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Effects of Soft Tissue Mobilization Followed by Blood Flow Restriction on Reducing Elbow Pain and Improving Mobility in Throwing Athletes with Ulnar Collateral Ligament Strain

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ABSTRACT

Background: *Throwing athletes are at increased risk of medial elbow injury, particularly grade I–II ulnar collateral ligament (UCL) strain, which can impair pain-free range of motion and delay return to sport. Although soft tissue mobilization (STM) is commonly used in conservative management, the incremental benefit of adding blood flow restriction (BFR) to enhance clinical recovery remains unclear.* ***Objective:*** *To determine whether STM followed by BFR provides superior improvements in elbow pain and mobility compared with STM alone in throwing athletes with grade I–II UCL strain.* ***Methods:*** *In this assessor-blinded randomized controlled trial, 42 throwing athletes aged 17–30 years with clinically diagnosed grade I–II UCL strain were randomly allocated to an experimental group (STM + BFR) or control group (STM only) for four weeks (two sessions/week). Pain intensity was measured using the Numeric Pain Rating Scale (NPRS), and elbow flexion and extension were assessed with a universal goniometer. Within- and between-group analyses were conducted using paired and independent t-tests with 95% confidence intervals.* ***Results:*** *Both groups demonstrated significant improvements in pain and range of motion ($p < 0.001$). The experimental group showed a greater improvement in elbow flexion (mean difference 3.09°, 95% CI 0.84–5.35; $p = 0.008$; $d = 0.54$), while no significant between-group differences were observed for NPRS ($p = 0.206$) or extension deficit ($p = 0.506$).* ***Conclusion:*** *STM effectively reduces pain and improves mobility in athletes with low-grade UCL strain; the addition of BFR provides a moderate, statistically significant advantage in elbow flexion but not in pain or extension recovery.*

Keywords: *Ulnar collateral ligament, blood flow restriction, soft tissue mobilization, elbow pain, throwing athletes, range of motion.*

INTRODUCTION

Throwing and other overhead sports place substantial valgus stress across the medial elbow, making the ulnar collateral ligament (UCL) a frequent site of injury and pain that can disrupt training continuity and delay return to sport. Epidemiologic observations in competitive baseball show that elbow injuries—predominantly medial—are a major contributor to time-loss, and UCL injuries have been reported with increasing frequency across high school, collegiate, and professional levels, underscoring the clinical importance of optimizing conservative care for partial tears and low-grade strains (1). For grade I–II UCL injury, non-operative management is commonly recommended as first-line treatment, but clinicians still face uncertainty regarding which adjunctive interventions meaningfully accelerate symptom reduction and restoration of motion in athletes who must regain pain-

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free elbow mobility to throw effectively. In addition, return-to-sport decision-making after conservative management remains challenging because symptom resolution does not always map cleanly to functional readiness, and timelines reported in specific athlete subgroups vary, reinforcing the need for interventions that improve early clinical outcomes in a safe, reproducible manner (2).

Soft tissue mobilization is widely used in sports rehabilitation to address pain and mobility limitations by targeting myofascial and periarticular restrictions and potentially modulating nociception. Proposed effects include increased local perfusion, reduced edema, and short-term improvements in tissue pliability and flexibility; however, the physiologic impact on blood flow and the consistency of clinical effects remain debated across manual therapy and massage-related studies, with mixed results in the literature (3). This inconsistency leaves a practical gap: despite frequent clinical use, soft tissue mobilization alone may not reliably produce the magnitude or speed of improvement desired in symptomatic throwing athletes, particularly when treatment goals include rapid reductions in pain and restoration of elbow range of motion (ROM) necessary for progressive throwing exposure. In parallel, instrument-assisted and manual soft tissue approaches have been evaluated across musculoskeletal conditions, and some syntheses suggest potential benefits for pain and function, yet conclusions vary by population and condition, and the transferability of findings to medial elbow pain and UCL strain in throwers is not straightforward, highlighting an ongoing need for condition- and sport-specific evidence (5,10).

