EFFICACY OF POSTERIOR CAPSULE STRETCHING AND ECCENTRIC LOADING ON FUNCTIONAL KINEMATICS AND SERVE VELOCITY IN ADOLESCENT VOLLEYBALL ATHLETES WITH GIRD: A RANDOMIZED CONTROLLED TRIAL

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ABSTRACT

Background. Glenohumeral Internal Rotation Deficit (GIRD) is a significant limitation to athletic performance. Newer research findings suggest that the incidence of Glenohumeral Internal Rotation Deficit (GIRD) amongst young volleyball players stands at around 37.5% (Mine et al., 2024; Wilcox et al., 2021). **Objectives.** To this end, the current study investigates a novel rehabilitation protocol comprising posterior capsule stretching in association with eccentric strengthening. **Method.** Twenty-four adolescent athletes were randomly assigned to an experimental (EG) or a control group (CG; n = 12 per group) in a single-blind experimental design. In the experiment group, there was an 8-week targeted stretching protocol together with eccentric training for the external rotator muscles. **Results.** Statistical analyses indicated that the experimental group significantly outperformed control on each post-test measure ($p< 0.001$; 95% CI), with large effect sizes Cohen's $d > 0.8$). **Conclusion.** The experimental group experienced significant changes in internal rotation range of motion, functional strength and spike serve speed. Combining eccentric loading with targeted stretching appears effective for restoring shoulder kinematic symmetry and performance parameters in young athletes.

Keywords; posterior capsule, eccentric load, functional kinematics, serve speed, volleyball athletes, GIRD.

A. INTRODUCTION

Kinetic chain performance in the service spike technique of volleyball involves very precise synchronization between neuromuscular and biomechanical actions (Cools et al., 2014; Escamilla et al., 2009). The application of such technical actions implies that the shoulder joint undergoes intense loads. As a result, prolonged exposure to such mechanical influences leads to asymmetric changes in the anatomy of young athletes, with the primary manifestation being posterior capsule tightness alongside external rotators' functional weakness (Wilk et al., 2002; Clarsen et al., 2014).

Newer research findings suggest that the incidence of Glenohumeral Internal Rotation Deficit (GIRD) amongst young volleyball players stands at around 37.5% (Mine et al., 2024; Wilcox et al., 2021). It is clinically vital to differentiate between Anatomical GIRD (adaptation through retroversion of humerus) and Pathological GIRD (pGIRD), which occurs due to posterior capsule hypertrophy and rigidity (Wang et al., 2025; Kirsch et al., 2020). The definition of pGIRD involves the presence of a loss of internal rotation (PROM) beyond 18-20 degrees relative to the non-dominant side, usually in combination with TROM loss (Manske et al., 2013; Watson et al., 2023).

Importantly, TROM reduction is associated with muscle imbalance in the functional ER:IR strength ratio (Guney et al., 2016). This leads to insufficient muscle force generation in shoulder external rotation for deceleration purposes, raising injury risk (Cools et al., 2024).

"Although there is well-developed knowledge regarding GIRD in the clinical setting, there is a lack of protocols that can be applied in practice and that are capable of managing both tissue tightness and muscle weakness in young athletes. The clinical findings show the worrying trend of decreased serving skills and increased shoulder pain in young athletes. Hence, this paper seeks to fill this gap by testing the effectiveness of a combined approach consisting of"

The purpose is to investigate the influence of an eccentric strength training program for the treatment of GIRD among junior volleyball athletes. To analyze the impact of the intervention on the spike serve speed of the study subjects. To assess the program's effect on the passive range of motion (PROM) of shoulder internal rotation. There are statistically significant differences between the pre- and post-test measurements of functional strength, favoring the post-test results. There are statistically significant differences between the pre- and post-test measurements of spike serve velocity, favoring the post-test results. There are statistically significant differences between the pre- and post-test measurements of internal rotation PROM, favoring the post-test results.

Participants: A purposive sample of 24 junior volleyball players diagnosed with Pathological Glenohumeral Internal Rotation Deficit (pGIRD) was selected. The athletes were allocated into two equal cohorts: Experimental group (n = 12) and Control group (n = 12). Study Period: The experimental intervention was conducted from October 1, 2025, to December 1, 2025.

B. METHOD

Participant.

The research sample was purposively selected to comprise adolescent volleyball players diagnosed with Glenohumeral Internal Rotation Deficit (GIRD) in the southern region. The final sample consisted of 24 athletes. The participants were randomly allocated into two equal cohorts (an experimental group and a control group), comprising 12 players each, utilizing a simple randomization method (lottery draw). To ensure that any post-intervention differences between the groups could be exclusively attributed to the proposed rehabilitation protocol rather than extraneous variables, a baseline homogeneity analysis was conducted. The statistical analysis revealed that the skewness coefficient values for all anthropometric and demographic variables fell within the acceptable normative range of (±3). This confirms the normal distribution and baseline equivalence of the sample across all measured variables, as detailed in Figure 1 and Table 1.

