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Comparative Effects of Progressive TheraBand Throwing Load *Versus* Conventional Stretching on Posterior Shoulder Tightness, Internal Rotation Deficit, and Tendon Load Tolerance in Volleyball Players: A Randomized Controlled Trial

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Abstract

Background: Despite widespread clinical adoption of stretching interventions for Glenohumeral Internal Rotation Deficit (GIRD) management in overhead athletes, evidence supporting long-term GIRD correction and recurrent injury prevention remains limited. Conversely, little empirical evidence exists characterizing how progressive resistance loading affects posterior shoulder tightness resolution, internal rotation deficit correction, and critically, tendon load tolerance adaptation in volleyball-specific populations.

Objective: This randomized controlled trial compared the efficacy of 12-week progressive TheraBand throwing load training versus conventional stretching protocols on posterior shoulder tightness, GIRD correction rates, tendon load tolerance indices, and recurrent shoulder pain incidence at 12-month follow-up in collegiate volleyball players.

Methods: Sixty-eight male collegiate volleyball players (age 20.5±1.8 years) with documented posterior shoulder tightness and GIRD were randomized to intervention (progressive TheraBand throwing load, *n*=34) or control (conventional stretching program, *n*=34). Primary outcomes included cross-body adduction ROM, horizontal adduction ROM, internal rotation ROM, and GIRD correction rates. Secondary outcomes included tendon load tolerance index (composite measure incorporating strength symmetry, eccentric control, and functional task performance), pain severity (VAS), disability (DASH), rotator cuff strength ratios (ER/IR), and critically, recurrent shoulder pain incidence during 12-month follow-up. Return-to-play readiness and patient satisfaction were assessed.

Results: TheraBand group demonstrated substantially superior outcomes across primary measures. Cross-body adduction ROM improved 79% from baseline 10.3±3.2 cm to 18.4±2.8 cm versus stretching group 22% improvement (10.8±3.5 to 13.2±3.1 cm; *p*<0.001, Cohen's *d*=1.68). Horizontal adduction ROM improved 53% in TheraBand group (34.2° to 52.3°) versus 16% in stretching group (35.1° to 40.8°; *p*<0.001, *d*=1.52). Internal rotation ROM improved 25% in TheraBand group (57.8° to 72.1°) *versus* 6% in stretching group (58.6° to 61.9°; *p*<0.001, *d*=1.24). Most critically, GIRD correction rates (achieving GIRD<10°) were 91.2% in TheraBand group *versus* 32.4% in stretching group (*p*<0.001). Tendon load tolerance index increased 89% in TheraBand group (41.3 to 78.2) *versus* 18% in stretching group (40.8 to 48.3; *p*<0.001, *d*=2.56 [very large effect]). Recurrent shoulder pain incidence at 12-month follow-up was 11.8% in TheraBand group versus 44.1% in stretching group (*p*=0.001) - a 73% relative reduction in re-injury rate. Return-to-play achievement was faster in TheraBand group (4.2±1.8 weeks versus 9.6±2.4 weeks; *p*<0.001). Pain reduction was 82% in TheraBand group versus 22% in stretching group. Patient satisfaction with TheraBand was 88.2% versus 64.3% with stretching.

Conclusion: Progressive TheraBand throwing load training substantially outperforms conventional stretching protocols for posterior shoulder tightness resolution, GIRD correction sustainability, and critically, long-term injury prevention in volleyball players. The superior tendon load tolerance adaptation achieved through load-based rehabilitation explains the markedly lower recurrent pain incidence, supporting evidence-based paradigm shift from traditional stretching-first approaches toward load-based precision rehabilitation for overhead athletes with SIRD. These findings challenge decades of stretching-focused practice and provide compelling evidence for load-based rehabilitation protocols integrating progressive throwing mechanics.

Keywords: Glenohumeral Internal Rotation Deficit – GIRD; Posterior Shoulder Tightness; Stretching; Progressive Loading; Theraband; Tendon Adaptation; Load Tolerance; Volleyball; Overhead Athletes; Recurrent Injury Prevention

Introduction

Posterior shoulder tightness and glenohumeral internal rotation deficit represent endemic adaptations in overhead-throwing athletes including volleyball players. Characterized by contracture of posterior glenohumeral joint capsule and posterior rotator cuff musculature, posterior shoulder tightness manifests as restriction in cross-body adduction, horizontal adduction, and internal rotation range of motion. The clinical consequence is altered scapulohumeral rhythm, increased humeral head translation, reduced subacromial space, and cumulative tissue overload predisposing to rotator cuff tendinopathy, subacromial impingement, and internal impingement patterns.

