success. It comes right

after spiking in terms of tactical importance. Teams that have strong blocking strategies tend to have higher win rates. Lobiatti (2009) emphasized that effective volleyball defences fundamentally originate from an organized and skilled block.

The biomechanics of blocking primarily involve shoulder flexion, scapular elevation, upward scapular rotation, and repetitive overhead arm elevation. These movements place eccentric stress on the infraspinatus muscle, increasing the risk of muscle strain, neuromuscular imbalances, and nerve-related complications (Jonathan C. Reeser & Roald Bahr, 2017). Efficient blocking execution depends on strength, intermuscular coordination, and neuromuscular symmetry to sustain performance across the season (Cabarkapa et al., 2020). However, there is a lack of detailed investigations into the functional asymmetry and altered muscle activation of the infraspinatus following overuse injuries such as Grade I/II infraspinatus strain (GIS), particularly during high-demand volleyball actions like blocking. GIS, a common injury in volleyball players, especially in the dominant arm, results from chronic overuse and is characterized by isolated atrophy, weakness, and micro trauma due to repetitive eccentric loading (Aido et al., 2011). Overhead athletes with such injuries face degeneration and functional impairment. Moreover, suprascapular neuropathy has been reported with a prevalence of 13.6% to 18.2% among male collegiate players and up to 12.5% among elite athletes (Miura et al., 2019), leading to altered muscle activation and bilateral asymmetry in the rotator cuff. The rising number of injuries in volleyball highlights the need for research. This study describes the injury patterns and looks into the underlying neuromuscular issues that may continue even after standard rehabilitation.

Many volleyball players recovering from infraspinatus injuries still report pain, discomfort, and performance issues, even after following standard 12-week physiotherapy programs. This discomfort in players may indicate neuromuscular imbalances or differences in muscle activation on both sides that standard rehabilitation might not fix. Understanding the functional muscle activation asymmetry in the infraspinatus can help improve rehabilitation methods, prevent injuries, and enhance player performance. To address this knowledge gap, the present study employed surface electromyography (sEMG) to analyse the bilateral activation patterns of the superior, medial, and inferior regions of the infraspinatus muscle in volleyball players with and without GIS.

sEMG is a validated tool for evaluating neuromuscular function and can effectively identify asymmetries or compensatory activation during dynamic and high-intensity movements like blocking. The study compared injured and non-injured groups to assess muscle activation asymmetry and its potential implications for athletic performance and risk of re-injury. An overview of the study design and methodology is illustrated in the graphical abstract (Fig. 1), depicted as a flowchart. By examining these selected muscles activation patterns, this study offers new insights that may inform more effective, targeted rehabilitation strategies specifically designed for overhead athletes, ultimately contributing to enhanced recovery and sustained athletic performance.

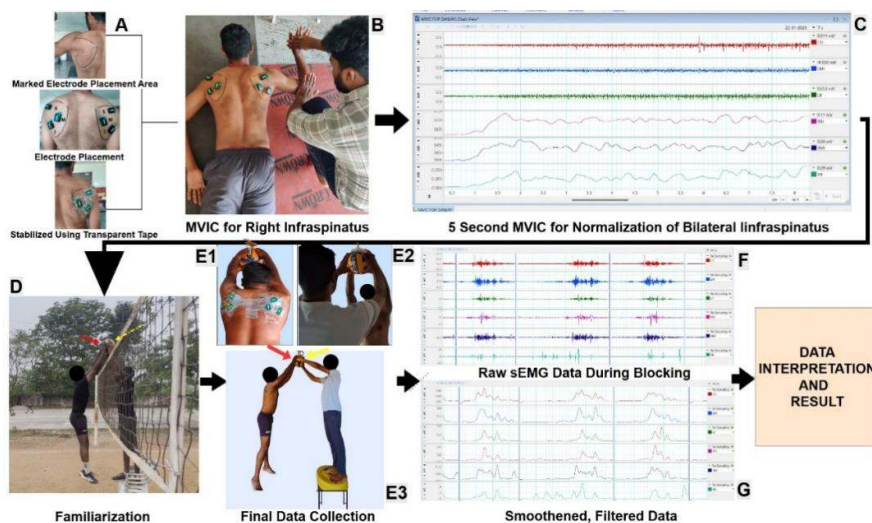


Fig.1. From electrode placement to final analysis, a Graphical representation of sEMG analysis for bilateral infraspinatus activation during volleyball blocking in injured and non-injured players.