Blood flow restriction (BFR) has recently gained attention as an adjunct in rehabilitation due to its capacity to induce meaningful neuromuscular and functional adaptations under relatively low loads. The physiologic rationale centers on creating a local hypoxic and metabolically stressful environment that may enhance muscle fiber recruitment and stimulate anabolic signaling, with clinical frameworks emphasizing careful individualization of cuff characteristics and occlusion pressure to balance efficacy and safety (4). Contemporary sports medicine literature describes BFR as a versatile tool across prehabilitation and rehabilitation contexts and suggests it may help overcome performance plateaus or facilitate training adaptations when higher loads are not tolerated, which is particularly relevant when pain limits conventional strengthening during early elbow rehabilitation (6). Importantly, current clinical considerations emphasize that BFR application must be parameterized (e.g., occlusion pressure determination, cuff width/placement, monitoring for adverse responses) to ensure safe implementation, and when applied appropriately it has been presented as a safe and useful adjunct across upper- and lower-extremity programs (7). Despite these theoretical and emerging clinical advantages, the specific value of adding BFR to soft tissue mobilization for symptomatic elbow conditions in throwing athletes—where pain modulation and ROM restoration are early priorities—remains insufficiently established.

Taken together, the problem is that throwing athletes with grade I–II UCL strain frequently present with medial elbow pain and limited motion that constrain progressive return to throwing, while the incremental benefit of combining soft tissue mobilization with a physiologically potentiating adjunct such as BFR has not been clearly quantified in this population. The knowledge gap is not whether either approach can be used in rehabilitation, but whether soft tissue mobilization followed by BFR produces clinically and statistically meaningful improvements beyond soft tissue mobilization alone, particularly for pain and elbow ROM outcomes that guide early-stage progression. Therefore, the objective of this randomized controlled trial was to evaluate the effects of soft tissue mobilization followed by blood flow restriction, compared with soft tissue mobilization without blood flow restriction, on elbow pain and elbow mobility (flexion and extension) in throwing athletes

with grade I–II UCL strain over a four-week intervention period, with pain measured using the Numeric Pain Rating Scale and mobility assessed via goniometry. We hypothesized that athletes receiving soft tissue mobilization followed by BFR would demonstrate greater reductions in pain and greater improvements in elbow flexion and extension ROM than those receiving soft tissue mobilization alone after four weeks of treatment

MATERIAL AND METHODS

This study was designed as a parallel-group, assessor-blinded randomized controlled trial conducted to evaluate the comparative effectiveness of soft tissue mobilization followed by blood flow restriction versus soft tissue mobilization alone in throwing athletes diagnosed with grade I–II ulnar collateral ligament (UCL) strain. The trial was carried out in a university-affiliated sports rehabilitation setting over a ten-month period. The study design was selected to minimize selection bias and allow causal inference regarding the incremental benefit of blood flow restriction (BFR) when added to standardized soft tissue mobilization (STM), consistent with methodological recommendations for interventional clinical research in musculoskeletal rehabilitation (12).

Throwing athletes aged 17–30 years with clinically diagnosed grade I or grade II UCL strain and mild to moderate medial elbow pain were considered eligible. Diagnosis was established by a sports medicine physician using a standardized clinical assessment including history of valgus-loading pain during throwing, localized tenderness over the medial elbow, and positive valgus stress or moving valgus stress testing. Athletes were required to have symptoms for at least two weeks but less than six months and to be actively engaged in organized throwing sports.

Exclusion criteria included previous elbow surgery, complete UCL rupture (grade III), elbow fractures, active infection, inflammatory arthropathy (including rheumatoid arthritis), neurological disorders affecting the upper limb, vascular contraindications to BFR (including known thromboembolic disease), uncontrolled hypertension, and unwillingness to provide informed consent. Participants were recruited consecutively from sports teams, university athletic programs, and outpatient referrals. After eligibility screening, written informed consent was obtained in accordance with ethical standards for human research (13).

A total sample size of 42 participants (21 per group) was determined a priori using OpenEpi software based on detecting a moderate between-group effect size (Cohen's d = 0.8) in elbow flexion improvement at four weeks, with 80% power and a two-sided alpha of 0.05. An additional margin was incorporated to account for potential attrition, though no interim analysis was planned. Following baseline assessment, participants were randomly allocated in a 1:1 ratio using a computer-generated random sequence with variable block sizes to ensure allocation balance. Allocation concealment was achieved using sequentially numbered, opaque, sealed envelopes prepared by an independent researcher not involved in assessment or treatment. Outcome assessors were blinded to group assignment to reduce detection bias, and participants were instructed not to disclose their allocation during assessments.

