



The impact of blood flow restriction therapy on orthopaedic conditions of the upper extremity: a systematic review of randomized controlled trials

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Background: Blood flow restriction therapy (BFRT) has gained recognition in recent years as an adjunct to rehabilitation to maximize results for patients with poor strength and endurance. However, literature on the effects of BFRT for conditions afflicting the upper extremity is limited. The purpose of this study was to analyze the available literature regarding the role of BFRT in upper extremity conditions and evaluate its influence on functional and patient reported outcomes.

Methods: PubMed, Embase, and Cochrane Trials were searched in July 2024. Only randomized controlled trials (RCTs) with upper-extremity BFRT were included. Several variables were extracted, including number of patients per study, patient demographics, type of pathology, and functional outcomes. The risk of bias for each eligible RCT was evaluated using the Revised Cochrane Risk-of-Bias Tool for Randomized Trials. Standard descriptive statistics were used to report outcomes for all the included study findings. BFRT protocols were reviewed and presented in a narrative manner.

Results: The systematic literature search yielded 605 articles, of which four RCTs involving 133 patients met the inclusion criteria. The conditions evaluated included distal radius fractures, osteoarthritis of the hand, and lateral elbow tendinopathy. The evidence for all studies was deemed low risk of bias. Overall, patients who received BFRT demonstrated marginally greater strength, improved pain control, and improved patient-reported outcome measures (PROMs) when compared to a non-BFRT counterpart.

Conclusions: A comprehensive review of the literature examining BFRT as an adjunct treatment for upper extremity conditions was conducted. Patients treated with BFRT may experience greater strength, improved pain control, and improved PROMs when compared to a non-BFRT counterpart. Future, large-scale studies are necessary to further define the benefits of BFRT in orthopaedic conditions of the upper extremity.

Keywords: Blood flow restriction therapy (BFRT); upper extremity; distal radius fracture; osteoarthritis (OA); lateral epicondylitis

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Introduction

Upper extremity injuries are highly prevalent and among the most common orthopaedic conditions treated (1,2). Physical therapy and exercise are critical components of rehabilitation for upper extremity injuries and degenerative processes as early rehabilitation may accelerate tissue healing, reduce inflammation and pain, and aid in preserving the surgical repair (3-5). However, some patients, especially those in the early postoperative recovery period, have significant load restrictions and cannot tolerate early aggressive motion or resistance therapy. Others may present with disuse atrophy due to underlying pain, leading to poor strength and endurance entering therapy (6-8). Thus, alternative recovery measures have been introduced and explored, including blood flow restriction therapy (BFRT) which promotes hypertrophy while decreasing muscle load requirements (9-13).

BFRT was first used in the context of physical therapy and has gained recognition recently as a supplemental modality for patients with poor strength, endurance, and chronic inflammation (14,15). BFRT utilizes a cuff to reduce arterial and venous blood flow to and from skeletal muscle. It is proposed that BFRT amplifies hypoxic conditions in the muscle, which enhances the natural changes in cellular metabolism and exercise stress response, including increasing muscle strength and hypertrophy (16,17). Furthermore, low oxygen tension from induced ischemia can induce angiogenesis, reactive oxygen species

production, mitochondrial biogenesis, and glucose transporter 4 expression, all which have been shown to increase muscle mass and strength (18). Studies examining the effects aging has on skeletal muscle have shown that BFRT with low-intensity resistance training can prevent muscle weakness and atrophy after disuse, which is a critical problem post-surgical patients face after long periods of immobilization (19-22).

Despite the clinical promise of BFRT, there is a paucity of literature examining the use of BFRT in injuries and degenerative conditions affecting the upper extremity. Prior systematic reviews evaluated BFRT in healthy athletes instead, noting its improvements in muscle and overall sports performance (23). Evaluating if BFRT could enhance more traditional recovery protocols for ill patients is essential to determine whether or not this therapy adjunct can holistically improve patient outcomes and results. Furthermore, BFRT has been used to treat lower extremity conditions, however in order to minimize the considerable heterogeneity in study design, intervention protocols, and outcome measures when evaluating BFRT, our study was focused on solely upper extremity conditions.