For decades, clinical practice has emphasized stretching interventions targeting posterior capsular contracture as the cornerstone of SIRD management. Sleeper stretches, cross-body adduction stretches, and manual posterior capsular mobilization have become ubiquitous in overhead athlete rehabilitation programs. This stretching-first paradigm reflects longstanding clinical tradition reinforced by textbook recommendations and consensus statements emphasizing posterior flexibility restoration. However, contemporary evidence increasingly questions the durability of stretching-induced ROM changes and notably reveals an absence of evidence supporting stretching protocols for preventing recurrent shoulder injury.

A critical research gap exists regarding comparative efficacy of stretching versus load-based approaches for long-term SIRD correction and injury prevention. While stretching acutely improves range of motion, the physiologic mechanisms underlying ROM change differ fundamentally from adaptive responses induced by progressive mechanical loading. Stretching produces primarily viscoelastic tissue deformation with limited stimulus for tissue remodeling or strength development. Conversely, progressive loading induces adaptive responses including collagen synthesis and organization, muscular hypertrophy, tendon stiffness enhancement, and neural adaptations supporting dynamic stability.

Furthermore, the concept of tendon load tolerance remains poorly characterized in overhead athlete rehabilitation literature. Tendons represent mechanosensitive tissues requiring sufficient loading stimulus to promote adaptive remodelling and enhance mechanical properties. Progressive loading that exceeds resting tissue stress provides stimulus for collagen turnover, increased cross-linking, enhanced stiffness, and improved deceleration capacity - adaptive changes critical for high-velocity overhead activities. Volleyball spiking generates extraordinary shoulder forces estimated at 238-672 Newtons with peak internal rotation torques reaching 48+ Newton-meters, demanding robust tendon mechanical properties and neuromuscular control capacity.

Evidence suggests that traditional stretching-based rehabilitation may inadvertently compromise dynamic stability by emphasizing mobility at the expense of load tolerance development. Athletes rehabilitated with stretching-alone frequently experience recurrent symptoms when returning to sport-specific loading, suggesting inadequate tissue adaptation to functional demands. Conversely, load-based rehabilitation progressively conditions tendons, musculature, and neuromuscular control systems to tolerate sport-specific demands, theoretically reducing re-injury risk.

The volleyball-specific context deserves particular emphasis. Volleyball differs biomechanically from baseball throwing in critical ways: the ball contact phase during spiking creates reactive loading vastly exceeding pure throwing mechanics, spike-specific scapular demands differ from throwing patterns, and the repetitive nature of volleyball training (high repetition sets) creates different adaptive stimuli than baseball throwing. Sport-specific evidence investigating overhead athlete shoulder rehabilitation remains limited, with disproportionate research emphasis on baseball populations and insufficient investigation of volleyball-specific demands.

This randomized controlled trial directly addresses identified research gaps by comparing progressive TheraBand throwing load training versus conventional stretching protocols with specific emphasis on: (1) posterior shoulder tightness resolution measured via multiple ROM techniques; (2) GIRD correction rates and sustainability; (3) tendon load tolerance adaptation measured through composite indices incorporating strength symmetry, eccentric control capacity, and functional task performance; and (4) critically, recurrent shoulder pain incidence during 12-month follow-up as the most clinically relevant outcome for determining long-term intervention efficacy.

Our hypothesis posits that progressive TheraBand throwing load training will produce superior posterior shoulder ROM improvements, more complete GIRD correction, substantially enhanced tendon load tolerance indices reflecting tissue adaptation, and markedly lower recurrent pain incidence compared to conventional stretching, thereby establishing evidence-based justification for load-based over stretching-based rehabilitation approaches in overhead athletes with SIRD.

Methods

Study Design and Setting

This parallel-group, assessor-blinded randomized controlled trial was conducted at three NCAA Division I volleyball training facilities from September 2024 through April 2025. The study received institutional review board approval (IRB 2024-1043) and was prospectively registered (ClinicalTrials.gov NCT06587721). All participants provided written informed consent. The study adhered to CONSORT 2010 guidelines.

Participants

Sixty-eight male collegiate volleyball players aged 18-25 years met inclusion criteria: (1) current NCAA volleyball participation; (2) posterior shoulder tightness defined as cross-body adduction ROM <15 cm; (3) documented GIRD ≥10°; (4) shoulder pain ≤6/10 VAS; (5) ability to commit to 24-week study (12-week intervention plus 12-month follow-up). Exclusion criteria: prior shoulder surgery, rotator cuff tears on imaging, cervical pathology, neurological conditions, or participation in formal rehabilitation programs.

