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Original Article

Physiotherapy Section

Effect of Single Bout of Exercise with Blood Flow Restriction Training on Muscle Girth and Cardiovascular response: A Pretest, Post-test Quasi-experimental Study

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ABSTRACT

Introduction: Blood Flow Restriction Training (BFRT) was developed by Southeast Asia Treaty Organisation (SATO) in Japan in 1966. BFRT is a method that mimics the effects of high-intensity training by combining low-intensity exercise with blood flow obstruction. It involves limb compression using compression cuffs to limit venous outflow and minimise arterial inflow during rehabilitation training. By allowing individuals to lift smaller loads and increase strength training gains, BFRT can reduce the overall stress exerted on the limb.

Aim: To assess the difference in muscle girth and blood pressure after a single bout of BFRT.

Materials and Methods: This was a single-blinded, single-site pretest, post-test quasi-experimental study. A total of 30 subjects were enrolled (16 females and 14 males) between the ages of 18 to 25 years. This study was conducted at the Department of Physiotherapy, Galgotias University, Greater Noida, Uttar Pradesh, India. Outcome measures included muscle girth measured using a flexible tape and blood pressure using an automatic oscillometric device (Omron Hem 7113, São Paulo, Brazil). Paired t-test and Wilcoxon test were performed using Statistical Package for Social Sciences (SPSS) software version 20.0.

Results: It was found that an acute bout of BFRT caused improvement in all outcome measures. There was a statistically significant increase in muscle girth and blood pressure after BFRT (p-value<0.001).

Conclusion: There was a significant increase in blood pressure (both Systolic Blood Pressure (SBP) and Diastolic Blood Pressure (DBP)) and muscle girth after BFRT with no reported adverse effects.

Keywords: Blood flow restriction exercise, Blood pressure, Forearm girth, Muscle development

INTRODUCTION

The BFRT is an innovative method utilised in athletic and therapeutic settings to increase muscular strength and hypertrophy that has recently gained attention and been shown to be both effective and safe [1]. It was developed by SATO in Japan and permits compression of the limb using compression cuffs encircled to a limb to limit venous outflow and minimise arterial inflow during rehabilitation training [2]. Over the past 10 years, BFRT-also referred to as hypoxic, occlusion, or Kaatsu training-has gained favour as a means of improving strength [3]. Combining low-intensity exercise with BFRT yields outcomes comparable to those of high-intensity training [4]. It causes muscle development by several suggested mechanisms, such as cellular swelling, anaerobic metabolism, and induction of type 2 muscular fibers, by combining low-load resistance training and venous occlusion [5]. There are many theories as to how BFRT might be useful in increasing muscular hypertrophy and strength. One study postulated that when exercise is combined with training, BFRT causes ischaemia and a hypoxic muscle state that results in high levels of mechanical tension and metabolic stress [6].

BFRT has been demonstrated to have benefits on cardiovascular response, muscle growth, and strength that are comparable to training at a 40% strength level without BFR [7]. BFRT has the potential to exacerbate reflex-mediated cardiovascular reactions by activating the muscular metaboreflex arm of the exercise pressor reflex. A surge in muscle metabolites, which occurs during exercise, activates the sympathoexcitatory reflex known as the metaboreflex, which increases BP [8].

Additionally, BFRT has proven to be very adaptable because it can be done passively or as a supplement to resistance or aerobic training [9]. It has been demonstrated that resistance training at low loads (20% of 1 repetition maximum) can quickly enhance muscle size as well as strength in athletic populations when combined with an applied occlusion to limit blood flow [10,11].

Protocols for BFRT vary widely across studies [12,13], making it challenging to compare results and establish optimal training parameters. Most research on [14,15] BFRT has focused on its chronic effects following multiple training sessions. This study explores the acute effects of BFRT after a single bout of exercise, providing novel insights into the immediate physiological responses to BFRT. While previous studies [16,17] have examined muscle hypertrophy following chronic BFRT, few [18] have investigated acute changes in muscle girth. Understanding the acute BP response to BFRT is crucial for evaluating its safety and potential cardiovascular benefits.