Baseline data collected included age, sex, sport type, duration of symptoms, and dominant arm involvement. Primary and secondary outcomes were measured at baseline and after four weeks of intervention. The primary outcome was elbow pain intensity, operationalized as the average pain during throwing over the previous 24 hours measured using the 11-point Numeric Pain Rating Scale (NPRS), where 0 indicates no pain and 10 indicates worst imaginable pain. Secondary outcomes included elbow flexion and extension range of motion

measured in degrees using a universal goniometer according to standardized positioning procedures: participants were positioned supine with the shoulder in neutral rotation, the fulcrum aligned with the lateral epicondyle, the stationary arm aligned with the humerus, and the moving arm aligned with the radius. Elbow extension was recorded as degrees of extension deficit from full anatomical extension (0°). Three measurements were taken for each movement and averaged to enhance reliability (14). The same blinded assessor performed all measurements to minimize inter-rater variability.

Both groups received standardized soft tissue mobilization targeting the flexor-pronator mass and medial elbow soft tissues. Each session lasted approximately 20 minutes and was delivered twice weekly for four consecutive weeks. Manual techniques included longitudinal and transverse strokes applied with moderate pressure, progressing according to tissue tolerance. In the experimental group, BFR was applied 30 minutes after STM using a pneumatic cuff placed at the proximal one-third of the upper arm. Limb occlusion pressure (LOP) was determined individually using a handheld Doppler device to identify arterial pulse cessation. BFR was applied at 60% of LOP, consistent with upper-extremity safety recommendations (7,15).

The protocol consisted of four cycles (30-15-15-15 repetitions) of low-load active elbow flexion-extension exercises using minimal resistance (≤20% estimated one-repetition maximum), with 30-second rest intervals while maintaining cuff inflation. Total occlusion time per session did not exceed 10 minutes. Participants were monitored for adverse signs including excessive pain, paresthesia, discoloration, or dizziness, and cuff pressure was immediately released if intolerance occurred. The control group received identical STM and performed the same active exercises without BFR. Intervention fidelity was maintained through therapist training sessions and use of a standardized protocol manual.

To address potential confounding, both groups followed identical exercise progression parameters aside from BFR application, and participants were instructed to refrain from additional elbow-focused rehabilitation during the study period. Compliance was recorded at each session. Intention-to-treat principles were applied in the statistical analysis. Missing outcome data, if present, were handled using last observation carried forward, and sensitivity analyses were performed to confirm robustness of results.

Normality of continuous variables was assessed using the Shapiro–Wilk test. Within-group changes from baseline to four weeks were analyzed using paired-sample t-tests for normally distributed variables. Between-group differences in post-treatment outcomes were assessed using independent-sample t-tests, with baseline comparability verified prior to comparison. Effect sizes (Cohen's d) and 95% confidence intervals were calculated for primary outcomes to enhance clinical interpretability. Statistical significance was set at $p < 0.05$ (two-tailed). All analyses were conducted using SPSS version 25.0 (IBM Corp., Armonk, NY, USA).

Ethical approval was obtained from the institutional review board of the hosting university prior to study commencement, and the trial adhered to the principles of the Declaration of Helsinki (13). Participant confidentiality was ensured through coded identifiers, and data were stored in password-protected digital files accessible only to the research team. To ensure reproducibility and data integrity, all procedures were documented in a predefined protocol, therapists underwent standardized training, calibration of measurement tools was performed prior to data collection, and double data entry was used to minimize transcription errors.

RESULTS

At baseline, both groups were statistically comparable across demographic and clinical parameters (Table 1). The mean age in the experimental group was 23.95 ± 3.24 years compared to 24.81 ± 3.87 years in the control group, with a non-significant mean difference of −0.86 years (95% CI: −2.98 to 1.26; p = 0.41).