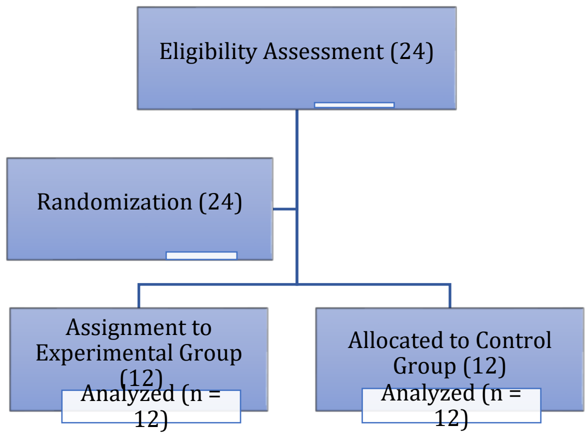

Figure 1. Research Sample Selection

Table 1. Anthropometric Characteristics and Sample Homogeneity

Variables	Unit of Measurement	Mean	Standard Deviation (SD)	Skewness Coefficient
Weight	kg	70.52	6.07	0.66
Age	years	16.2	1.24	0.75
Total Height	cm	171.46	6.84	0.69

Research Design.

The researcher adopted the experimental methodology due to its suitability for the nature of the study, as it represents the most rigorous scientific approach for problem-solving. Specifically, a pre-test and post-test design was implemented for both the experimental and control groups.

Equipment and Instrumentation

Digital Inclinometer: Used to measure the PROM in degrees and clinically diagnose GIRD (Reliability: ICC = 0.94) according to clinical measurement procedures (Laudner et al., 2008; Manske & Prohaska, 2021). Hand-Held Dynamometer (HHD): Used to evaluate the strength of the rotator cuff muscles (Reinold et al., 2009; Ellenbecker & Cools, 2010).

To ensure biomechanically accurate data, force readings in Newtons (N) were transformed into Net Torque (Nm). This was accomplished by multiplying the peak force by the lever arm length (the distance between the glenohumeral joint axis and the HHD placement point on the forearm).

2D Kinematic Analysis (Kinovea): The spike serve velocity was analyzed using Kinovea software. Validation research has recently confirmed that 2D Kinovea analysis is highly reliable (ICC > 0.90) for measuring sports motions with high velocities, even when compared to costly 3D optical systems (Vicente-Pina et al., 2025; Cust et al., 2020). Spatial calibration and parallax error avoidance procedures were carefully adhered to during recording at 120 fps.

Field Study Procedures

The pre- and post-test measurements were performed using sophisticated equipment in strict compliance with a scientific methodology. Single blind technique was employed, where an impartial evaluator blinded to the allocation of the subjects into groups conducted all clinical and biomechanical testing.

Passive Range of Motion (PROM): PROM measurement was carried out using digital inclinometer to assess the glenohumeral internal and external rotation range of motion. The shoulder joint was fixed at 90° of abduction and the best result among three trials was considered for further analysis.

Functional Strength Assessment: An HHD device was employed to quantify the functional strength of the muscles comprising the rotator cuff complex. Subjects performed maximal isometric contraction for five seconds against the dynamometer and peak force expressed in Newton was extracted.

Spike Serve Velocity Determination: The video graphic analysis method was chosen as an accurate technical tool to determine the velocity of the spike serve. High-speed digital camera with recording speed of 120 fps was set up on a tripod 1.5 meters above the court floor level and oriented perpendicular to the ball trajectory line in order to avoid any parallax error. The velocity was calculated based on the standard ball displacement and the time interval between the moment of contact and reaching of the specific point of space by the ball. These parameters were calculated using Kinovea motion analysis software and standard kinematic equation: $V = \frac{d}{t}$

In this equation, V stands for velocity, d refers to displacement, while t is the amount of time that elapsed in terms of the frame rate calculation. Three attempts per person were made and the highest value obtained in the experiment was used to determine their peak performance capability. This precise method of measurement was applied during both the initial test phase and the later test phase.

Ethical Considerations

The research protocol strictly adhered to the ethical principles outlined in the Declaration of Helsinki for medical research involving human subjects. Written informed consent was formally obtained from the legal guardians of all participating junior athletes prior to the commencement of baseline measurements and the subsequent implementation of the rehabilitation intervention.