This study aimed to provide insights into whether there is a major difference in the effect of a single-bout exercise in BFRT on elbow flexors in terms of muscle girth and BP in terms of cardiovascular response.

MATERIALS AND METHODS

This was a single-blinded, single-site, clinical pretest, post-test quasi-experimental study conducted in the laboratory of the Department of Physiotherapy at Galgotias University, Greater Noida, Uttar Pradesh, India between July 2023 and October 2023. The subjects were blinded to pressure estimation; they were unaware of their limiting blood flow pressure. The Department Ethics Committee approved the study (Ref No: Dec/008/23). The procedures outlined in this section adhere to the standards outlined in the 1975 Helsinki Declaration and its 2008 amendment.

Inclusion criteria: College students within the age range of 18 to 25 years with no complaints of elbow pain and no history of upper extremity injury, subjects who were independent in their daily activities were included in the study.

Exclusion criteria: The subjects with presence of any blood anticoagulant medicine, diabetes, hypertension, peripheral vascular disease, cardiovascular disease, smoking, and/or any medical condition that makes weight lifting were impossible were excluded from the study.

Sample size calculation: The sample size of 30 was calculated using G*Power software version with the following parameters: Effect Size (ES) of 0.3, Significance Level (α) of 0.05, Power (1-β) of 0.80 with BFRT as the Independent variable and BP and muscle girth as Dependent variables. The snowball sampling method was used to recruit 30 participants who met the specified inclusion and exclusion criteria. None of the subjects used stimulants like caffeine or performance-enhancing drugs atleast 72 hours before the training.

Study Procedure

Students of Galgotias University were selected for this study via snowball sampling. Before the initiation of the study, subjects completed a BFRT screening questionnaire [19]. A clear explanation was given to the subjects about the procedure, and written consent was obtained. All 30 subjects underwent low-intensity BFRT. A measuring tape placed 10 cm distal to the midpoint between the lateral epicondyle and olecranon process was used to measure the forearm girth in centimeters [Table/Fig-1]. Using an automated oscillometric instrument, SBP and DBP phases of blood pressure were measured in mmHg (Omron Hem 7113, São Paulo, Brazil) [20].

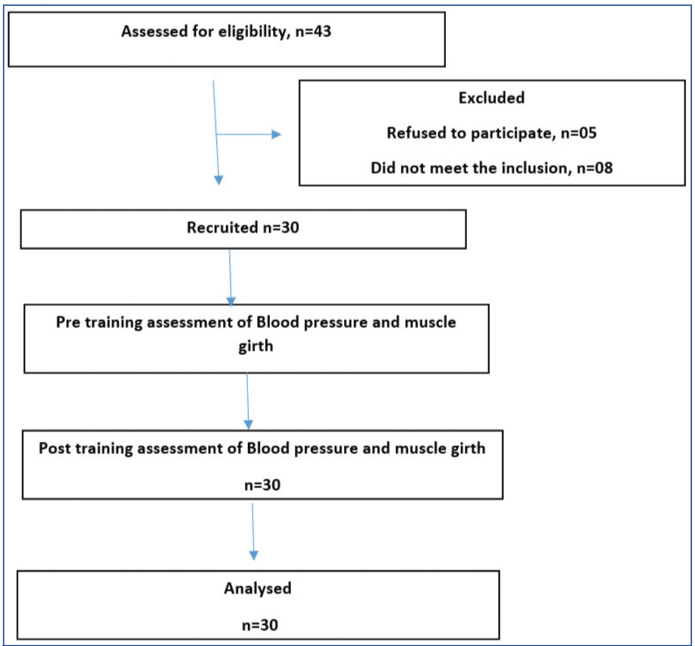
[Table/Fig-1]: Exercise training.