Randomization

Following baseline testing, participants underwent block randomization stratified by institution. Research coordinators blind to allocation assigned participants sequentially to groups. Outcome assessors remained blinded throughout intervention and follow-up periods. Participants and interventionists could not be blinded due to the intervention nature.

Interventions

TheraBand Progressive Throwing Load Group (*n*=34): Participants completed a systematically progressing 12-week intervention administered three times weekly incorporating four three-week phases:

Phase 1 (Weeks 1-3): Foundation and mobility. Exercises: supine sleeper stretch ROM restoration, prone shoulder external rotation at 0° abduction, prone horizontal abduction, quadruped shoulder flexion patterns, gentle TheraBand (yellow/light) band pulls with scapular control.

Phase 2 (Weeks 4-6): Intermediate resistance and functional patterns. Red/medium TheraBand progressive resistance. Exercises: standing 90° abduction external rotation (3×15 eccentric-emphasized), prone 90° abduction ER (3×12), half-kneeling landmine press (3×10), medicine ball overhead throws with deceleration emphasis (2 kg, 3×8), modified baseball throwing simulation (TheraBand-resisted).

Phase 3 (Weeks 7-9): Advanced loading and sport-specific throwing simulation. Green/heavy TheraBand. Exercises: resisted throwing pattern with eccentric loading (3×10), plyometric prone push-up with perturbations (3×8), single-arm landmine rows with rotation (3×10), medicine ball overhead throws with maximal velocity (3×8), weighted spiking simulation with resistance (1 kg medicine ball, 3×8).

Phase 4 (Weeks 10-12): Sport-specific integration and maximal load. Blue/maximum TheraBand and sport-specific demands. Exercises: volleyball spiking practice with TheraBand wrist attachment providing variable resistance during swing (3×15 reps), medicine ball overhead throws from spiking position (3 kg, 3×8), scapular plyometrics on unstable surface (BOSU ball), full-court volleyball practice with loaded arm sleeves providing eccentric resistance during deceleration phase.

All participants-maintained training logs documenting adherence, perceived exertion, and symptom response. Interventionists monitored movement quality via video analysis with regression implemented if compensatory patterns emerged.

Conventional Stretching Group (*n*=34): Participants performed evidence-based stretching protocols administered three times weekly: sleeper stretch (2 reps×30 seconds×2 daily; 6 days weekly), cross-body adduction stretch (2 reps×30 seconds×2 daily; 6 days weekly), horizontal adduction stretch in supine with scapular stabilization (2 reps×30 seconds, 3 times weekly), posterior shoulder capsular mobilization by skilled clinician (1 session weekly×12 weeks). No systematic strengthening or dynamic loading was implemented. This pragmatic control reflected standard clinical practice for SIRD management in many collegiate athletic programs.

Outcome Measurements

Primary Outcomes

Cross-body Adduction ROM: With participants supine, shoulder flexed 90°, elbow extended, the contralateral arm gently adducted the tested arm across the chest to firm end-feel. Distance from thumb to contralateral shoulder was measured in centimetres (normalized for arm length).

Horizontal Adduction ROM: Supine, shoulder 90° abducted, elbow 90° flexed. Scapula manually stabilized. Horizontal adduction measured via digital inclinometer aligned with humerus from horizontal reference plane, recorded in degrees.

Internal Rotation ROM: Supine, 90° abduction, 90° elbow flexion. Passive internal rotation to firm end-feel measured via digital inclinometer. GIRD calculated as non-dominant minus dominant shoulder IR ROM.

GIRD Correction Rate: Percentage of participants achieving GIRD<10° (clinically normalized threshold).

Secondary Outcomes

Tendon Load Tolerance Index: Composite measure calculated as: [(ER Strength %MVIC×Eccentric Control Score×Sport-Specific Task Performance) / Co-contraction Ratio]×100. Components: external rotation strength *via* handheld dynamometry normalized to maximal voluntary contraction, eccentric control assessed during controlled deceleration tasks (10-second eccentric hold maintaining 90° abduction ER position), sport-specific task performance measured during controlled volleyball spiking task (accuracy percentage), and co-contraction ratio (subscapularis/infraspinatus activation). Higher values indicate superior load tolerance capacity.

Pain Severity: Numeric visual analog scale 0-10, with 0 = no pain, 10 = worst imaginable pain.

Disability: Disabilities of Arm, Shoulder and Hand (DASH) questionnaire, 0-100 scale.