The purpose of this systematic review of randomized controlled trials (RCTs) was to (I) analyze the available literature regarding the role of BFRT in upper extremity conditions and (II) evaluate its influence on functional and patient reported outcomes. We present this article in accordance with the PRISMA reporting checklist (available at <https://aoj.amegroups.com/article/view/10.21037/aoj-25-31/rc>) (24).

Highlight box

Key findings

- Blood flow restriction therapy (BFRT) uses in upper extremity conditions resulted in superior strength gains, improved pain control, and improved patient reported outcomes when compared to exercise alone.

What is known and what is new?

- BFRT has gained recognition, primarily in lower extremity conditions, as a supplemental modality to low-intensity resistance training to aid in building muscle bulk and strength.
- In various conditions of the upper extremity, BFRT appears to enhance strength while reducing pain and improving patient-reported outcome measures when compared to a non-BFRT cohort.

What is the implication, and what should change now?

- BFRT is a safe and promising adjunct to traditional therapy with particular promise in the post-operative setting where weight-bearing restrictions and disuse atrophy may hinder optimal progress.

Methods

A protocol for this review was not previously registered in the international systematic review registry (PROSPERO). Other upper extremity protocols have been registered in PROSPERO (25), however, these vary in their protocol as it solely is reviewing shoulder pathology (rotator cuff, shoulder girdle, tendonitis) while this study evaluates additional upper extremity pathology, including fractures, elbow pathology (i.e., lateral epicondylitis), and osteoarthritis (OA).

Eligibility criteria

Studies were considered for inclusion based on the following Population-Intervention-Comparator-Outcomes-Study Design (PICOS) framework (26): (P) adults with upper-

extremity musculoskeletal conditions; (I) BFRT used as an adjunct to traditional therapy; (C) traditional therapy alone or alternative rehabilitation protocols without BFRT; (O) studies reporting functional, strength, or patient-reported outcomes related to upper-extremity rehabilitation, (S) RCTs only.

This review excluded studies if they did not meet the PICOS criteria, if they were not in the English language, or did not have full-texts with full datasets available.

Search strategy

An electronic literature search was performed using PubMed, Embase, and Cochrane Trials from database inception to July 2024. Our search strategy was developed and modified with the assistance of the Northwestern University library and is in keeping with similar literature on the topic (25). The Boolean query involved a combination of the following medical subject headings and related synonyms: (“Upper Extremity”[Mesh] OR “Bones of Upper Extremity”[Mesh] OR hand[tiab] OR hands[tiab] OR arm[tiab] OR arms[tiab] OR wrist*[tiab] OR finger*[tiab] OR elbow*[tiab] OR axilla*[tiab] OR forearm*[tiab] OR thumb*[tiab] OR metacarpus[tiab] OR shoulder*[tiab] OR “upper extremity”[tiab] OR upper limb*[tiab]) AND (“Blood Flow Restriction Therapy”[Mesh] OR “Blood flow restriction”[tiab] OR BFRT[tiab] OR “kaatsu”[tiab] OR BFR Therap*[tiab] OR “vascular occlusion”[tiab] OR “BFR Train”[tiab]). Reference lists for included studies were also reviewed for studies that may be eligible for inclusion.

Study selection

Relevant title and abstract screening were conducted independently by two of the coauthors (D.H. and L.N.) to determine if the study met inclusion criteria. Duplicate studies were removed. For any study whose inclusion eligibility was questionable, articles were promoted to the full-text screening phase. Full-text articles were then screened for inclusion criteria. If a conflict occurred at this phase, a senior author (U.S.) reviewed the study for inclusion.

Data extraction

This study collected data from RCTs to compare the outcomes following recovery protocols with and without BFRT. Several variables were extracted, including number

of patients per study, patient demographics, type of pathology, and functional outcomes.

Assessment of risk of bias in eligible studies

The risk of bias for each eligible RCT was evaluated using the Revised Cochrane Risk-of-Bias Tool for Randomized Trials (RoB 2.0) (27). This framework assesses the quality of randomized studies based on five domains: bias arising from the randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result. Each domain is rated as low risk, some concerns, or high risk of bias, leading to an overall risk of bias judgment for each study. This structured approach ensures a comprehensive and standardized evaluation of bias in the included trials.

Analysis

Given the heterogenous nature of the sample size, type of injury, and outcomes of interest, standard descriptive statistics were used to report outcomes for all the included study findings. BFRT protocols were reviewed and are presented in a narrative manner.

