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Original research papers

EFFECTS OF BLOOD FLOW RESTRICTED RESISTANCE TRAINING ON PEAK UPPER BODY STRENGTH IN YOUNG MALE POPULATION

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Abstract

Introduction. Various strength training methods exist, with Blood Flow Restricted Resistance Training (BFRRT) emerging as a novel approach. This study aimed to compare BFRRT effectiveness against traditional resistance training for improving upper body strength in young males. ***Material and Methods.*** Sixty male participants (18-26 years) were assigned to the experimental group or the control group that received BFRRT or conventional resistance training respectively (n = 30 each). Both groups completed four weeks of bench press training (three sessions weekly) with the BFRRT group applying cuff pressures at 40-80% of arterial occlusion pressure. Upper body strength was assessed using 1-repetition maximum bench press testing before and after 4 weeks of intervention. Data were analysed using GraphPad Prism (version 9.5.1). Paired sample t-test was used to analyse within-group data and independent-samples t-test was used to analyse between-group differences. ***Results.*** The BFRRT group demonstrated strength increases from 80.33 ± 8.19 kg to 89.50 ± 8.23 kg (Δ = 9.17 kg; $p < 0.05$). The control group improved from 81.50 ± 9.11 kg to 87.67 ± 8.78 kg (Δ = 6.17 kg; $p < 0.05$). Although within-group gains were significant for both protocols, between-group comparison did not reach statistical significance ($p > 0.05$). ***Conclusions.*** Both training methods enhanced upper body strength effectively, with BFRRT demonstrating greater improvement potential. BFRRT integration into resistance programs may optimize strength development in young adults.

Keywords: blood flow restriction, resistance exercise, strength training, bench press, young adults, muscle strength

Introduction

People have always strived to become stronger, and athletes as well as fitness enthusiasts are continually in search of innovative methods to push the boundaries of their physical capabilities. Traditionally, it has been believed that to achieve muscle growth and strength, individuals need to lift weights that are about 70% of their 1 Repetition Maximum (1RM) [1]. This level of intensity is thought to be crucial for promoting muscle hypertrophy and strength improvements. Recent studies have shown that training with lighter weights to the point of failure can lead to muscle hypertrophy similar to that observed with heavier weights after 6 to 8 weeks of working out three times a week [2, 3]. However, when it comes to building strength, heavy-load training still comes out on top. Comparisons suggest that while light-load training can boost muscle size and strength, the gains are not quite as substantial as those from lifting heavier weights [2]. Among the plethora of contemporary training techniques, Blood Flow Restricted (BFR) resistance training has surfaced as a revolutionary approach, particularly for enhancing body strength by using lighter loads in comparison to conventional heavy load training.

BFR training, also known as occlusion training, involves the strategic restriction of blood flow to specific muscles during exercise. By using specialized cuffs or bands to partially restrict venous return while allowing arterial inflow, BFR training creates a unique physiological environment [4]. This environment amplifies the muscle's response to relatively low-intensity exercises, leading to significant gains in strength and hypertrophy. The technique not only minimizes the risk of injury associated with high-intensity workouts but also accelerates recovery, making it an invaluable tool for both rehabilitation and performance enhancement [5]. The efficacy of BFR training lies in its ability to elicit a high level of muscle activation while using much lighter weights than traditional strength training. This is particularly beneficial for individuals who may be recovering from injuries or those who are unable to lift heavy loads due to medical conditions. By creating a metabolic stress environment, BFR training promotes muscle hypertrophy and strength gains, even with low-load exercises. This innovative approach challenges the conventional belief that high-intensity resistance training is the only path to significant muscle growth [5]. Furthermore, BFR training has shown promise in improving cardiovascular health, increasing muscle endurance, and enhancing overall athletic performance [4]. Its adaptability makes it suitable for various populations, from elite athletes seeking to break performance plateaus to older adults aiming to maintain muscle mass and functional strength. The integration of BFR training into regular workout routines can offer a strategic advantage, promoting more efficient and effective strength development [6].