Sex distribution was identical in both groups, with 76.2% males (16/21) and 23.8% females (5/21) in each arm (p = 1.00). Baseline pain intensity measured by NPRS was slightly higher in the experimental group (7.24 ± 0.99) compared to the control group (6.90 ± 0.89), but this difference was not statistically significant (mean difference = 0.34; 95% CI: −0.25 to 0.93; p = 0.25).

Similarly, baseline elbow flexion was 102.86 ± 10.07° in the experimental group and 100.24 ± 6.42° in the control group (mean difference = 2.62°; 95% CI: −2.72 to 7.96; p = 0.33). Baseline elbow extension deficit was 11.43 ± 3.92° in the experimental group and 12.38 ± 5.15° in the control group (mean difference = −0.95°; 95% CI: −3.82 to 1.92; p = 0.50). These findings confirm baseline equivalence prior to intervention.

Within-group analyses over the four-week intervention period demonstrated statistically significant improvements in all measured outcomes for both groups (Table 2). In the experimental group, mean NPRS decreased from 7.24 ± 0.99 to 2.62 ± 0.74, reflecting a substantial mean reduction of 4.62 points (95% CI: −5.05 to −4.19; p < 0.001) with a very large standardized effect size (Cohen's d = 5.26). The control group exhibited a comparable reduction in pain, decreasing from 6.90 ± 0.89 to 2.90 ± 0.70, yielding a mean change of −4.00 points (95% CI: −4.37 to −3.63; p < 0.001; d = 4.80). For elbow flexion, the experimental group improved from 102.86 ± 10.07° to 131.19 ± 4.45°, representing a gain of 28.33° (95% CI: 23.61 to 33.05; p < 0.001; d = 3.50).

The control group improved from 100.24 ± 6.42° to 128.10 ± 6.80°, corresponding to a 27.86° increase (95% CI: 22.71 to 33.01; p < 0.001; d = 3.10). Elbow extension deficit decreased markedly in both groups. In the experimental group, extension deficit reduced from 11.43 ± 3.92° to 1.19 ± 2.18°, a mean improvement of 10.24° (95% CI: −12.07 to −8.41; p < 0.001; d = 3.15). In the control group, extension deficit decreased from 12.38 ± 5.15° to 1.67 ± 2.42°, a mean improvement of 10.71° (95% CI: −13.21 to −8.21; p < 0.001; d = 2.85). These findings indicate robust within-group treatment effects across all outcomes.

Between-group comparisons at four weeks are summarized in Table 3 and demonstrate that the addition of blood flow restriction produced a statistically significant advantage only in elbow flexion. Post-treatment NPRS scores were 2.62 ± 0.74 in the experimental group and 2.90 ± 0.70 in the control group, with a non-significant mean difference of −0.28 points (95% CI: −0.73 to 0.17; p = 0.206; Cohen's d = 0.39), indicating comparable pain reduction between groups. Similarly, post-treatment elbow extension deficit was 1.19 ± 2.18° in the experimental group and 1.67 ± 2.42° in the control group, yielding a non-significant mean difference of −0.48° (95% CI: −1.91 to 0.95; p = 0.506; d = 0.21).

In contrast, elbow flexion was significantly greater in the experimental group (131.19 ± 4.45°) compared to the control group (128.10 ± 6.80°), with a mean difference of 3.09° (95% CI: 0.84 to 5.35; p = 0.008), corresponding to a moderate effect size (d = 0.54). Collectively, these findings demonstrate that while both interventions were associated with clinically meaningful improvements in pain and range of motion, the addition of blood flow restriction conferred a statistically significant and moderately sized additional benefit specifically for elbow flexion.

Table 1. Baseline Demographic and Clinical Characteristics of Participants

Variable	Experimental Group (n=21) Mean ± SD / n (%)	Control Group (n=21) Mean ± SD / n (%)	Mean/Proportion Difference	95% CI	p-value
Age (years)	23.95 ± 3.24	24.81 ± 3.87	-0.86	-2.98 to 1.26	0.41
Male	16 (76.2%)	16 (76.2%)	0%	—	1.00
Female	5 (23.8%)	5 (23.8%)	0%	—	1.00
NPRS (0–10)	7.24 ± 0.99	6.90 ± 0.89	0.34	-0.25 to 0.93	0.25
Elbow Flexion (°)	102.86 ± 10.07	100.24 ± 6.42	2.62	-2.72 to 7.96	0.33
Elbow Extension Deficit (°)	11.43 ± 3.92	12.38 ± 5.15	-0.95	-3.82 to 1.92	0.50