Results

Literature search

A PRISMA flow diagram (*Figure 1*) depicts the results of the search strategy and criteria for inclusion. Our literature search generated 605 potential studies for screening. After removal of duplicates, 414 studies were left for review. Title and abstract screening eliminated 401 studies, leaving 13 available for full-text review. Upon completion of full-text review, four studies were deemed eligible and included for further analysis. Review of the reference lists for these four studies did not identify additional studies meeting the inclusion criteria.

Study characteristics and outcomes

Four studies were eligible for inclusion, comprising 133 total patients between BFRT and non-BFRT cohorts. An overview of the studies, their characteristics, and outcome measures are summarized in *Table 1*. The pathology treated included distal radius fractures (28,29), lateral elbow tendinopathy (30), and OA of the hand (31). One study involved operative intervention for the injury of

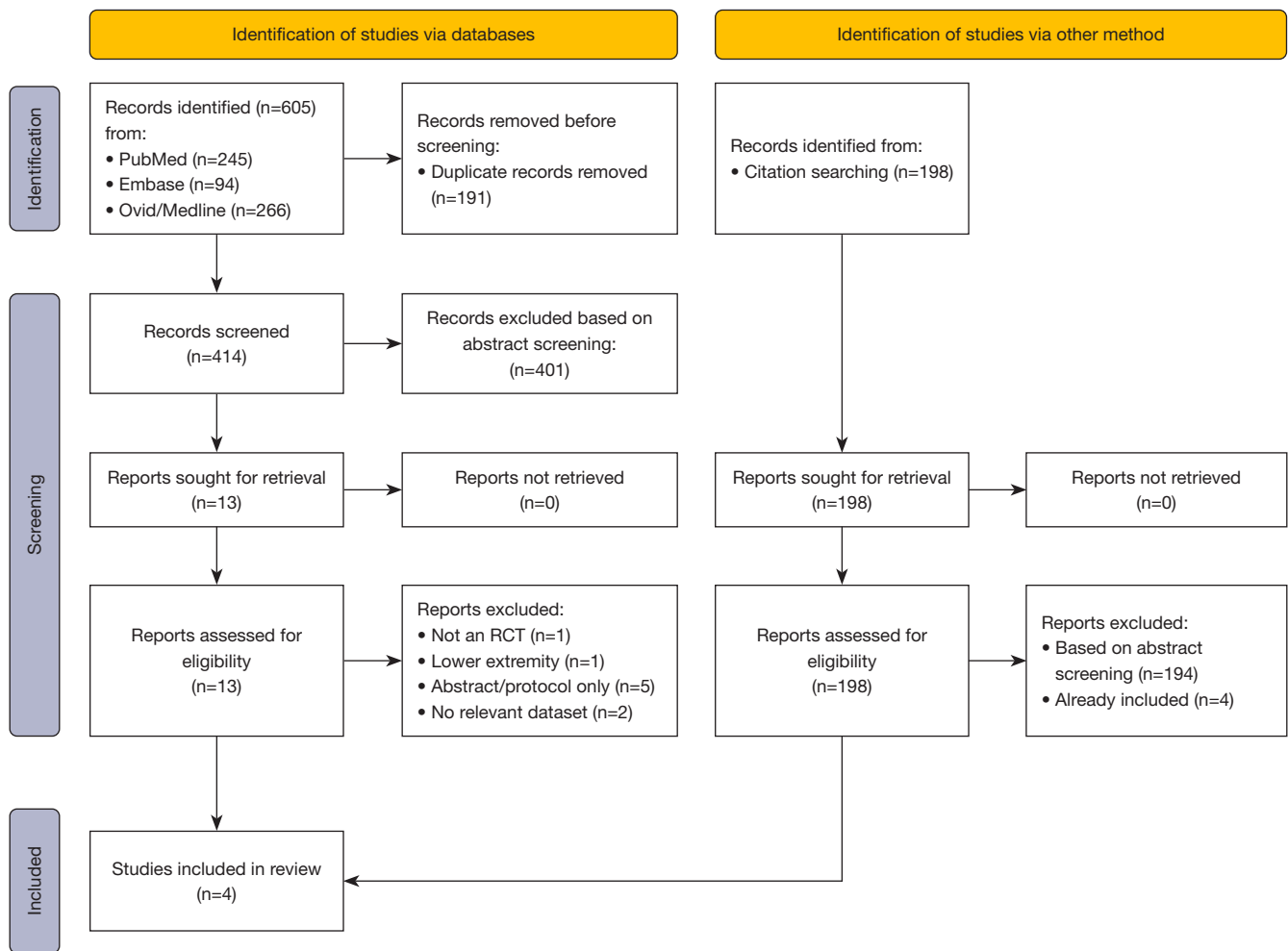


Figure 1 PRISMA flow diagram depicting study selection for inclusion. RCT, randomized controlled trial.

interest (29), while the remaining three were treated nonoperatively (28,30,31). The BFRT training program varied by study (*Table 1*). Reported outcomes were grouped into the following categories: range of motion, strength, pain, and patient-reported outcome measures (PROMs). These categories were evaluated for differences between BFRT and non-BFRT cohorts.

Range of motion

Two studies reported range of motion outcomes before and after a dedicated training program, both studies focusing on distal radius fractures (28,29). Measurements analyzed included by Cancio *et al.* included flexion/extension and pronosupination arc of motion, while Fan *et al.* examined flexion, extension, pronation, supination, radial deviation,

and ulnar deviation (28,29). There was no significant difference between all pre- and post-training measurements for both studies when comparing BFRT and non-BFRT study participants (*Table 2*).

Strength