While BFR training is recognized for performance improvements, existing literature focuses on Western or East Asian populations and lower-limb adaptations. A critical gap to isolate the specific physiological advantage of BFR on upper-body compound movements (such as the bench press), specifically against volume-matched, low-intensity conventional training remains unexplored. Standard low-load training often yields suboptimal strength gains, and high-load protocols carry injury risks. This study addresses the question of whether integrating individualized arterial occlusion pressures (AOP) into a low-

-load bench press regimen significantly enhances peak strength compared to volume-matched conventional training. Uniquely, it can help to validate the BFR protocols in young Indian males, bridging the gap between general BFR efficacy claims and population-specific applicability for regional rehabilitation and performance standards.

Material and Methods

The current study followed a quasi-experimental design approved by Institutional Ethics Committee (Ref. No. SU/SMS&R/76-A/2022/238) and it was undertaken in compliance with the Helsinki Declaration. Before enrolment in the study, every participant signed a consent form. All possible risk factors were explained, and participants were instructed to inform the investigator right away if they experienced any problems. A certified BFR practitioner was always present during the study interventions and assessments.

Participants

A total of 60 male participants were recruited for the current study and randomly assigned to the experimental and control groups using the odd-even method (n = 30 in each group). All participants were aged between 18 and 26 years, had prior experience with bench press resistance training within the past year, but had not trained the exercise during the preceding month. Individuals with any acute or chronic trauma in the past 3 months, as well as those with any cardiovascular, musculoskeletal and neurological conditions were excluded from the study [5, 7].

Procedure

Proper clinical screening for risk assessment was done using a risk assessment tool [8]. The equipment used for intervention included BFR cuffs (5 cm in width), bench press setup, barbell (20 kg), weight plates, portable ultrasonic vascular doppler. The maximal strength generation analysis for upper body was done using 1 repetition maximum (1RM) bench press test [9]. Prior to maximal testing, each participant performed a general warm-up consisting of light cardiovascular activity to elevate core temperature, followed by dynamic upper-body mobility drills. The specific warm-up commenced with a set of 5-10 repetitions at self-selected light resistance (approximately 40-50% of the participant's estimated 1RM). After a one-minute rest interval, a second warm-up set of 3-5 repetitions was performed at a moderate load (approximately 60-80% of estimated 1RM) to prepare the neuromuscular system for the exercise without inducing fatigue. Following the specific warm-up, participants were instructed to perform a single repetition with proper technique i.e. lowering the barbell in a controlled manner to lightly touch the mid-sternum and then extending the elbows fully to return the bar to the starting position. The first 1RM attempt was set at approximately 90-95% of the estimated maximum. If the lift was successful with proper form, a rest period of 2-4 minutes was provided to ensure full phosphocreatine resynthesis [9]. The load was then increased by 2.5-5.0 kg (5-10 lbs) depending on the participant's perceived exertion and bar velocity. If an attempt failed, the load was decreased by 2.5-5.0 kg, and a final attempt was made after a 4-minute rest. After the determination of 1RM capacity, every participant completed a structured, low load bench press program, but only the experimental group trained with BFR, exactly as outlined in the protocol [5]. The BFR protocol for the experimental group was referred from guidelines suggested in a relevant study (Tab. 1).

For BFR sessions, BFR cuffs were wrapped around the most proximal part of both arms, just below the axilla, and a portable Doppler was used at brachial artery to determine each person's AOP. Training pressure was then set as a percentage within the 40-80% AOP range in a weekly progressive pattern so that the load was individually tailored rather than fixed. Bench press was performed three days per week for four consecutive weeks, using 20-40% of each participant's measured 1RM and a high volume structure of one set of 30 repetitions followed by three sets of 15 repetitions (30 × 15 × 15 × 15), with the cuffs kept inflated for about 5-10 minutes in total to sustain metabolic stress without excessively prolonging ischemia. The intensity and number of sets were kept progressive to allow the participants to adapt to the protocol in a much more ethical manner and avoid any major discomfort. The progressiveness of these variables was dependent upon the response of the participant.