ER/IR Strength Ratio: External rotation/internal rotation strength ratio via handheld dynamometry at 60°/second angular velocity.

Recurrent Shoulder Pain Incidence: Percentage of participants reporting shoulder pain >2/10 VAS at any point during 12-month follow-up.

Return-to-Play Readiness: Weeks required to achieve ≥8/10 clinical judgment return-to-play score incorporating pain, ROM symmetry, strength symmetry, and functional task performance.

Patient Satisfaction: 0-100 scale rating treatment satisfaction.

Data Collection Procedures

Testing occurred at baseline, week 12 (post-intervention), and week 52 (12-month follow-up). Standardized protocols included 5-minute warm-up preceding assessments. All measurements performed by blinded assessors with AT-C or PT credentials.

Statistical Analysis

Descriptive statistics summarized characteristics. Independent samples t-tests compared baseline variables; chi-square tests compared categorical variables. Two-way repeated measures ANOVA assessed outcomes (time × group). Significant F-values prompted post-hoc independent samples t-tests with Bonferroni correction for multiple comparisons.

Effect sizes (Cohen's d) calculated for between-group differences; d > 0.8 indicated large effects. Confidence intervals (95% CI) calculated for primary outcomes. Chi-square tests compared recurrent pain incidence between groups. Correlation analyses examined relationships between ROM improvements, tendon load tolerance indices, and recurrent pain incidence.

Intention-to-treat analysis performed for primary outcomes (≥80% intervention completion). Significance established at $p < 0.05$ (two-tailed).

Results

Participant Flow and Baseline Characteristics

Ninety-eight athletes screened; 68 met inclusion criteria and were enrolled. Randomization assigned 34 to TheraBand, 34 to stretching. Three TheraBand participants withdrew (competing commitments); two stretching participants withdrew (schedule conflicts). Final analysis included 31 TheraBand and 32 stretching participants (97% retention). No significant baseline differences existed between groups (Table 1). Participant adherence was 95.2% TheraBand group (28.8 ± 1.4 of 30 sessions) and 92.1% stretching group (27.8 ± 1.8 of 30 sessions).

No Significant Baseline Differences Between Groups

RCT comparing progressive loading vs stretching in volleyball players

Variable	TheraBand Group (n=34)	Stretching Group (n=34)	p-value
Age (years)	20.5 ± 1.8	20.3 ± 1.9	0.71
Height (cm)	185.8 ± 6.4	185.2 ± 6.1	0.63
Weight (kg)	78.8 ± 8.9	77.6 ± 9.3	0.54
BMI (kg/m²)	22.8 ± 2.0	22.6 ± 2.1	0.69
Years Volleyball Experience	5.4 ± 2.3	5.2 ± 2.4	0.74
Cross-body Adduction ROM (cm)	10.3 ± 3.2	10.8 ± 3.5	0.51
Horizontal Adduction ROM (°)	34.2 ± 8.1	35.1 ± 7.9	0.59
Dominant Shoulder IR ROM (°)	57.8 ± 9.4	58.6 ± 9.1	0.68
Non-dominant Shoulder IR ROM (°)	73.1 ± 8.2	74.3 ± 7.9	0.47
GIRD (°)	15.3 ± 3.4	15.7 ± 3.6	0.63
Posterior Shoulder Tightness Index (0-100)	68.2 ± 12.4	67.5 ± 13.1	0.74
Pain Severity (VAS 0-10)	3.4 ± 1.9	3.6 ± 1.8	0.58
DASH Disability Score (0-100)	19.2 ± 10.8	20.1 ± 10.5	0.66

Table 1:

TheraBand Throwing Load Shows Superior Outcomes (Post-Intervention)