Materials and Methods

Subjects

This study was conducted with 24 right-hand dominant collegiate volleyball players, with a mean age of 21.00 ± 1.75 years, weight of 72.50 ± 2.92 kg, and height of 179.41 ± 3.75 cm. All subjects had a playing experience of 6.02 ± 0.7 years (Table 1). The exclusion criteria included musculoskeletal injuries or other significant medical conditions (Samuel H Ellestad, 2024). Additionally, those not actively engaged in physical

activity and with a BMI exceeding 30 kg/m² were excluded to ensure a consistent and reliable comparison of muscle activation patterns (Akshay et al., 2024). The selection of study participants involved a careful screening process. The final inclusion of subjects was systematically represented through a detailed flowchart (Fig. 2). The Institutional Human Ethics Review Board of the Central University of Tamil Nadu approved the study protocol. All subjects provided informed written consent by the approved protocol and the principles of (Declaration of Helsinki), ensuring the protection of their rights and well-being (Subbiah et al., 2024).

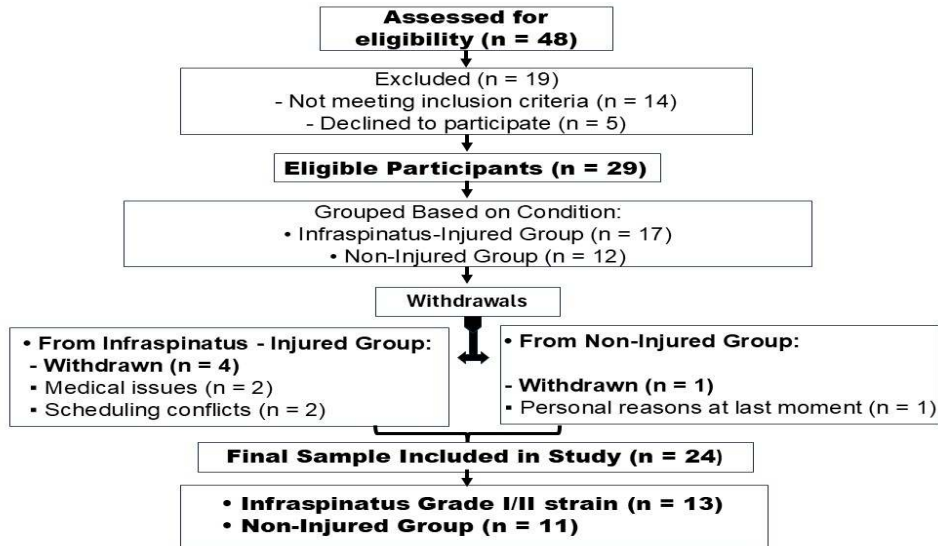


Fig. 2. Flowchart of subject recruitment and grouping process

Table 1

Descriptive statistics of demographic and anthropometric characteristics of Injured and Non-injured groups

Variable	Injured Group (n = 13)	Non-injured Group (n = 11)	Total Sample (N = 24)
Age (years)	21.14 ± 1.70	20.80 ± 1.85	21.00 ± 1.76
Weight (kg)	73.10 ± 2.85	71.70 ± 2.95	72.52 ± 2.89
Height (cm)	179.00 ± 3.40	180.00 ± 3.90	179.42 ± 3.61
BMI (kg/m ²)	22.80 ± 0.50	22.10 ± 0.45	22.51 ± 0.48
Playing Experience (years)	6.1 ± 0.7	5.9 ± 0.7	6.02 ± 0.70

*Values are presented as mean ± standard deviation

Procedures

Before the study, participants were given a thorough description of the testing process, including potential uses and risks, a self-administered questionnaire to complete, and informed consent was obtained. Players with a history of shoulder injury were recruited for this study. An orthopaedic surgeon diagnosed these players as Infraspinus injury (Grade I / II) (Table 2). They received conservative treatment, which included pain relievers, anti-inflammatory drugs, and follow-up with physical therapy.

Table 2 Characteristics of the players recruited for the study

No	Side	Grade		Duration
		I	II	
13	Right	9	4	± 8 months

Players with other major injuries, fractures, and recent surgeries were excluded from this study. To ensure consistency, all subjects underwent a familiarization process that included verbal instructions and gentle full-body stretching, followed by upper and lower-extremity warm-up exercises designed to enhance muscle activation and coordination at an individualized pace. Before electrode placement, the skin over the anatomical centre of the muscle was cleansed with 70% isopropyl alcohol and shaved, if necessary, after which custom double-sided adhesives were applied to secure the electrodes in place (St-Onge et al., 2019).

sEMG Data Collection and Maximum Voluntary Isometric Contraction

sEMG was used to assess muscle activation in three bilateral infraspinus muscle regions: Right Superior Infraspinus (RSI), Right Medial Infraspinus (RMI), Right Inferior Infraspinus (RII), Left Superior Infraspinus (LSI), Left Medial Infraspinus (LMI), and Left Inferior Infraspinus (LII). Data were collected using non-invasive Trigno Avanti sEMG sensors (Delsys Inc., Boston, MA, USA) (K et al., 2025) (Dhayalan et

al., 2025), which provide high-precision measurements. Electrodes were placed bilaterally on the infraspinatus muscle following the SENIAM guidelines (Fig. 1A), with anatomical markers using a body marker to ensure accurate placement (Hermens et al., 2000). After applying the sEMG on the superficial landmarks, electrodes were secured using transparent tape. To normalize the sEMG data, maximum voluntary isometric contraction (MVIC) was employed (Fig. 1B) (Hodder & Keir, 2013).