All four studies reported a measurement of strength. Studies focused on the hand and wrist reported on a combination of grip, pinch (3-point, lateral), wrist flexion, and wrist extension strength (28,29,31). Karanasios *et al.* reported elbow flexor and extensor strength in addition to grip strength (30). Two of four studies identified improved strength for varied measurements in the BFRT group when compared to the non-BFRT group (29,30). The remaining two of four studies reported no differences in strength

Table 1 Study characteristics for all eligible studies

First author	Journal	Year	Condition	Sample size, total [BFR], n	Age (years), mean	Female (%)	BFR intervention	Length of BFR protocol	Control intervention	Outcomes measured
Cancio (28)	<i>Journal of Wrist Surgery</i>	2019	Distal radius fracture	13 [6]	46	53.8	50% occlusion pressure with Defli PTS II portable tourniquet on upper brachium with four sets (30-15-15-15 repetitions) and 30-second rest time per set	Weeks: 8. Sessions per week: 2-3	A standardized hand therapy rehabilitation protocol alone	Range of motion, strength, pain, PROMs
Fan (29)	<i>Annals of Medicine</i>	2023	Distal radius fracture	35 [17]	46	51.4	40-80% occlusion pressure with a 5-cm, B-Strong America bandage on upper third of the arm with four sets (30-15-15-15 repetitions) and 30-second breaks per set	Weeks: 4. Sessions per week: 5	Regular therapy	Range of motion, strength, pain
Karanasios (30)	<i>Journal of Orthopaedic and Sports Physical Therapy</i>	2022	Lateral elbow tendinopathy	46 [23]	45.2	47.8	30-50% occlusion pressure with a Mad-Up Pro tourniquet on proximal site of arm with four sets (30-15-15-15 repetitions) and 30-second break per set	Weeks: 6. Sessions per week: 2	A sham-BFR treatment, advice, and a home-exercise program	Strength, pain, PROMs
Magni (31)	<i>Musculoskeletal Science and Practice</i>	2022	Osteoarthritis of the hand	39 [19]	67.9	84	50% occlusion pressure with a 13.5-cm adult blood pressure cuff proximal to the hand with 2-4 sets that increased by week (30 repetitions for set one, then 15 thereafter) with 30-second break per set	Weeks: 6. Sessions per week: 3	Advice only	Strength, pain, PROMs

BFR, blood flow restriction; BFRt, blood flow restriction therapy; PROMs, patient-reported outcome measures; PTS, personalized tourniquet system.