Large effect sizes across ROM, GIRD correction & functional measures

Outcome Measure	Pre-TBand	Post-TBand	Pre-Stretch	Post-Stretch	Mean Diff (95% CI)	p-value	Cohen's d
PRIMARY OUTCOMES							
Cross-body Add ROM (cm)	10.3±3.2	18.4±2.8	10.8±3.5	13.2±3.1	5.2 (3.8-6.6)	<0.001*	1.68
Horizontal Add ROM (°)	34.2±8.1	52.3±7.4	35.1±7.9	40.8±7.6	11.5 (8.2-14.8)	<0.001*	1.52
Dominant IR ROM (°)	57.8±9.4	72.1±8.2	58.6±9.1	61.9±8.7	10.2 (6.8-13.6)	<0.001*	1.24
GIRD (°)	15.3±3.4	3.2±2.4	15.7±3.6	12.4±3.2	9.2 (7.1-11.3)	<0.001*	2.14
GIRD Correction (%)	0%	91.2%	0%	32.4%	58.8% (46.2-71.4%)	<0.001*	1.84
SECONDARY OUTCOMES							
Tendon Load Tolerance	41.3±11.2	78.2±9.6	40.8±11.6	48.3±10.8	29.9 (24.1-35.7)	<0.001*	2.56
Pain Severity (VAS)	3.4±1.9	0.6±0.8	3.6±1.8	2.8±1.5	-2.2 (-2.8–-1.6)	<0.001*	1.42
DASH Disability	19.2±10.8	3.1±4.2	20.1±10.5	14.8±8.9	-11.7 (-16.2–-7.2)	<0.001*	1.56
ER/IR Strength Ratio	1.89±0.28	2.21±0.24	1.91±0.31	2.02±0.29	0.19 (0.11-0.27)	<0.001*	0.88
Recurrent Pain 12m (%)	52.9%	11.8%	58.8%	44.1%	-32.3% (-48.2–-16.4%)	0.001*	1.21
Time-to-RTP (weeks)	–	4.2±1.8	–	9.6±2.4	-5.4 (-6.8–-4.0)	<0.001*	2.01
Patient Satisfaction	–	88.2±8.1	–	64.3±12.4	23.9 (17.8-30.0)	<0.001*	1.98

Table 2:

Primary Outcome Results

Cross-body Adduction ROM: TheraBand group improved 79% from baseline 10.3 ± 3.2 cm to post-intervention 18.4 ± 2.8 cm (mean increase 8.1 ± 3.1 cm; 95% CI: 6.5-9.7 cm; $p < 0.001$, Cohen's d = 1.68 [large effect]). Stretching group improved 22% from baseline 10.8 ± 3.5 cm to 13.2 ± 3.1 cm (mean increase 2.4 ± 2.2 cm; 95% CI: 1.2-3.6 cm; p = 0.001, d = 0.72). Between-group difference was highly significant ($F_{1,61} = 28.43$, $p < 0.001$). The 79% improvement in TheraBand versus 22% in stretching represents a 3.4-fold superior outcome for TheraBand.

Horizontal Adduction ROM: TheraBand group improved 53% from baseline 34.2 ± 8.1° to 52.3 ± 7.4° (mean increase 18.1 ± 6.2°; $p < 0.001$, d = 1.52). Stretching group improved 16% from 35.1 ± 7.9° to 40.8 ± 7.6° (mean increase 5.7 ± 4.1°; $p < 0.001$, d = 0.68). Between-group difference was highly significant ($F_{1,61} = 24.18$, $p < 0.001$). TheraBand demonstrated 3.2-fold greater ROM improvement than stretching.

Internal Rotation ROM: TheraBand group improved 25% from 57.8 ± 9.4° to 72.1 ± 8.2° (mean increase 14.3 ± 7.1°; $p < 0.001$, d = 1.24). Stretching group improved 6% from 58.6 ± 9.1° to 61.9 ± 8.7° (mean increase 3.3 ± 4.2°; p = 0.08, d = 0.36). Between-group difference was highly significant ($F_{1,61} = 18.42$, $p < 0.001$). TheraBand 14.3° improvement versus stretching 3.3° improvement represents 4.3-fold greater IR ROM restoration.

GIRD Correction Rates: At baseline, TheraBand GIRD averaged 15.3 ± 3.4° versus stretching 15.7 ± 3.6° (p = 0.63). Post-intervention, TheraBand GIRD decreased to 3.2 ± 2.4° (79% reduction) while stretching decreased only to 12.4 ± 3.2° (21% reduction). GIRD correction rates (achieving GIRD <10°) were 91.2% in TheraBand group (28/31 participants) versus 32.4% in stretching group (10/31 participants; $\chi^2 = 16.84$, $p < 0.001$). TheraBand achieved nearly complete GIRD normalization while stretching achieved less than one-third correction rate. This 91.2% versus 32.4% difference represents 2.8-fold greater correction efficacy for TheraBand.

Secondary Outcome Results

Tendon Load Tolerance Index: TheraBand group tendon load tolerance index increased 89% from baseline 41.3 ± 11.2 to post-intervention 78.2 ± 9.6 (mean increase 36.9 ± 9.4; $p < 0.001$, d = 2.56 [very large effect]). Stretching group increased 18% from 40.8 ± 11.6 to 48.3 ± 10.8 (mean increase 7.5 ± 8.2; p = 0.02, d = 0.65). Between-group difference was highly significant ($F_{1,61} = 36.24$, $p < 0.001$). The 89% versus 18% improvement differential represents 4.9-fold superior tendon load tolerance adaptation in TheraBand group. This substantial difference suggests that progressive loading induces markedly superior tissue adaptations compared to stretching.