For MVIC assessment of the selected infraspinatus regions, each subject was prone on an elevated surface (Alenabi et al., 2018), with the arm outward laterally and from the shoulder to elbow bent at a 90° angle, parallel to the floor. Resistance was applied above the wrist and forearm during external rotation (Fig. 1B), and an isometric contraction was maintained to prevent compensatory movements (Alenabi et al., 2018). Each subject performed 5-second MVIC three times for the infraspinatus muscle group (Fig. 1C). A one-minute rest period was allowed between contractions to reduce fatigue and restore normal average peak activation (Alenabi et al., 2018).

Phase-Specific Muscle Activation Analysis in Volleyball Blocking

Following MVIC testing, subjects proceeded with dynamic volleyball blocking assessment. The study considered three movement phases: take off, airborne, and landing. The analysis, however, concentrated only on the airborne phase, with detailed examination conducted by experts in biomechanics and physiotherapists. sEMG data were collected when the blocker made contact with the ball during the airborne phase, posterior view (Fig. E1), anterior (Fig. E2), and lateral view (Fig. E3) (Wenchao Xu, 2020), with the hands contacting the ball, which hangs above the standard net level.

The crossover step-blocking technique was used. It involves the left foot crossing over the right foot toward the net. The right foot then closes the movement, ending with a two-footed push-off to jump (Lobietti, 2009). Execution of the blocking skill as a countermovement jump includes a hand swing. This technique aims to reach higher for better blocking. This improvement connects to the eccentric loading of the hip extensors (Lobietti, 2009). Subjects performed two sets of five repetitions, with a 30-second rest interval between repetitions and a five-minute recovery period between sets. Verbal encouragement was provided throughout the trials to maintain consistency in effort. To capture the blocking actions, a high-definition video camera (Sony Handycam FDR-AX700 4K HDR camcorder) was aligned laterally with the top of the net, focusing on the sagittal direction (Ficklin et al., 2014). Finally, the subjects were instructed to avoid high-intensity physical activity for at least 24 hours following testing to prevent excessive fatigue (Akshay et al., 2024).

sEMG analysis

Muscle activity was recorded using a sixteen-channel, pre-amplified Ag/AgCl non-invasive surface electrode system with cordless Trigno Avanti surface EMG sensors (Delsys Inc., Boston, MA, USA) (Dewar & Martin, 2020). During a volleyball block, raw sEMG signals were collected from 100 ms before ball contact to 100 ms after the blocking action (Fig. 1F). They were synchronized using a common trigger signal to ensure temporal alignment of muscle activation patterns with kinematic events during the volleyball blocking action and sEMG data. Each muscle underwent signal processing through a bandpass filter with a 4th-order butterworth design, employing cutoff frequencies of 20 Hz and 450 Hz to eliminate motion artefacts (Akshay et al., 2024). Low- and high-frequency noise was noted and removed by zero padding and offset removal. This data analysis was performed using Lab Chart 8 Reader (ADInstruments, Dunedin, New Zealand). To obtain a more precise representation of muscle activity, the filtered signal's root mean square (RMS) was smoothed (Fig. 1G) (Romero et al., 2015). Each muscle's activation during the blocking task was assessed by selecting three repetitions of the entire blocking movement, averaging the peak activation, and expressing it as a percentage of its maximum sEMG amplitude from the MVIC (Fig. 3).

Statistical analysis

Statistical analyses evaluated differences between the WtGIS and WGIS groups and variations within each group. Descriptive statistics included mean and standard deviation for all variables. The Shapiro-Wilk test checked for normality. Since most measures did not follow a normal distribution, non-parametric tests were used. Between-group comparisons were analysed using Mann-Whitney U tests and Welch's t-tests, depending on Levene's test results for variance homogeneity. Within-group differences were tested using the Wilcoxon signed-rank test for WGIS and paired t-tests for WtGIS. A significance level of $p < 0.05$ was used, and effect sizes were calculated to determine the magnitude of observed differences.