The control group followed the same schedule, intensity, and repetition scheme but without cuff inflation, ensuring that any difference in outcomes could be attributed to BFR rather than differences in workload. Across all sessions, a certified practitioner supervised technique, monitored for pain, numbness, or unusual cardiovascular responses, adjusted set number or pressure if needed, and peak upper body strength was quantified for every participant before the first session and after the fourth week using a standardized 1RM bench press test.

Statistical analysis

Data were analysed using GraphPad Prism (version 9.5.1). Descriptive statistics (mean ± standard deviation) were calculated. Within-group comparisons (pre- vs post-intervention) were performed using paired-sample t-test to assess the effect of training protocols on upper body strength. Between-group differences in post-intervention outcomes were analysed using independent-samples t-test to determine the relative efficacy of BFRRT versus conventional training. All statistical tests were conducted with a 95% confidence level, and results were considered statistically significant at $p < 0.05$. All analyses assumed normal distribution of data, and assumptions were verified before test application.

Results

Table 2 shows baseline demographic characteristics of the study participants. Baseline peak upper body strength did not show any significant differences pointing towards a comparable upper body strength level of the participants before the administration of the training regimen.

Table 3 shows within-group comparison of peak upper body strength in experimental and control groups. The analysis con-

Table 1. BFR protocol for the experimental group.

BFR site	Restriction Pressure	Frequency	Intensity	Blood Flow Restriction Time	Repetitions	Sets	Exercise Type
Upper Limb (Bilateral)	40 to 80% of AOP	3 days per week	20% to 40% of 1 RM	5-10 minutes	30 x 15 x 15 x 15	2 to 4	Bench Press

firms that the four-week training intervention was highly effective for both groups, with statistical testing validating significant improvements in upper body strength for all participants relative to their baseline levels (Fig. 1 and 2). However, the experimental group utilizing the blood flow restriction protocol demonstrated a notably superior degree of strength enhancement.

Table 4 shows the comparison of peak upper body strength between the groups, reported as statistically not significant ($p > 0.05$) (Fig. 3)

Discussion

The present study investigated the effectiveness of BFRRT compared to conventional resistance training for enhancing upper body strength in young male adults over a four-week intervention period. The findings demonstrated that both training regimes resulted in significant improvements in peak upper body strength, with BFRRT showing superior gains (9.17 kg improvement) compared to conventional training (6.17 kg improvement), though the between-group difference was not statistically significant.

The experimental group utilizing BFRRT demonstrated a 11.4% increase in peak upper body strength (80.33 kg to 89.50 kg), which aligns with previous research by Yamanaka et al., who reported 7.0% improvements in bench press strength following four weeks of occlusion training in Division IA football players [10]. Similarly, Yasuda et al. observed significant increases in bench press 1RM (6%) following two weeks of BFR bench press training at 30% 1RM, supporting the efficacy of low-load BFRRT protocols for strength enhancement [11]. Recent systematic reviews have consistently demonstrated BFRRT's effectiveness for upper extremity strength development [12].

Table 2. Baseline demographic statistics of the participants.

Variables	Experimental Group (Mean ± SD)	Control Group (Mean ± SD)	t value	p value
Age (years)	24.57 ± 2.34	24.70 ± 2.03	0.23	0.81
Height (cm)	171.4 ± 4.71	171.1 ± 4.95	0.18	0.85
Weight (kg)	71.79 ± 6.27	70.59 ± 6.49	0.72	0.46
Baseline Peak Upper Body Strength (kg)	80.33 ± 8.19	81.50 ± 9.11	0.52	0.60

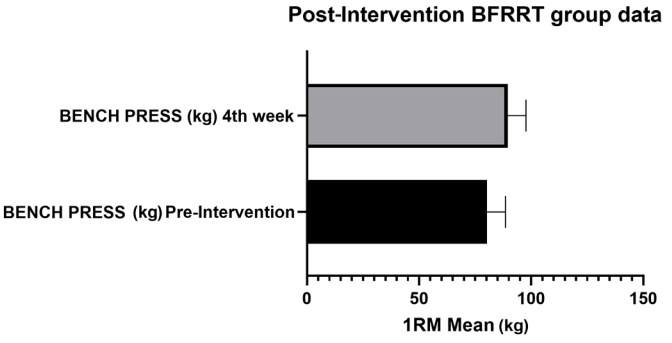


Figure 1. Post-intervention peak upper body strength in the experimental (BFRRT) group ($p < 0.05$)