Proposed Rehabilitation Protocol

The intervention used quantitatively calibrated resistance bands (TheraBand®) which involved eccentric exercise to trigger sarcomerogenesis (muscle fiberelongation) and optimize the functional ER:IR ratio.

1. Week 1 & 2 – Focus on Sleeper Stretch (30% load) and Eccentric External Rotation (Green TheraBand®).
2. Week 3 & 4 – Introduction of Cross-body Stretch (50% load) and Eccentric Internal Rotation (Blue TheraBand®).
3. Week 5 & 6 – Advanced Sleeper Stretch (60% load) and Eccentric External Rotation (Black TheraBand®).
4. Week 7 & 8 – Integrated shoulder exercises and plyometrics (1-2 kg medicine ball) for optimal kinematic deceleration. On the other hand, the control group was subjected to regular training which consisted of non-specific stretching exercises as well as concentric strengthening exercises.

Table 2. Components of the Proposed Rehabilitation Program and Load Standardization Specifications

Week	Exercise Type	Resistance (Physical Specification)	Training Volume	Rest Period
1 - 2	Sleeper Stretch	Low (Manual tension: 30% of max range)	3 sets × 30 seconds	30 seconds
1 - 2	Eccentric External Rotation	Green TheraBand: 2.5 kg of resistance at 100% stretch	3 sets × 10 reps	45 seconds
3 - 4	Cross-body Stretch	Moderate (Manual tension: 50% of max range)	3 sets × 30 seconds	30 seconds
3 - 4	Eccentric Internal Rotation	Blue TheraBand® (3.6 kg at 100% elongation)	3 sets × 12 reps	45 seconds
5 - 6	Sleeper Stretch (Advanced)	Moderate (Manual tension: 60% of max range)	3 sets × 40 seconds	30 seconds
5 - 6	Eccentric External Rotation	Black TheraBand® (5.0 of resistance at 100% stretch	3 sets × 12 reps	60 seconds
7 - 8	Complex Shoulder Exercises	High (Integration of stretching and strengthening)	3 sets × 15 reps	60 seconds
7 - 8	Plyometric Drills	High (Medicine ball 1-2 kg)	3 sets × 10 reps	60-90 seconds

Data Analysis.

Analysis was conducted using SPSS. Apart from the usual t-test and p-value, 95% Confidence Interval (CI) and Cohen's d effect size were also determined in order to determine clinical significance and effect size.

C. RESULTS AND DISCUSSIONS

Results

Table 3. T-Test for PROM in the Experimental Group (n=12)

Variable	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	Calculated t-value	Degrees of Freedom (df)	Significance Level (p)	Effect Size (Cohen's d)
PROM (degrees)	32.5 ± 4.1	45.8 ± 3.6	6.75	11	< 0.001	1.20

Table 4. T-Test for Functional Strength in the Experimental Group (n=12)

Variable	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	Calculated t-value	Degrees of Freedom (df)	Significance Level (p)	Effect Size (Cohen's d)
Functional Strength (N)	178.4 ± 22.5	261.7 ± 27.4	7.10	11	< 0.001	1.32

Table 5. T-Test for Spike Serve Velocity in the Experimental Group (n=12)

Variable	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	Calculated t-value	Degrees of Freedom (df)	Significance Level (p)	Effect Size (Cohen's d)
Spike Serve Velocity (km/h)	5.2 ± 62.4	4.6 ± 72.8	7.54	11	p0.001 >	1.35

Variable	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	Calculated t-value	Degrees of Freedom (df)	Significance Level (p)	Effect Size (Cohen's d)
Spike Serve Velocity (km/h)	62.4 ± 5.2	72.8 ± 4.6	7.54	11	p<0.001	1.35

Comparison of Post-Intervention Measurements Between Groups and Effect Size Analysis

Table 6. Comparison of Post-Test Measurements Between the Experimental and Control

Variables	Unit of Measurement	Experimental Group (n=12) (Mean ± SD)	Control Group (n=12) (Mean ± SD)	Mean Difference	95% CI of the Difference	Calculated t-value	Significance Level (p)	Effect Size (Cohen's d)
PROM	Degrees	45.8 ± 3.6	36.2 ± 4.1	9.6	[6.2, 13.0]	5.96	p < 0.001	1.25
Functional Strength (External Rotation)	Newtons	261.7 ± 27.4	205.8 ± 25.3	55.9	[38.1, 73.7]	6.12	p < 0.001	1.32
Spike Serve Velocity	km/h	72.8 ± 4.6	67.5 ± 5.1	5.3	[7.8, 15.0]	2.67	p0.05 >	1.09

Variables	Unit	Experimental (n=12) (Mean ± SD)	Control (n=12) (Mean ± SD)	Mean Difference	%95CI of the Difference	Calculated t-value