Table 3. Descriptive Statistics of Muscle Activation Levels

Muscle	Groups	Mean	SD	Minimum(mV)	Maximum(mV)
LSI	WtGIS	71.1	10.68	57.1	94.0
	WGIS	75.0	12.21	54.9	99.6
LMI	WtGIS	70.8	11.71	48.9	87.9
	WGIS	70.5	8.83	53.5	81.6
LII	WtGIS	67.8	13.06	51.7	98.4

Muscle	Groups	Mean	SD	Minimum(mV)	Maximum(mV)
RSI	WGIS	58.2	16.69	33.1	93.5
	WtGIS	82.3	11.75	59.4	99.2*
RMI	WGIS	57.6	12.99	29.5	71.5
	WtGIS	77.3	5.12	68.1	85.8
RII	WGIS	66.9	13.29	46.1	85.8
	WtGIS	71.8	11.25	54.2	86.2
	WGIS	56.7	14.98	37.9	84.2

Note: WtGIS- without infraspinatus Grade I/II strain; WGIS - with infraspinatus Grade I/II strain * $p < 0.05$

Results

The study's findings indicate notable variations in muscle activation between the WtGIS and WGIS groups as described in Table 3. The LSI demonstrated comparable mean activation levels of 71.1 (SD = 10.68) for WtGIS and 75.0 (SD = 12.21) for WGIS. However, the RSI activation levels differed between the groups, with WtGIS showing a mean activation of 82.3 (SD = 11.75) and WGIS displaying a mean activation of 57.6 (SD = 12.99). This variation in RSI activation highlights the impact of GIS on muscle function, suggesting that muscle activation may not be symmetrically distributed across both shoulders.

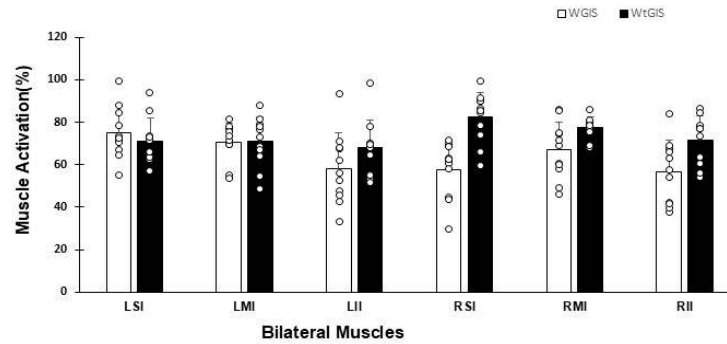


Fig. 3. The mean sEMG activity of normalized bilateral muscles (WGIS and WtGIS) during blocking is expressed as 100% of MVIC.

Table 4. Comparison of muscle activation and imbalance between WGIS and WtGIS

Muscle	Test	df	P-value
LSI	Welch's t	0.8098	19.7
	Mann-Whitney U	47.0	0.428
LMI	Welch's t	0.0670	18.6
	Mann-Whitney U	60.0	0.947
LII	Welch's t	1.5031	18.9
	Mann-Whitney U	34.0	0.149
RSI	Welch's t	4.6835	19.8
	Mann-Whitney U	10.0	< .001**
RMI	Welch's t	2.4291	12.9
	Mann-Whitney U	28.0	0.031*
RII	Welch's t	2.6753	18.6
	Mann-Whitney U	27.0	0.015*

** $p < 0.01$, * $p < 0.05$

The analysis of muscle activation asymmetry between individuals with and without GIS revealed significant differences, particularly in the right-side infraspinatus region. Welch's t-test and the Mann-Whitney U test (Table 4) demonstrated that RSI differed significantly between the groups ($p < 0.001$), along with RMI ($p = 0.031$, $p = 0.034$) and RII ($p = 0.015$, $p = 0.028$), highlighting a substantial muscle imbalance in individuals with GIS. In contrast, no significant differences were observed on left-side infraspinatus activation, as LSI ($t = 0.8098$, $df = 19.7$, $p = 0.428$; $U = 47.0$, $p = 0.401$), LMI ($t = 0.0670$, $df = 18.6$, $p = 0.947$; $U = 60.0$, $p = 1.000$) and LII ($t = 1.5031$, $df = 18.9$, $p = 0.149$; $U = 34.0$, $p = 0.088$) showed statistically no significant variation between the groups. These findings suggested that GIS mainly affects the right-sided infraspinatus muscle activation after an injury, contributing to uneven muscle function. These results match existing research, which shows that shoulder injuries often result in imbalances, especially on the dominant side (injured side) (Riemann & Davies, 2023). The observed decline trends in RSI activation align with previous studies indicating that injury-induced neuromuscular imbalances can lead to delayed neuromuscular response and compromised muscle function (Salles et al., 2013).