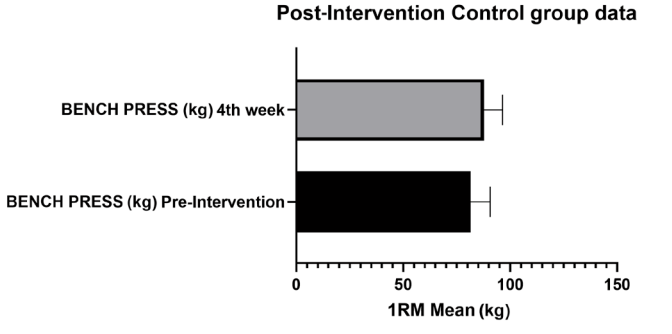


Figure 2. Post-intervention peak upper body strength in the control group ($p < 0.05$).

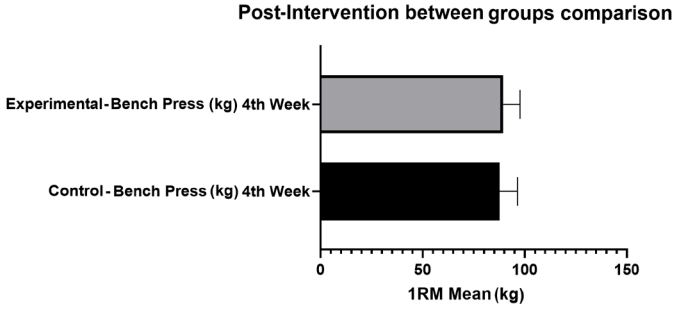


Figure 3. Comparison of post-intervention peak upper body strength between both groups ($p > 0.05$)

Table 3. Within-group comparison of peak upper body strength in experimental and control groups.

Peak Upper Body Strength (n = 30 each)	Baseline		4th Week		Mean Difference	t	p
	Mean	Std. Deviation	Mean	Std. Deviation			
Experimental Group	80.33	± 8.19	89.50	± 8.23	9.17	26.49	< 0.001*
Control Group	81.50	± 9.11	87.67	± 8.78	6.17	15.70	< 0.001*

* – statistically significant at $p < 0.001$.

Table 4. Between-group comparison of post-intervention peak upper body strength.

	Groups	Mean	Std. Deviation	Effect Size (Cohen's d)	Confidence Interval	p
Peak Upper Body Strength	Experimental (n = 30)	89.50	± 8.23	0.215	-7.033 to 3.367	0.476N.S
	Control (n = 30)	87.67	± 8.78			

N.S – non-significant at $p > 0.05$.

A comprehensive meta-analysis by Jing et al. including 220 participants found that low-load BFRRT produced similar effects to high-load resistance training in improving upper extremity muscle strength, while showing greater advantages compared to conventional low-load training without blood flow restriction [13]. This finding directly supports our results, where BFRRT at 20-40% 1RM produced substantial strength gains.

The superior performance of BFRRT can be attributed to several physiological mechanisms. Blood flow restriction creates hypoxic environment that leads to enhanced metabolite accumulation, including lactate and hydrogen ions. This metabolic stress triggers increased growth hormone production and fast-twitch fibre recruitment, facilitating strength adaptations at lower mechanical loads. The partial arterial occlusion and complete venous occlusion applied at 40-80% of arterial occlusion pressure in our study likely optimized these metabolic conditions while maintaining safety [12, 14]. Research by Roehl et al. demonstrated that occlusion pressures around 50% of limb occlusion pressure optimize muscle activation while minimizing discomfort, which corresponds well with our protocol parameters [15]. The individualized approach to determining arterial occlusion pressure using Doppler ultrasound in our study ensured appropriate restriction levels for each participant, potentially contributing to the observed effectiveness.