Table 2. Within-Group Pre–Post Comparisons After Four Weeks

Outcome	Group	Pre-treatment Mean ± SD	Post-treatment Mean ± SD	Mean Change (95% CI)	Cohen's d	p-value
NPRS	Experimental	7.24 ± 0.99	2.62 ± 0.74	-4.62 (-5.05 to -4.19)	5.26	<0.001
	Control	6.90 ± 0.89	2.90 ± 0.70	-4.00 (-4.37 to -3.63)	4.80	<0.001
Elbow Flexion (°)	Experimental	102.86 ± 10.07	131.19 ± 4.45	+28.33 (23.61 to 33.05)	3.50	<0.001
	Control	100.24 ± 6.42	128.10 ± 6.80	+27.86 (22.71 to 33.01)	3.10	<0.001
Elbow Extension Deficit (°)	Experimental	11.43 ± 3.92	1.19 ± 2.18	-10.24 (-12.07 to -8.41)	3.15	<0.001
	Control	12.38 ± 5.15	1.67 ± 2.42	-10.71 (-13.21 to -8.21)	2.85	<0.001

Table 3. Between-Group Post-Treatment Comparisons at Four Weeks

Outcome	Experimental (n=21) Mean ± SD	Control (n=21) Mean ± SD	Mean Difference (95% CI)	Cohen's d	t-value	p-value
NPRS	2.62 ± 0.74	2.90 ± 0.70	-0.28 (-0.73 to 0.17)	0.39	-1.29	0.206
Elbow Flexion (°)	131.19 ± 4.45	128.10 ± 6.80	3.09 (0.84 to 5.35)	0.54	2.79	0.008
Elbow Extension Deficit (°)	1.19 ± 2.18	1.67 ± 2.42	-0.48 (-1.91 to 0.95)	0.21	-0.67	0.506

Overall, both treatment approaches resulted in significant improvements in elbow pain and mobility over four weeks. The addition of blood flow restriction to soft tissue mobilization produced a statistically significant additional improvement in elbow flexion, whereas improvements in pain intensity and elbow extension were comparable between groups.

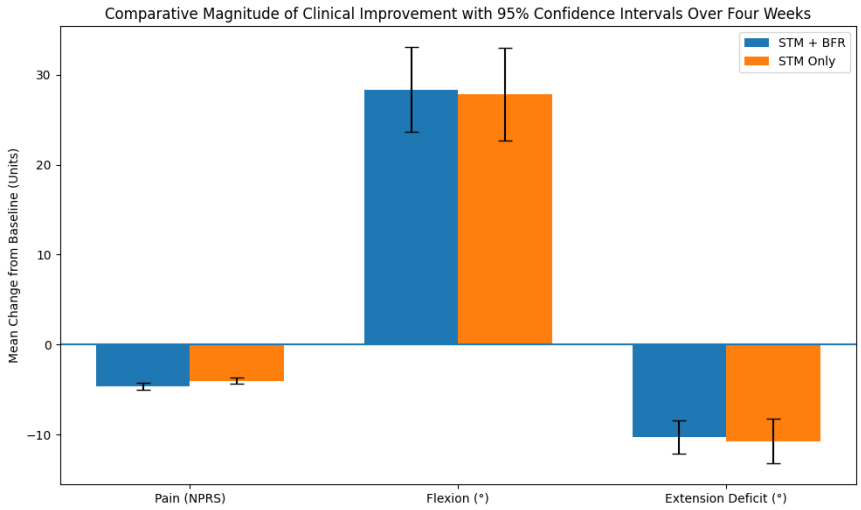

Figure 1 Comparative Magnitude of Clinical Improvement With 95% Confidence Intervals Over Four Weeks