Table 5. Wilcoxon Signed-Rank Test for Muscle Activation Differences

Muscles			Statistic	p-value
LSI	RSI	Wilcoxon W	60.0	0.014*
LMI	RMI	Wilcoxon W	48.0	0.206
LII	RII	Wilcoxon W	40.0	0.577

* $p < 0.05$

Table 6. Paired Samples t-Test for Muscle Activation Differences

Muscles		Statistic	df	p-value
LSI	RSI	-1.742	10.0	0.112
LMI	RMI	-1.890	10.0	0.088
LII	RII	-0.683	10.0	0.510

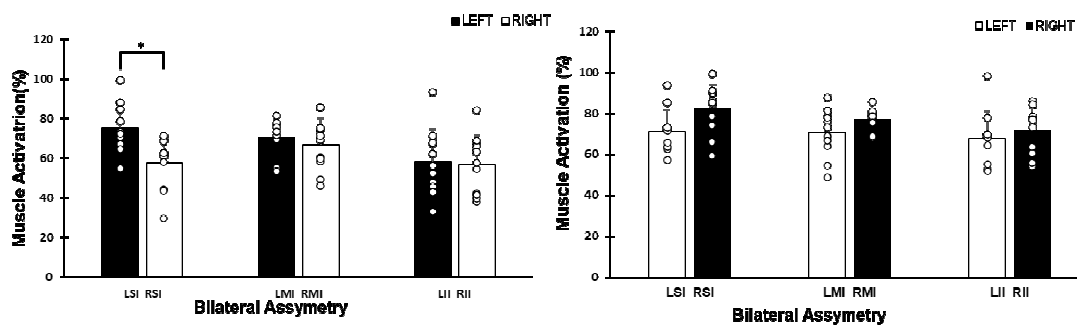


Fig. 4. Bilateral muscle asymmetry within the groups (a) WGIS and (b) WtGIS.

Note: * indicates a significant difference ($p < 0.05$).

The Wilcoxon Signed-Rank test examined the differences in muscle activation between the bilateral infraspinatus regions in the WGIS group (Table 5). The analysis showed a significant asymmetry between LSI and RSI ($W = 60.0$, $p = 0.014$), indicating a clear difference in activation levels between these muscle groups. However, no significant differences were observed between LMI and RMI ($W = 48.0$, $p = 0.206$) or between LII and RII ($W = 40.0$, $p = 0.577$). These findings suggest that GIS primarily affects superior infraspinatus muscle activation on the dominant side, contributing to muscle imbalances. The significant asymmetry in LSI-RSI highlights potential compensatory mechanisms or neuromuscular adaptations due to injury, which may increase the risk of further dysfunction. The non-significant differences in medial and inferior infraspinatus regions indicate that these areas may not be as heavily impacted. (Fig. 4a) visually represents these disparities and all the samples of the WGIS group, reinforcing the presence of substantial bilateral asymmetry in the superior infraspinatus region.

The paired samples t-test (Table 6) revealed statistically no significant differences in muscle activation between bilateral sides in the WtGIS group (Fig. 4b). The comparison between LSI and RSI ($t = -1.742$, $p = 0.112$), LMI and RMI ($t = -1.890$, $p = 0.088$), and LII and RII ($t = -0.683$, $p = 0.510$) demonstrated no substantial asymmetry. These findings indicated that infraspinatus muscle activation remains balanced, which shows that both sides have similar activity during muscle function in blocking movements without injury.

Discussion

The present study observed a significant asymmetry of infraspinatus activation during blocking maneuver in competitive volleyball players following Grade I-II injury. Specifically, the superior region of the injured infraspinatus exhibited asymmetrical muscle activity, whereas the medial and inferior regions showed relatively balanced activation levels. This asymmetry indicated that players with infraspinatus injuries might significantly reduce RSI activation during important performance like blocking. Additionally, RMI and RII exhibited significant differences, with p-values of 0.031 and 0.015, respectively, reinforcing that shoulder injuries lead to compensatory activation patterns that may hinder performance (Owens et al., 2024). These adaptations could contribute to reduced shoulder stabilization and weakened external rotation, particularly in overhead movements like volleyball blocking. The asymmetry in infraspinatus muscle activation, especially in the superior region, may further compromise shoulder stability, affect external rotation efficiency, and increase the risk of injury during repetitive overhead actions (Cordova & Owens, 2014).

The asymmetrical activation of the superior infraspinatus in individuals with GIS suggests a neuromuscular deficit that may compromise stability. Previous research highlights the crucial role of this region in maintaining rotator cuff function through increased activation during external rotation (Calver et al., 2022), which is essential during blocking. However, this instability, coupled with an imbalance in external rotator strength, increases joint stress and the risk of rotator cuff injuries in volleyball players (Challoumas & Dimitrakakis, 2017; Kim et al., 2015). Therefore, reduced superior infraspinatus muscle activation may contribute to asymmetric movement patterns during blocking. The increased activation of the LSI in the GIS group (Owens et al., 2024; Reinold et al., 2004) aligns with findings from previous studies that reported altered muscle activation patterns during functional tasks, suggesting the presence of compensatory mechanisms. One possible explanation for this adaptation is a shift in neuromuscular control strategies, leading to altered load distribution across the rotator cuff muscles (Yao & Yew, 2016). These changes can lead to muscle weakness and changes in movement patterns, which can make functional problems worse. These results imply that while injury-related neuromuscular imbalances may be present in specific regions of the infraspinatus, compensatory mechanisms exist to maintain overall function across the muscle group. A notable imbalance in muscle activation between the superior region of the bilateral rotator cuff in the GIS group aligns with previous research indicating that rotator cuff dysfunction significantly affects the infraspinatus muscle. A clear muscle activation difference exists in the rotator cuff's superior region for the GIS group. This matches earlier studies showing that rotator cuff problems significantly impact the infraspinatus muscle. This dysfunction is common among volleyball players, particularly on the dominant side.