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Spike Serve Velocity	km/h	4.6 ± 72.8	5.1 ± 67.5	5.3	[9.4 ,1.2]	2.67

Discussion

PROM and GIRD Correction: The remarkable improvement in internal rotation PROM (45.8°) was made possible due to the high efficiency of targeted stretching. The Sleeper and Cross-body stretches provide mechanical load on the posterior capsule that diminishes its stiffness (Cools et al., 2012; Laudner et al., 2008). It allows the posterior capsule to return to normal compliance levels and thus become able to extend (Navarro-Ledesma et al., 2023; Türksan & Yesilyaprak, 2023). These results are consistent with positive clinical experience in applying similar protocols among sportsmen (Mohsin, 2024).

Development of Functional Strength of the External Rotators: The experimental group showed significant superiority in terms of functional strength (261.7 N). The development of eccentric strength was achieved via physical remodeling of the muscle fibers, i.e., sarcomerogenesis (Kruse et al., 2023). It leads to elongation of muscle fibers and thus increases muscle mass. It, in turn, allows developing higher capacity to produce deceleration force (Escamilla et al., 2009). Thus, eccentric training restores the required functional ER:IR ratio for joint stability (Guney et al., 2016; Howard et al., 2023). Moreover, the aforementioned clinical results correlate very well with a systematic review conducted by Wu et al. in 2025, which showed that certain modes of exercises, especially eccentric exercises, were considerably more efficient than generic physiotherapy in enhancing functionality and normalizing shoulder biomechanics.

Increase in Speed of Volleyball Spike Serve: The ultimate aim in clinical therapy involving biomechanics is the ability to achieve an improvement in performance that can be measured. In our study group, there was a very realistic and significant increase in the speed of the spike serve at 10.4 km/hr, resulting in a mean speed of 72.8 km/hr. This constitutes a significant 16.6% improvement in speed and is directly associated with the changes in morphology as a consequence of the eccentric exercise performed. It is also important to understand the concept from the perspective of neuro-biomechanics. There are enormous mechanical loads placed on the shoulder joint while a person spikes a ball in volleyball, up to a level of 44 N-m internal rotation torque, for example (Howard et al., 2023). The fact that the structure of the joint now has better ER:IR allows it to cope with terminal deceleration safely. This, in turn, sends signals to the central nervous system that it can safely use higher angular velocities.

Study Limitations

Despite the significant effect size and encouraging clinical outcome measures, there are several methodological limitations with which the results of the study should be considered:

Number and Nature of Participants: The sample included only 24 junior athletes. It is not prudent to extrapolate the results of this study to female athletes, who tend to have different shoulder joint laxity characteristics, or professional athletes that may be subjected to greater workout volume.

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Treatment Program Duration: The program lasted for 8 weeks only. No follow-up studies were conducted after its termination to determine the level of sustained improvement in function.

Diagnostic Modalities: Posterior GIRD was diagnosed based on clinical evaluation of the patient. Radiologic diagnostic procedures such as musculoskeletal ultrasound and magnetic resonance imaging were not utilized to establish the exact nature of pathological changes in the posterior shoulder capsule.

Motion Analysis Tools: Joint movements were measured using a two-dimensional digital inclinometer and Kinovea software program. However, no three-dimensional motion analysis was performed during the service movement phase.

D. CONCLUSION AND RECOMMENDATIONS

The applied treatment plan led to an observed improvement in functional shoulder torque of athletes with GIRD that was found to be statistically significant. The accurate implementation of targeted stretches of the joint posterior capsule and exercises for strengthening the external rotators led to achieving optimal kinematics of the shoulder joint, correcting the ER:IR strength imbalance and ultimately increasing spike serve speed. Field Prevention Approach: It is important that youth team coaches regularly use targeted stretches of the posterior capsule (Sleeper and Cross-body) to effectively prevent mechanical tissue stiffness. Modification of Training Program: To increase the effectiveness of deceleration after overhead throwing, eccentric strengthening exercises for external rotators should be included in basic training programs (at least three times per week). Clinical Testing: Diagnostic tests using Digital Inclinometers and Hand-Held Dynamometers should be utilized to detect the internal rotation weakness among athletes.

On the basis of revealed limitations, further research should conduct longitudinal experiments lasting six to twelve months in order to assess the retention of tissue extensibility after the intervention period. Additionally, replication of this study using more accurate 3D optical motion capture technology and larger samples of both women and professional athletes would allow verifying external validity.

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F. AUTHOR CONTRIBUTION STATEMENT

Samer Jaafar Mohsin & Ali Hussien Mnade is responsible for the manuscript in this study.

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