Table 2 Range of motion outcomes and conclusions for included studies

Table 2 Range of motion outcome and considerations for included studies							
First author	Joint	Outcome measure	Measurement, mean $\pm$ SD (95% CI)				Takeaway
			BFRT		Control		
			Pre	Post	Pre	Post	
Cancio [†] (28)	Wrist	Flexion/extension	71.7°	117.5°	72.9°	123.6°	No difference between groups
		Pronosupination	136.7°	174.2°	125.7°	170.0°	
Fan (29)	Wrist	Flexion	51.41° $\pm$ 12.41° (44.93°, 57.19°)	14.41° $\pm$ 6.42° (11.29°, 17.59°)	51.17° $\pm$ 16.63° (42.65°, 59.29°)	15.06° $\pm$ 6.92° (11.82°, 18.27°)	No difference between groups
		Extension	53.53° $\pm$ 12.03° (47.73°, 58.88°)	14.12° $\pm$ 6.11° (11.15°, 16.82°)	52.39° $\pm$ 13.78° (45.56°, 58.55°)	14.89° $\pm$ 6.30° (11.90°, 17.85°)	
		Pronation	31.12° $\pm$ 14.88° (24.28°, 38.30°)	4.82° $\pm$ 5.58° (2.37°, 7.45°)	26.28° $\pm$ 19.19° (17.24°, 35.38°)	6.11° $\pm$ 5.87° (3.67°, 9.00°)	
		Supination	44.76° $\pm$ 14.15° (37.90°, 51.47°)	10.59° $\pm$ 6.73° (7.77°, 13.95°)	47.17° $\pm$ 12.55° (41.72°, 52.59°)	14.56° $\pm$ 6.94° (11.50°, 17.67°)	
		Radial deviation	14.94° $\pm$ 3.21° (13.50°, 16.45°)	4.47° $\pm$ 2.94° (3.06°, 5.89°)	26.28° $\pm$ 19.19° (17.24°, 35.38°)	5.67° $\pm$ 4.02° (3.83°, 7.47°)	
		Ulnar deviation	23.00° $\pm$ 7.53° (19.87°, 26.50°)	7.94° $\pm$ 3.65° (6.20°, 9.58°)	24.06° $\pm$ 8.16° (20.24°, 27.65°)	7.94° $\pm$ 3.00° (6.58°, 9.29°)	

[†], no SD or 95% CI was reported. BFRT, blood flow restriction therapy; CI, confidence interval; SD, standard deviation.

between group (*Table 3*) (28,31). Overall for strength, the pooled study results still favored BFRT but the difference was less pronounced (28-30).

Pain

All included studies reported an outcome on pain control before and after the training program. Pain levels were measured by visual analogue scale for all included studies. All four studies concluded that the BFRT group achieved a significant reduction in pain after the training program when compared to a non-BFRT cohort (28-31). A summary of pain control amongst the four studies is included in *Table 4*.

PROMs

Three studies reported one or more PROMs both before and after the training program, including Disabilities of the Arm, Shoulder, Hand (DASH), Patient-Rated Wrist Evaluation (PRWE), Patient-Rated Tennis Elbow Evaluation (PRTEE), Functional Index of Hand Osteoarthritis (FIHOA), Global Assessment of Disease (GAD), and Patient Specific Functional Scale (PSFS)

scoring systems (28,30,31). Two studies found a statistically significant improvement in the BFRT group when compared to the non-BFRT group (28,30). Specifically, Cancio *et al.* demonstrated that patients in the BFRT group displayed improved PWRE scores and greater reduction in PRWE scores compared to the control group after 8 weeks of BFRT (28). Similarly, Karanasios *et al.* demonstrated that patients undergoing BFRT had improved PRTEE at 6- and 12-week follow-up compared to those who underwent the sham intervention (30). Another study found improvement in PROMs for both BFRT and non-BFRT groups for DASH, FIHOA, GAD and PSFS with no statistically significant difference between groups (*Table 5*) (31). For PROMs, the pooled study results favored BFRT but the difference was less pronounced (28-30).

Study quality

The eligible studies were assessed for study quality using the Cochrane Risk of Bias Tool (27). All four studies were deemed to be low-risk for bias given that there was randomization, maintained intervention protocols, limited missing outcome data, and standardized measurement of outcomes (*Figure 2*).