Furthermore, considering the functional role of rotator cuff muscles, the infraspinatus and subscapularis work synergistically to stabilize and mobilize the shoulder joint. This interaction shows how neuromuscular issues can affect shoulder movement. It stresses the importance of focused treatments to correct muscle imbalances and prevent injuries in volleyball players.

On the other hand, the WtGIS group showed a more balanced activation pattern in the infraspinatus muscles. There were no noticeable differences between the muscles on both sides in the upper, middle, and lower areas. This finding suggests that players without GIS sustain well-regulated neuromuscular function, supporting that balanced muscle activation is crucial for maintaining shoulder stability. This symmetry suggests that non-injured players keep their rotator cuff stable, which might help avoid changes that raise the risk of injury. Further, the symmetry in the infraspinatus muscle seen in the WtGIS group indicated good neuromuscular synchronization (Hamill et al., 2012). This coordination reduces asymmetry and lowers the chance of overuse injuries during blocking. Research has also shown that neuromuscular electrical stimulation (NMES) can enhance shoulder external rotation force production and infraspinatus muscle activation (Reinold et al., 2008), emphasizing the importance of neuromuscular efficiency in shoulder stability. The WGIS group's asymmetry may reflect underlying deficits, whereas the WtGIS group's symmetrical activity suggests a natural, well-regulated neuromuscular function. These findings highlight the potential benefits of targeted neuromuscular interventions, including NMES, to help injured players restore muscle balance and reduce the risk of further dysfunction. Our limitation was the sample size; a larger sample with a diverse range of subjects exhibiting various grades of rotator cuff injuries should be investigated further, specifically examining external rotation during the blocking motion. Additionally, all necessary measures were implemented to minimize signal interference from neighbouring muscles; however, a drawback of utilizing sEMG electrodes is that, due to the complex nature of the human musculoskeletal system, complete elimination of such interference cannot be guaranteed (Akshay, Subbiah, Rajeev, et al., 2024). Second, using MVIC normalization is important because the validity of isometric normalization for dynamic movements is still a matter of ongoing debate (Bordelon et al.,

2021). Nonetheless, the authors deemed MVIC normalization appropriate for this study, as the infraspinatus muscle is primarily engaged statically to ensure shoulder stability during the blocking motion in volleyball. The final was the absence of ball attacks from opposing players (Miura et al., 2020). However, the findings may still provide valuable insights for coaches and physiotherapists to enhance rehabilitation and training for GIS.

Conclusions

The current study proves that Grade I/II Infraspinatus Strain (GIS) causes clear and statistically significant neuromuscular asymmetry in infraspinatus activation during volleyball blocking, with the dominant side being mostly impaired in WGIS compared to WtGIS. The frequent presence of weak infraspinatus muscle function shows that GIS impacts more than muscle activation patterns. It may also lead to lasting functional differences that standard rehabilitation does not entirely fix. These findings highlight the importance of including bilateral muscle activation measurement in the diagnosis and return-to-play procedures for injured players. Region-specific rehabilitation interventions, especially those addressing the superior infraspinatus muscle, are essential to achieve functional symmetry and avoid recurrence. The emerging differences in activation revealed above justify the need to apply more advanced, customized rehabilitation programs instead of more generic rotator cuff strengthening programs. Coaches, players, and educators should use surface electromyography (sEMG) to identify muscle imbalances and improve blocking performance in volleyball. Future studies should look at infraspinatus muscle activity and use imaging techniques like ultrasound or magnetic resonance imaging. This will help better understand muscle structure and guide effective rehabilitation plans. Additionally, studying the long-term effects of blocking techniques through sEMG could clarify recovery timelines for injured and uninjured players. This insight could help create targeted training plans that combine sEMG with AI-driven non-marking motion capture analysis, which could help with early detection of neuromuscular imbalances and improve preventative strategies for athletes in overhead sports.