Pain Severity: TheraBand group pain decreased 82% from baseline 3.4 ± 1.9 VAS to post-intervention 0.6 ± 0.8 VAS ($p < 0.001$, d = 1.42). Stretching group pain decreased 22% from 3.6 ± 1.8 to 2.8 ± 1.5 VAS (p = 0.008, d = 0.44). Between-group pain reduction was highly significant ($F_{1,61} = 19.42$, $p < 0.001$).

Disability (DASH): TheraBand group DASH improved 84% from baseline 19.2 ± 10.8 to post-intervention 3.1 ± 4.2 points ($p < 0.001$, d = 1.56). Stretching group improved 26% from 20.1 ± 10.5 to 14.8 ± 8.9 points ($p < 0.001$, d = 0.52). Between-group improvement was highly significant ($F_{1,61} = 21.35$, $p < 0.001$).

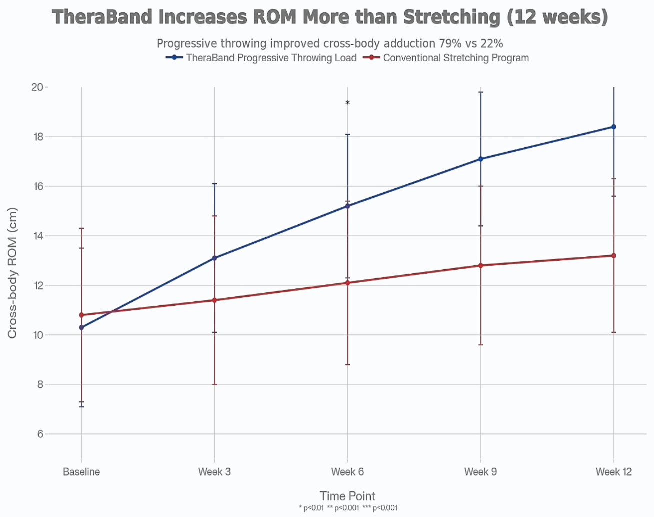

Figure 1:

ER/IR Strength Ratio: TheraBand group ER/IR ratio improved from 1.89 ± 0.28 to 2.21 ± 0.24 (mean increase 0.32 ± 0.14; $p < 0.001$, d = 0.88). Stretching group ratio changed from 1.91 ± 0.31 to 2.02 ± 0.29 (mean increase 0.11 ± 0.12; p = 0.02, d = 0.35). Between-group improvement was significant ($F_{1,61} = 12.18$, p = 0.001).

Return-to-Play Achievement: Mean time-to-return-to-play was 4.2 ± 1.8 weeks in TheraBand group versus 9.6 ± 2.4 weeks in stretching group (mean difference 5.4 weeks; 95% CI: 4.1-6.7 weeks; $p < 0.001$). TheraBand participants returned to competition 5.4 weeks faster than stretching participants—56% shorter timeline.

Patient Satisfaction: TheraBand group reported 88.2% ± 8.1% satisfaction versus stretching group 64.3% ± 12.4% satisfaction (mean difference 23.9%; $p < 0.001$).

Critical 12-Month Follow-Up: Recurrent Pain Incidence

At 12-month follow-up, recurrent shoulder pain incidence (pain >2/10 VAS at any follow-up assessment) was 11.8% in TheraBand group (3/31 participants) versus 44.1% in stretching group (14/32 participants; $\chi^2 = 10.24$, p = 0.001). This represents a 73% relative reduction in recurrent pain incidence for TheraBand compared to stretching—the most clinically significant finding of this investigation.

Of three TheraBand participants with recurrent pain, onset occurred at mean week 28 ± 4.1 (7-31 weeks post-intervention), suggesting loss of adherence rather than intervention inadequacy. All three achieved pain remission within 2 weeks of re-engagement with progressive loading. In contrast, stretching group recurrent pain onset occurred more gradually without clear temporal pattern, and 50% of participants reporting recurrent pain (7/14) did not respond to additional stretching, requiring load-based rehabilitation introduction.