Table 3 Strength outcomes and conclusions for included studies

First author	Joint	Outcome measure	Measurement, mean ± SD (95% CI)				Takeaway
			BFRT		Control		
			Pre	Post	Pre	Post	
Cancio [†] (28)	Wrist	Grip	24.2	56.2	26.9	55.1	No difference between groups
		3-point pinch	7.3	14.3	7.6	12.3	
		Lateral pinch	12.8	17	11.1	16.6	
Fan [‡] (29)	Wrist	Flexion	0.30±0.11 (0.25, 0.35)	0.70±0.06 (0.67, 0.73)	0.28±0.11 (0.25, 0.32)	0.52±0.08 (0.48, 0.56)	Improved flexion and extension strength in BFR group
		Extension	0.26±0.08 (0.22, 0.29)	0.72±0.08 (0.68, 0.76)	0.25±0.10 (0.21, 0.30)	0.52±0.05 (0.50, 0.55)	
		Grip	0.19±0.08 (0.16, 0.23)	0.62±0.07 (0.59, 0.65)	0.21±0.12 (0.16, 0.27)	0.62±0.07 (0.58, 0.65)	
		Pinch	0.29±0.09 (0.25, 0.33)	0.67±0.08 (0.63, 0.70)	0.28±0.12 (0.23, 0.33)	0.64±0.08 (0.60, 0.67)	
Karanasios [‡] (30)	Elbow/ wrist	Flexor	0.97±0.17 (0.90, 1.05)	1.07±0.11 (1.05, 1.15)	0.93±0.23 (0.85, 1.05)	0.92±0.17 (0.84, 1.0)	Improved flexor strength in BFR group. Improved pain-free grip strength in BFR group at 62 weeks (not at 12 weeks)
		Extensor	0.92±0.24 (0.82, 1.03)	1.02±0.23 (0.91, 1.12)	0.97±0.25 (0.86, 1.08)	1.01±0.24 (0.89, 1.11)	
		Pain free grip	0.71±0.2 (0.61, 0.81)	0.94±0.2 (0.84, 1.04)	0.75±0.2 (0.65, 0.85)	0.80±0.2 (0.70, 0.91)	
Magni [§] (31)	Hand	Grip	23.0±9.9	2.2 (−0.3, 4.7)	22.0±8.0	0.4 (−1.1, 1.9)	No difference between groups

[†], measured in kilograms, no SD or 95% CI was reported; [‡], measured as ratio compared to unaffected side; [§], pre scores are represented with mean $\pm$ SD, post scores are reported as the change from baseline and are represented with mean (95% CI). BFR, blood flow restriction; BFRT, blood flow restriction therapy; CI, confidence interval; SD, standard deviation.

Table 4 Pain outcomes and conclusions for included studies

First author	Joint	Outcome measure	Measurement, mean ± SD (95% CI)				Takeaway
			BFRT		Control		
			Pre	Post	Pre	Post	
Cancio [†] (28)	Wrist	Rest VAS	3	0.2	1.3	0.3	Greater reduction in activity-related pain for BFR group
		Active VAS	5.5	1.5	4.4	2.3	
Fan (29)	Wrist	VAS	3.76±0.56 (3.50, 4.00)	0.06±0.24 (<0.01, 0.19)	3.72±0.75 (3.38, 4.05)	1.28±0.67 (0.94, 1.59)	Greater reduction in pain for BFR group
Karanasios (30)	Elbow	Most severe pain	7.47±2.2 (6.5, 8.4)	1.73±2.1 (0.78, 2.68)	6.64±2.1 (5.71, 7.5)	3.27±2.1 (2.3, 4.24)	Greater reduction in pain for BFR group
Magni [†] (31)	Hand	Average pain	4.1±2.1	2.3 (1.5, 3.1)	4.0±1.8	−0.3 (−1.1, 0.6)	Greater reduction in pain for BFR group

[†], no SD or 95% CI was reported; [‡], pre scores are represented with mean $\pm$ SD, post scores are reported as the change from baseline and are represented with mean (95% CI). BFR, blood flow restriction; BFRT, blood flow restriction therapy; CI, confidence interval; SD, standard deviation; VAS, visual analog score.