Credit authorship contribution statement Dhayalan K: Writing- original draft, Investigation, Conceptualization. Akshay K: Writing- original draft, Investigation, Data collection and interpretation, Review. Akash Tom Mattakotttil: Data Collection, editing, project administration. Babu Subbiah: Writing- review & editing. Mohanakrishnan Jagadevan: Data administration/ originality and methodology. S Jayaraman: Writing-review & editing, Supervision, Project administration, Conceptualization.

Funding source This research was conducted without any specific grant or financial support from public, private, or non-profit funding agencies.

References

- Aido, R., Massada, M., Leitão, N., Magalhães, C., Vasconcelos, J. C., Lourenço, J. M., & Puga, N. (2011). Tendinopathy in volleyball elite players: prevalence of injuries, clinical and imaging evaluation. *British Journal of Sports Medicine*, 45(6), 544.1-544. <https://doi.org/10.1136/bjsm.2011.084558.31>
- Akshay, K., Subbiah, B., & Ashokkumar, J. (2024). Unveiling the Dynamics: Kinematics and Activation Patterns of Gluteus Maximus in Inclined Treadmill Sprinting. In *Sports Analytics* (pp. 129–143). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-63573-1_8
- Alenabi, T., Whittaker, R., Kim, S. Y., & Dickerson, C. R. (2018). Maximal voluntary isometric contraction tests for normalizing electromyographic data from different regions of supraspinatus and infraspinatus muscles: Identifying reliable combinations. *Journal of Electromyography and Kinesiology*, 41, 19–26. <https://doi.org/10.1016/j.jelekin.2018.04.007>
- Bordelon, N. M., Wasserberger, K. W., Cassidy, M. M., & Oliver, G. D. (2021). The Effects of Load Magnitude and Carry Position on Lumbopelvic-Hip Complex and Scapular Stabilizer Muscle Activation During Unilateral Dumbbell Carries. *Journal of Strength and Conditioning Research*, 35(1), S114–S119. <https://doi.org/10.1519/JSC.0000000000003880>
- Cabarkapa, D., Fry, A., Cabarkapa, D., Rogers, A., & Mosier, E. (2020). GROUND REACTION FORCES OF COMMONLY USED VOLLEYBALL BLOCKING APPROACHES. *Journal of Kinesiology and Exercise Sciences*, 30(89), 13–20. <https://doi.org/10.5604/01.3001.0014.5851>
- Calver, R., Alenabi, T., Cudlip, A., Dickerson, C. R., Mondal, P., & Kim, S. Y. (2022). Regional activation of supraspinatus and infraspinatus sub-regions during dynamic tasks performed with free weights. *Journal of Electromyography and Kinesiology*, 62, 102308. <https://doi.org/10.1016/j.jelekin.2019.05.009>
- Challoumas, D., Stavrou, A., & Dimitrakakis, G. (2017). The volleyball athlete's shoulder: biomechanical adaptations and injury associations. *Sports Biomechanics*, 16(2), 220–237. <https://doi.org/10.1080/14763141.2016.1222629>
- Cordova, C. B., & Owens, B. D. (2014). Infraspinatus muscle atrophy from suprascapular nerve compression. *Journal of the American Academy of Physician Assistants*, 27(2), 33–35. <https://doi.org/10.1097/01.JAA.0000442701.87975.42>
- Dewar, C., & Martin, K. D. (2020). Comparison of Lower Extremity EMG Muscle Testing With Hands-Free Single Crutch vs Standard Axillary Crutches. *Foot & Ankle Orthopaedics*, 5(3), 2473011420939875. <https://doi.org/10.1177/2473011420939875>