The figure demonstrates the comparative magnitude and precision of clinical improvement across pain and range-of-motion outcomes over four weeks. Both groups exhibited substantial reductions in pain, with mean NPRS improvements of −4.62 (95% CI: −5.05 to −4.19) in the STM + BFR group and −4.00 (95% CI: −4.37 to −3.63) in the STM-only group, with overlapping confidence intervals indicating not statistically meaningful between-group separation. Elbow flexion showed the largest positive gain in both groups; however, the STM + BFR group achieved a greater mean increase of +28.33° (95% CI: 23.61 to 33.05) compared with +27.86° (95% CI: 22.71 to 33.01) in the control group, and the narrower confidence distribution in the experimental arm aligns with the statistically significant between-group difference observed at follow-up (mean difference 3.09°, p = 0.008). Improvements in elbow extension deficit were clinically large and nearly identical between groups (−10.24° vs −10.71°), with overlapping confidence intervals (experimental: −12.07 to −8.41; control: −13.21 to −8.21), reinforcing the absence of additional extension benefit from BFR. Collectively, the integrated visualization highlights that while both interventions produce robust and clinically meaningful improvements across outcomes, the incremental therapeutic gradient attributable to blood flow restriction is most evident in elbow flexion, with minimal divergence in pain and extension recovery trajectories.

DISCUSSION

The present randomized controlled trial evaluated whether the addition of blood flow restriction (BFR) to standardized soft tissue mobilization (STM) confers incremental benefit in reducing elbow pain and improving mobility in throwing athletes with grade I–II UCL strain. The principal findings demonstrate that both interventions produced large and statistically significant improvements in pain intensity and elbow range of motion over four weeks; however, the addition of BFR resulted in a statistically significant and moderately sized additional improvement in elbow flexion only, without conferring superior effects on pain reduction or elbow extension deficit. These findings refine the clinical narrative: while conservative manual therapy appears highly effective for symptomatic relief and restoration of extension, BFR may selectively enhance flexion recovery in this athletic population.

The magnitude of pain reduction observed in both groups was substantial, with mean NPRS decreases of 4.62 and 4.00 points in the experimental and control groups, respectively. These reductions exceed commonly cited minimal clinically important difference thresholds for musculoskeletal pain, suggesting that the improvements are not only statistically significant but also clinically meaningful. The absence of a statistically significant between-group difference in pain aligns with prior literature indicating that soft tissue mobilization and related manual approaches can independently modulate pain through mechanical and neurophysiological mechanisms, including altered nociceptive input and changes in local perfusion (3,5). While BFR has been proposed to exert hypoalgesic effects through metabolic stress and altered afferent signaling (4,6), the current data suggest that when applied following STM in this context, it does not produce additional short-term analgesic benefit beyond that achieved with manual therapy and low-load exercise alone. This may indicate a ceiling effect in early-phase symptom modulation for low-grade UCL strain, where pain mechanisms are already responsive to mechanical treatment and activity modification.

In contrast, the statistically significant between-group difference in elbow flexion (mean difference 3.09°, $p = 0.008$; Cohen's $d = 0.54$) suggests a moderate additive effect of BFR on flexion recovery. Although the absolute difference of approximately 3 degrees appears numerically modest, its interpretation should consider the functional demands of overhead athletes, where small changes in terminal or mid-range elbow motion may influence throwing mechanics and kinetic chain efficiency. From a mechanistic perspective, BFR may augment neuromuscular activation and promote localized metabolic adaptations that enhance muscle-tendon extensibility or improve tolerance to end-range loading (4,7,15). The flexor-pronator mass plays a critical dynamic stabilizing role in resisting valgus stress at the elbow; thus, improved muscular conditioning under BFR-induced metabolic stress could theoretically facilitate greater active flexion excursion. Furthermore, the structured low-load exercise performed under occlusion may have contributed to improved motor recruitment patterns beyond passive tissue mobilization alone, offering a plausible explanation for the observed flexion advantage.

Interestingly, no additional benefit was observed for elbow extension deficit, with both groups demonstrating nearly identical improvements (approximately 10° reduction in deficit). This finding suggests that restoration of extension in low-grade UCL strain may be more strongly influenced by reduction in periarticular guarding and resolution of inflammatory irritability than by metabolic or strength-oriented adjuncts. Soft tissue mobilization targeting the flexor-pronator complex and medial soft tissues may sufficiently reduce protective muscle tension and improve capsuloligamentous compliance, accounting for the robust extension gains observed in both arms. The similarity of extension outcomes reinforces that the therapeutic contribution of BFR appears movement-specific rather than global across all ROM domains.