Table 5 Patient-reported outcome measures and conclusions for included studies

First author	Joint	Outcome measure	Measurement, mean ± SD (95% CI)				Takeaway
			BFRT		Control		
			Pre	Post	Pre	Post	
Cancio [†] (28)	Wrist	DASH	51.3	8.8	44.1	20.1	Improvement in PRWE scores for BFR group
		PRWE	66.8	8.9	47.8	17.0	
Karanasios (30)	Elbow	PRTEE	38.74±13.2 (33.13, 44.55)	5.01±13.2 (0.79, 10.81)	36.99±12.25 (31.29, 41.87)	20.24±13 (14.31, 26.18)	Improvement in PRTEE scores for BFR group
Magni [‡] (31)	Hand	DASH	26.5±19.4	8.0 (0.4, 15.5)	27.4±14.0	1.0 (−5.0, 7.0)	No difference between groups for all outcomes measured
		FIHOA	25.0±20.0	5.0 (0.1, 9)	28.0±18.0	0.2 (−5, 5)	
		GAD	3.4±2.2	2.7 (1.7, 3.6)	3.1±1.9	−0.8 (−1.8, 0.2)	
		PSFS	5.6±2.4	1.1 (−0.1, 2.4)	6.3±2.1	1.0 (−0.04, 2)	

[†], no SD or 95% CI was reported; [‡], pre scores are represented with mean $\pm$ SD, post scores are reported as the change from baseline and are represented with mean (95% CI). BFR, blood flow restriction; BFRT, blood flow restriction therapy; CI, confidence interval; DASH, Disabilities of the Arm, Shoulder, Hand; FIHOA, Functional Index of Hand Osteoarthritis; GAD, Global Assessment of Disease; PRTEE, Patient-Rated Tennis Elbow Evaluation; PRWE, Patient-Rated Wrist Evaluation; PSFS, Patient Specific Functional Scale; SD, standard deviation.

Complications

There were no complications reported amongst BFRT and non-BFRT participants among the eligible studies (28-31).

Discussion

The present study is an all-encompassing review of the available literature on BFRT as a treatment adjunct for upper extremity injuries and degenerative conditions. In this systematic review, the predominant benefits of BFRT came in the domains of pain control, strength, and PROMs. This was most pronounced for pain control where all studies favored the BFRT cohorts with significant improvement in pain scores when compared to a non-BFRT cohort (28-31). For PROMs and strength, the pooled study results still favored BFRT but the difference was less pronounced (28-30). Of the two studies that reported on range of motion outcomes, no difference was identified between BFRT and non-BFRT groups (28,29). No studies that met inclusion criteria favored the non-BFRT cohort for any outcome measured at all time points. Importantly, no complications were reported amongst all studies, which is in keeping with previous literature suggesting that BFRT is

safe to undergo with minimal risk of harm (32,33).

Our findings are in keeping with several studies in the past decade that have examined BFRT as supplemental treatment in orthopaedic injuries and its subsequent effect on outcomes (23,34-39). Centner *et al.* conducted a systematic review and meta-analysis on the effects of BFRT as a supplement to resistance training and walking in older participants (age >50 years), concluding that the addition of BFRT elicited greater improvement in strength in this population (35). More recently, a 2021 systematic review examined the effects of strength and pain control in patients with various knee ailments, including OA, rheumatoid arthritis, patellofemoral pain, and anterior cruciate ligament tear. Their team found that low-resistance BFRT resulted in increased muscle strength and reduced pain scores when compared to conventional therapy (34).

There have been multiple advances in recent years within the field of upper extremity rehabilitation and treatment, including fracture care, athletic injuries, and degenerative conditions (40-51). BFRT is amongst the most rapidly evolving treatment modality (52). The first description of BFRT came in the 1960s and while it was not widely employed in medicine for much of the 20th century, the field has seen rapid evolution over the past