- Dhayalan, K., Akshay, K., & Subbiah, B. (2025). Impact of abdomen and lower back muscle relaxation on sleep quality in pregnant women. *Vidhyayana: An International Multidisciplinary Peer-Reviewed E-Journal*, 10(SI3). <https://doi.org/10.58213/vidhyayana.v10is3.2231>
- Ficklin, T., Lund, R., & Schipper, M. (2014). A comparison of jump height, takeoff velocities, and blocking coverage in the swing and traditional volleyball blocking techniques. *Journal of Sports Science & Medicine*, 13(1), 78–83.
- Hamill, J., Palmer, C., & Van Emmerik, R. E. A. (2012). Coordinative variability and overuse injury. *Sports Medicine, Arthroscopy, Rehabilitation, Therapy & Technology*, 4(1), 45. <https://doi.org/10.1186/1758-2555-4-45>
- Heller, G. Z., Manuguerra, M., & Chow, R. (2016). How to analyze the Visual Analogue Scale: Myths, truths and clinical relevance. *Scandinavian Journal of Pain*, 13(1), 67–75. <https://doi.org/10.1016/j.sjpain.2016.06.012>
- Hermens, H. J., Freriks, B., Disselhorst-Klug, C., & Rau, G. (2000). Development of recommendations for SEMG sensors and sensor placement procedures. *Journal of Electromyography and Kinesiology*, 10(5), 361–374. [https://doi.org/10.1016/S1050-6411\(00\)00027-4](https://doi.org/10.1016/S1050-6411(00)00027-4)
- Hodder, J. N., & Keir, P. J. (2013). Obtaining maximum muscle excitation for normalizing shoulder electromyography in dynamic contractions. *Journal of Electromyography and Kinesiology*, 23(5), 1166–1173. <https://doi.org/10.1016/j.jelekin.2013.06.012>
- Jonathan C. Reeser, M., & Roald Bahr, M. (2017). *Handbook of Sports Medicine and Science Volleyball* (second edition). Wiley Blackwell.
- Kim, J.-S., Oh, C.-H., & Jeong, I.-S. (2015). A Biomechanical Analysis on the Action of Volleyball Vertical Jumping Performance. *Korean Society For The Study Of Physical Education*, 19(4), 131. <https://doi.org/10.15831/JKSSPE.2015.19.4.131>
- Lobietti, R. (2009). A review of blocking in volleyball: from the notational analysis to biomechanics. *Journal of Human Sport and Exercise*, 4(2), 93–99. <https://doi.org/10.4100/jhse.2009.42.03>
- Miura, K., Tsuda, E., & Ishibashi, Y. (2019). Glenohumeral Rotational Deficit and Suprascapular Neuropathy in the Hitting Shoulder in Male Collegiate Volleyball Players. *Progress in Rehabilitation Medicine*, 4(0), n/a. <https://doi.org/10.2490/prm.20190002>
- Miura, K., Tsuda, E., Kogawa, M., & Ishibashi, Y. (2020). The effects of ball impact position on shoulder muscle activation during spiking in male volleyball players. *JSES International*, 4(2), 302–309. <https://doi.org/10.1016/j.jseint.2019.12.009>
- Owens, L. P., Khaiyat, O., & Coyles, G. (2024). Muscle Activations of the Upper Extremity and Core during Elevation and Rotational Movements in Overhead Throwing Athletes. *International Journal of Sports Physical Therapy*, 19(4). <https://doi.org/10.26603/001c.94604>
- Reinold, M. M., Macrina, L. C., Wilk, K. E., Dugas, J. R., Cain, E. L., & Andrews, J. R. (2008). The Effect of Neuromuscular Electrical Stimulation of the Infraspinatus on Shoulder External Rotation Force Production after Rotator Cuff Repair Surgery. *The American Journal of Sports Medicine*, 36(12), 2317–2321. <https://doi.org/10.1177/0363546508322479>
- Riemann, B. L., & Davies, G. J. (2023). Limb Dominance Effects on Seated Single-Arm Shot-Put Limb Symmetry Indices Following Shoulder Rehabilitation. *Journal of Sport Rehabilitation*, 32(2), 215–219. <https://doi.org/10.1123/jsr.2022-0225>
- Romero, F., Alonso, F. J., Cubero, J., & Galán-Marín, G. (2015). An automatic SSA-based de-noising and smoothing technique for surface electromyography signals. *Biomedical Signal Processing and Control*, 18, 317–324. <https://doi.org/10.1016/j.bspc.2015.02.005>
- Samuel H Ellestad, T. P. H. A. M. S. M. E. H. J. R. D. (2024). The Quantification of Muscle Activation During the Loaded Carry Movement Pattern. *International Journal of Exercise Science*, 17(1). <https://doi.org/10.70252/NWUE9985>
- St-Onge, E., Robb, A., Beach, T. A. C., & Howarth, S. J. (2019). A descriptive analysis of shoulder muscle activities during individual stages of the Turkish Get-Up exercise. *Journal of Bodywork and Movement Therapies*, 23(1), 23–31. <https://doi.org/10.1016/j.jbmt.2018.01.013>
- Subbiah, B., Akshay, K., Rajeev, R., & Jagadevan, M. (2024). Surface electromyographic analysis of the bilateral abdomen and back muscle during selected yoga posture. *Journal of Bodywork and Movement Therapies*, 40, 1994–2000. <https://doi.org/10.1016/j.jbmt.2024.10.015>
- Walker, C. R., Belisario, J. C. Y., & Vasudevan, J. M. (2021). Suprascapular Neuropathy in Collegiate Tennis Player: A Case Report. *Cureus*. <https://doi.org/10.7759/cureus.20824>
- Wenchao Xu. (2020). Teaching And Training Methods Of Volleyball Blocking Technique. *International Journal of Frontiers in Sociology*, 2(2), 60–67.
- Yao, K., & Yew, W. P. (2016). Suprascapular nerve injury: A cause to consider in shoulder pain and dysfunction. *Journal of Back and Musculoskeletal Rehabilitation*, 30(1), 39–44. <https://doi.org/10.3233/BMR-160711>