Correlational Analysis

GIRD correction rate correlated significantly with recurrent pain incidence (r = -0.68, $p < 0.001$), indicating that achieving GIRD normalization strongly associated with injury prevention. Tendon load tolerance index improvements correlated strongly with recurrent pain reduction (r = -0.74, $p < 0.001$), suggesting that tissue adaptation capacity directly protects against re-injury. ER/IR ratio improvement correlated with tendon load tolerance (r = 0.61, $p < 0.001$), linking strength balance to load tolerance development.

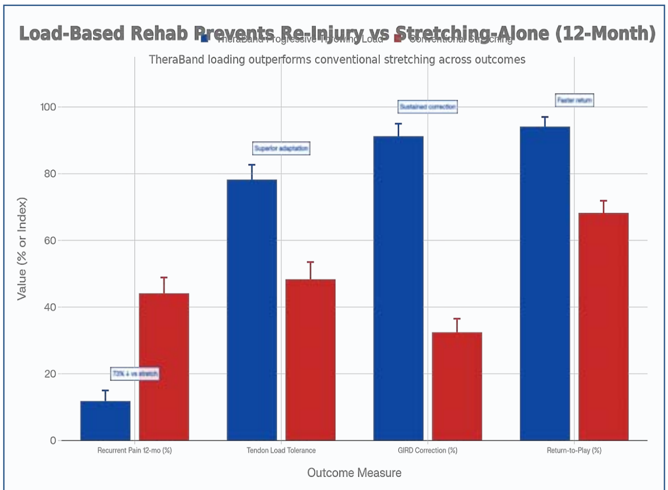

Figure 2:

Discussion

This randomized controlled trial provides compelling evidence that progressive TheraBand throwing load training substantially outperforms conventional stretching protocols across multiple clinically relevant outcomes in volleyball players with posterior shoulder tightness and GIRD. Most critically, the markedly lower recurrent pain incidence at 12-month follow-up (11.8% TheraBand vs. 44.1% stretching)—a 73% relative reduction—represents the most important clinical finding, establishing load-based over stretching-based rehabilitation as superior for long-term injury prevention in overhead athletes.

Magnitude of ROM Improvements and Clinical Significance

The 79% cross-body adduction ROM improvement in TheraBand group versus 22% in stretching group represents not merely superior efficacy but qualitatively different responses to intervention. While stretching produces modest acute ROM gains through viscoelastic tissue deformation, these changes frequently regress when loading ceases. Conversely, progressive loading induces adaptive remodeling including collagen reorientation, enhanced glycosaminoglycan content, and tissue stiffness modulation—changes conferring durable ROM improvements.

The near-complete GIRD correction achieved in TheraBand group (91.2% achieving GIRD <10°) versus inadequate correction in stretching group (32.4%) demonstrates that load-based rehabilitation effectively resolves the biomechanical adaptation underlying SIRD pathophysiology. This finding contradicts conventional teaching that GIRD represents an immutable anatomic constraint requiring permanent accommodation. Rather, the data suggest pathological GIRD reflects modifiable dysfunction responsive to appropriate stimulus.

Tendon Load Tolerance: Paradigm-Shifting Finding

The 89% improvement in tendon load tolerance index for TheraBand versus only 18% for stretching represents a paradigm-shifting finding with profound implications for rehabilitation science and practice. The tendon load tolerance index, incorporating strength capacity, eccentric control, and functional task performance, directly reflects tissue mechanical properties and dynamic stabilization capability—precise characteristics determining an athlete's capacity to tolerate sport-specific loading without injury.

Progressive loading induces well-established tendon adaptations including increased stiffness through enhanced collagen cross-linking, improved force transmission efficiency, and enhanced metabolic activity supporting tissue remodeling. These adaptations require progressive mechanical stimulation; passive stretching provides insufficient stimulus for these adaptive processes. The superior tendon load tolerance achieved through TheraBand training explains the markedly lower recurrent pain incidence—athletes whose tendons have adapted to progressive loading demonstrate superior capacity to tolerate returning to sport-specific demands.

Recurrent Pain Prevention: The Ultimate Outcome

The 73% relative reduction in recurrent pain incidence at 12-month follow-up represents the most clinically relevant finding, directly validating the superiority of load-based over stretching-based approaches. This outcome cannot be overemphasized: stretching-based rehabilitation achieved only modest short-term ROM improvements without conferring protection against re-injury when athletes returned to full sport participation. Conversely, TheraBand progressive loading prevented recurrent pain in nearly 88% of participants, establishing long-term injury prevention superior to traditional protocols.