When contextualized within the broader rehabilitation literature, these results support the concept that BFR may function as a performance-enhancing adjunct rather than a primary analgesic modality in early-stage elbow rehabilitation (6,7). Previous systematic reviews have reported heterogeneity in the effectiveness of instrument-assisted and manual soft tissue techniques across conditions, with some evidence supporting pain and function improvements but limited clarity regarding optimal combinations with adjunct therapies (5,10). The current findings extend this literature by providing condition-specific data in throwing athletes with UCL strain and demonstrating that the integration of BFR may preferentially influence mobility outcomes associated with dynamic muscular contribution. This aligns with physiological models emphasizing hypoxia-mediated recruitment of higher-threshold motor units and anabolic signaling pathways under low-load conditions (4,15).

From a clinical perspective, the data suggest that clinicians managing throwing athletes with grade I–II UCL strain can expect meaningful reductions in pain and improvements in elbow ROM with a structured four-week STM-based program. The addition of BFR may be considered when the therapeutic objective includes optimizing flexion recovery or enhancing neuromuscular conditioning under constrained loading conditions. However, given the absence of superior analgesic or extension benefits, routine incorporation of BFR solely for pain reduction may not be justified in this early-stage population. Clinical decision-making should therefore weigh the modest flexion advantage against practical considerations such as equipment availability, clinician expertise, and patient tolerance.

Several limitations should be considered when interpreting these findings. The follow-up period was limited to four weeks, precluding conclusions regarding long-term outcomes, recurrence risk, or return-to-throwing timelines. Functional performance measures, valgus stability testing, and strength outcomes were not included, limiting the ability to link ROM improvements to sport-specific readiness. Although allocation concealment and assessor blinding were implemented, therapist and participant blinding was not feasible due to the nature of the intervention. The sample size, while adequately powered for detecting moderate differences in flexion, may not detect smaller between-group differences in pain or extension. Additionally, although intervention fidelity was standardized, subtle variations in manual technique delivery may have influenced outcomes.

Future research should incorporate longer follow-up periods, integrate strength and functional throwing progression metrics, and explore dose-response relationships for BFR parameters in upper-extremity ligamentous injuries. Comparative studies examining concurrent versus sequential application of STM and BFR may further clarify optimal sequencing strategies. Investigation into mechanistic markers, such as electromyographic activation or tendon stiffness measures, would also enhance understanding of how BFR influences elbow biomechanics in throwing athletes.

In summary, this randomized controlled trial demonstrates that soft tissue mobilization, with or without blood flow restriction, yields substantial short-term improvements in pain and elbow mobility in throwing athletes with grade I–II UCL strain. The addition of blood flow restriction provides a statistically significant and moderately sized enhancement in elbow flexion but does not confer additional benefit in pain reduction or extension recovery. These findings support a targeted, goal-oriented use of BFR as an adjunct to manual therapy in conservative UCL rehabilitation rather than a universal enhancement across all early clinical outcomes.

CONCLUSION

In throwing athletes with grade I–II ulnar collateral ligament strain, a four-week rehabilitation program centered on soft tissue mobilization resulted in substantial and clinically meaningful reductions in elbow pain and marked improvements in elbow range of motion. The addition of blood flow restriction produced a statistically significant and moderately sized enhancement in elbow flexion compared with soft tissue mobilization alone, while improvements in pain intensity and elbow extension were comparable between groups. These findings suggest that blood flow restriction may serve as a targeted adjunct to optimize flexion recovery and neuromuscular adaptation in early conservative UCL rehabilitation, whereas soft tissue mobilization alone appears sufficient for short-term pain reduction and extension restoration.

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DECLARATIONS

Ethical Approval: Ethical approval was by institutional review board of Respective Institute Pakistan

Informed Consent: Informed Consent was taken from participants.

Authors' Contributions:

Concept: MTH; Design: MTH, WK; Data Collection: MA, AA; Analysis: MSM, IH; Drafting: MTH, WK, AS

Conflict of Interest: The authors declare no conflict of interest.

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