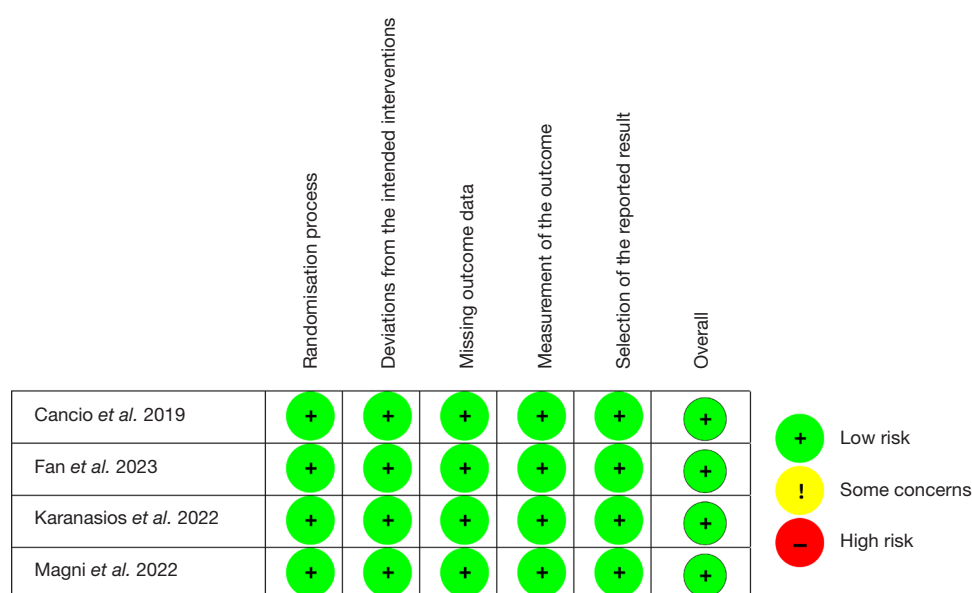


Figure 2 Risk of bias summary using the Cochrane Risk of Bias Tool.

two decades (53). Much of the research into BFRT relates to the added benefit for muscle bulk and strength (54). The current literature on the use of BFRT as an adjunct to standard treatment protocols for fractures, overuse injuries, and other orthopaedic pathology is scarce, but gaining popularity. As the population continues to age with a concomitant rise in degenerative conditions, a desire to optimize both nonoperative and operative protocols for common orthopaedic complaints (55).

The precise mechanisms for how BFRT reduces pain and improves strength is not well known, though hypotheses and potential mechanisms have been proposed (56-58). With regards to pain control, one leading theory is the activation of the endogenous opioid system. Low-load resistance training with BFRT has been shown to increase beta-endorphin production, which is known to produce an analgesic effect by binding to opioid receptors (36). Other proposed theories include the recruitment of high threshold motor units, adaptations in the cardiovascular system, and conditioned pain modulation (36). The impact of BFRT on improved strength is thought to originate with the induced hypoxic environment, triggering a metabolic cascade that results in protein production, gene regulation, and recruitment of muscle fibers. Taken together, these effects promote greater strength and endurance (38,59-63).

There are several limitations to this study that should be acknowledged. For several outcomes that were measured,

the superiority of BFRT was marginal and while it may reach statistical significance, the clinical significance remains uncertain. This, again, highlights the need for additional studies to further define the role of BFRT in rehabilitation and therapy protocols. Additionally, while this systematic review was an all-encompassing review of the available literature, our pooled total of 133 patients is a relatively small sample size. Future studies with more patients would strengthen the results and conclusions drawn from the present study. Perhaps the greatest limitation to this study is the considerable heterogeneity in study design, intervention protocols, and outcome measures. Due to the use of different outcome scoring among our studies, meta-analysis and heterogeneity analysis was not deemed appropriate. Consequently, findings must be interpreted with caution. As has been discussed, the literature on BFRT as a treatment adjunct in orthopaedic conditions is sparse, especially in the upper extremity. The strength of our study being all-encompassing carries the limitation of analyzing a diverse group of conditions and BFRT protocols. Pathology-specific BFRT studies with standardized outcome measures and recovery protocols are needed in the future to elucidate the benefits more effectively.

Conclusions

This study is a comprehensive review of the literature

examining BFRT as an adjunct treatment for upper extremity conditions. Although the literature remains sparse on the topic, data from various level-I studies suggest that patients treated with BFRT may experience greater strength, improved pain control, and improved PROMs compared to a non-BFRT counterpart in the treatment of injuries and degenerative conditions of the upper extremity. Specifically, BFRT may be used to improve post injury strength and patient reported outcomes in distal radius fractures and lateral elbow tendinopathy. BFRT may also be used to improve post injury pain in these conditions as well as in patients with hand OA. Future large-scale studies with standardized outcome measures and recovery protocols are necessary to further define the benefits and/or drawbacks of BFRT in orthopaedic conditions of the upper extremity.

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None.

Footnote

Reporting Checklist: The authors have completed the PRISMA reporting checklist. Available at <https://aoj.amegroups.com/article/view/10.21037/aoj-25-31/rc>

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