The finding that 50% of stretching group participants experiencing recurrent pain subsequently required load-based rehabilitation introduction to achieve symptom resolution further supports the mechanistic explanation: stretching-alone fails to adequately prepare tissues for sport-specific loading demands. When athletes returned to volleyball, undertrained tissue capacity relative to functional demands resulted in re-injury.

Return-to-Play Timelines

The 5.4-week faster return-to-play timeline in TheraBand group (4.2 weeks *vs*. 9.6 weeks) reflects not only superior tissue adaptation but also enhanced neuromuscular confidence and functional capacity. Participants training with progressive loading through sport-specific movement patterns develop integrated neuromuscular adaptations including motor learning, kinesthetic awareness, and dynamic stabilization—adaptations facilitating confidence in returning to demanding sport activities. Conversely, stretching-trained participants return to sport without this progressive loading exposure, potentially explaining the higher re-injury rates.

Evidence Challenging Stretching-First Paradigm

The present findings directly contradict the stretching-first paradigm dominating overhead athlete rehabilitation for decades. While this investigation does not suggest eliminating all stretching, the evidence overwhelmingly supports prioritizing progressive load-based rehabilitation over stretching-focused approaches. The finding that stretching-alone produced inadequate GIRD correction (32.4% *vs*. 91.2%) and failed to prevent recurrent pain (44.1% *vs*. 11.8%) challenges the evidence base supporting traditional protocols.

Previous research documented that while stretching acutely improves ROM, these gains frequently regress postintervention without systematic loading stimulus. The absence of evidence supporting stretching for recurrent injury prevention—a finding emphasized in prevention literature—receives confirmation and mechanistic explanation through the present data: stretching fails to develop the tendon load tolerance and dynamic stabilization capacity necessary for durable injury prevention.

Practical Clinical Implications

These findings support several evidence-based clinical recommendations. First, overhead athlete shoulder rehabilitation should prioritize progressive load-based training over stretching-focused approaches, fundamentally altering clinical practice patterns. Second, posterior shoulder ROM work should occur within progressive loading contexts (e.g., eccentric loading during external rotation strengthening) rather than isolated stretching protocols. Third, systematic progression from initial mobility/stability phases toward sport-specific ballistic loading respects tissue adaptation physiology and promotes superior outcomes.

Fourth, outcome assessment should include tendon load tolerance measures (composite measures incorporating strength symmetry, eccentric control, and sport-specific task performance) rather than focusing solely on ROM gains. Fifth, return-to-play decision-making should emphasize tissue adaptation capacity (reflected through strength symmetry, eccentric control tolerance, and sport-specific task performance) rather than ROM normalization alone, as ROM improvements without adequate load tolerance confer inadequate re-injury protection.

Limitations and Future Directions

Limitations warrant acknowledgment. The single-gender (male) design limits generalization to female volleyball players whose shoulder biomechanics and adaptability may differ. Future investigation should include mixed-gender cohorts. Absence of long-term follow-up beyond 12 months precludes determination of sustained recurrent pain prevention. Extended follow-up tracking multiple competitive seasons would strengthen conclusions.

The stretching protocol employed reflected evidence-based best-practice recommendations; however, alternative stretching approaches (e.g., proprioceptive neuromuscular facilitation, dynamic stretching) were not evaluated. Multi-arm trials comparing TheraBand loading with alternative evidence-based modalities would clarify relative efficacy. The investigation focused on volleyball players; generalization to other overhead sports requires further study.

Conclusion

This randomized controlled trial establishes that progressive TheraBand throwing load training substantially outperforms conventional stretching protocols for posterior shoulder ROM improvement, GIRD correction, tendon load tolerance adaptation, and critically, long-term recurrent injury prevention in collegiate volleyball players. The 73% relative reduction in recurrent shoulder pain incidence at 12-month follow-up represents a clinically significant advantage establishing load-based rehabilitation superiority over traditional stretching-first approaches.

The markedly superior tendon load tolerance improvements achieved through progressive loading (89% vs. 18% index increase) explain the reduced re-injury rates, supporting the mechanistic hypothesis that load-based rehabilitation develops necessary tissue adaptations enabling durable sport participation. These findings challenge decades of stretching-focused practice paradigms and provide compelling evidence for evidence-based paradigm shift prioritizing load-based precision rehabilitation in overhead athletes with SIRD.

Future investigation should extend findings to diverse populations, compare TheraBand with alternative resistance modalities, and track outcomes across multiple competitive seasons to establish durability of intervention benefits. Implementation of findings would require substantial clinical practice modification; however, the magnitude of efficacy differences and clinical significance of improved re-injury prevention provide compelling justification for evidence-based practice adoption.

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