While the conventional training group achieved meaningful strength improvements (7.6% increase), the magnitude was lower than the BFRRT group. This finding contrasts with some research suggesting equivalent outcomes between high-load and low-load BFR training but supports studies demonstrating BFRRT's superior effectiveness compared to conventional low--load training [16, 17]. The four-week intervention period in our study, though relatively short, produced clinically significant changes. This timeframe aligns with research by Li et al., who observed meaningful adaptations in Taekwondo athletes following four weeks of BFR circuit training, and Thiebaud et al., who demonstrated significant strength improvements within similar intervention periods [18, 19].

The progressive nature of the BFRRT protocol used, with intensity and volume adjustments based on participant response, likely contributed to the observed outcomes. Recent comparative research by Chang et al. demonstrated that progressive pressure applications in BFRRT can produce superior results compared to fixed pressure protocols, supporting our individualized approach [19]. Strength gains observed with BFR training are driven by a combination of metabolic and mechanical stress mechanisms. A key component involves the induction of a localized hypoxic state, which stimulates activation of the mammalian target of rapamycin complex 1 (mTORC1) – a central regulator of muscle protein synthesis. Research has shown that performing low-load resistance exercise under BFR conditions significantly augments this pathway, with one study reporting a 56% elevation in muscle protein synthesis within three hours after exercise. The critical role of mTORC1 in this process is reinforced by findings demonstrating that rapamycin, a selective mTORC1 inhibitor, completely suppresses the protein synthetic response normally elicited by BFR exercise [20, 21].

The present findings also add ethnicity-specific insight by demonstrating that low-load BFRRT elicits remarkable upper-body strength gains in young Indian males, a population under-represented in existing BFR literature that is dominated by Western and East Asian populations. Given the known ethnic differences in limb anthropometry, vascular characteristics, and baseline strength profiles, the responsiveness observed in this Indian sample suggests that current BFR pressure recommendations (40-80% AOP at 20-40% 1RM) are physiologically effective beyond the populations in which they were originally developed [22, 23]. Therefore, these data support the external validity of established BFRRT guidelines while also highlighting the need for future work directly comparing ethnic groups to refine truly population-specific prescriptions for occlusion pressure and training volume. The findings suggest that BFRRT can serve as an effective alternative to traditional high-load training for developing upper body strength in young males. This has relevance for individuals recovering from injury, those with joint limitations, or athletes seeking strength gains while minimizing mechanical stress. The ability to achieve substantial strength improvements with loads as low as 20-40% of 1RM makes BFRRT an accessible and practical training modality for diverse populations. The non-significant between-group difference, despite the BFRRT group's superior numerical improvements, suggests that both training methods are viable options for upper body strength development, with BFRRT potentially offering additional benefits in terms of safety and accessibility while maintaining effectiveness comparable to conventional approaches.

Conclusions

In conclusion, this study highlights the effectiveness of BFRRT in comparison to conventional low-load resistance training in enhancing peak upper body strength in a young population. The significant strength gains observed in the BFR group underscore the potential of this training method as a valuable addition to resistance training programs. Given the expanding therapeutic scope of BFR training, future investigations should target special populations, specifically geriatric and adolescent individuals. For these groups, traditional high-load resistance training often presents safety concerns due to orthopaedic fragility or developmental considerations; therefore, validating BFR as a low-load, osteo-protective alternative is imperative. Furthermore, a critical need exists to address the gender gap in current literature. Future research should explore how BFRRT interacts with menstrual cycle-related hormonal changes to better tailor training programs for females.

Limitations

The four-week intervention period, while sufficient to detect meaningful changes, may limit generalizability to longer--term adaptations. Additionally, the study focused exclusively on young male participants, limiting applicability to other populations. Future research should investigate longer intervention periods, female participants, sleep duration, dietary intake and different training populations to establish broader applicability of BFRRT protocols. Also, investigation of the underlying physiological mechanisms, including hormonal responses and muscle fibre adaptations, would enhance understanding of BFRRT's effectiveness.

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