The pneumatic blood pressure cuff was positioned on the dominant arm, 4 cm in front of the antecubital fossa. To ensure venous occlusion, the blood pressure cuff was inflated to 50 mmHg during the exercise [Table/Fig-1].

During exercise training, the participant gripped a digital hand dynamometer and used an electronic metronome to contract the muscle 15 times per minute at 20% resistance of 1 RM (Repetition maximum) [21]. The subjects had 20 minutes of training and were permitted to take 1-minute breaks; the cuff was deflated after four minutes of training. The load used was 20% of 1RM as per the standard guidelines of BFRT [12]. For all subjects, SBP and DBP were evaluated following a 10-minute passive rest period after arriving at the laboratory and 60 minutes after the administration of low-intensity BFRT. [Table/Fig-2] shows the flowchart of the study. In compliance with the International Society of Hypertension guidelines, measurements were taken while seated on the left arm.

STATISTICAL ANALYSIS

The data collected for the present study were entered into MS Excel



[Table/Fig-2]: Flowchart of the study procedure.

and analysed using descriptive statistics of SPSS version 20.0. Descriptive statistics were used to analyse the demographics of the subjects. The statistical values were expressed as mean±SD. All the variables were examined to ensure they comply with normalcy assumptions using the Shapiro-Wilk test. The Wilcoxon test was utilised to analyse the data that were not normally distributed. A paired t-test was utilised to examine the normally distributed variables. Statistical significance was set at 0.05.

RESULTS

The sample consisted of 30 subjects, out of which 14 (46.7%) were males and 16 (53.3%) were females. The mean age and BMI of the subjects is shown in [Table/Fig-3]. The mean SBP increased to 129±10.79 mmHg. A single bout of BFRT caused a statistically significant change in SBP (p-value<0.001). Similarly, a single bout of BFRT caused a statistically significant increase in DBP (p-value<0.001) [Table/Fig-4]. Muscle girth also increased from 9.24±1.57 cm before BFRT to 9.87±1.57 cm after BFRT (p-value<0.001).

Parameters	N	M±SD
Age (years)	30	23.30±1.62
Body Mass Index (kg/m^2)	30	22.18±3.77

[Table/Fig-3]: Demographic data of subjects.

Parameters	Pre BFRT	Post BFRT	p-value
Systolic BP (SBP)# (mmHg)	117±7.33	129±10.79	<0.001
Diastolic BP (DBP)# (mmHg)	69.46±5.178	74.67±12.023	<0.001
Muscle girth* (cm)	9.24±1.57	9.87±1.57	<0.001

[Table/Fig-4]: Mean score of all parameters and their p-values.
#: Wilcoxon signed test; *: Paired t-test

Other than numbness and tingling that went away when the cuff was taken off, no negative effects were seen or reported by the subjects.

DISCUSSION

This study was designed to investigate the effect of a single bout of BFRT on BP and girth. The results indicated that after a single bout of BFRT resulted in a gain in muscle girth and an increase in BP (p-value<0.001). The results of this study are similar to those of previously conducted studies [22], which imply that blood pressure increases during acute resistance exercise sessions with BFR-Low-Intensity (BFRLI) training.

A study by Brandner CR et al., found that BFR-LI exercise increased blood pressure when exercise was continued at 80% of SBP, albeit for all conditions examined, these values quickly reverted to baseline levels five minutes after the administration of the program. This demonstrated that "a high-pressure restriction coupled with relatively broad cuffs (BFR-I) enhances myocardial work compared to a low-pressure restriction applied continuously without release BFR with Continuous pressure (BFR-CP)" [23]. Downs ME et al., performed research on the effects of four different loads during supine unilateral leg press and heel raise exercises on local vascular responses, cardiovascular responses, and saturation of tissue oxygen (StO_2) [24]. Similar to this study, they discovered that SBP and DBP were elevated during the BFR sessions, as opposed to the High Load (HL) and Low Load (LL) sessions without an occlusion cuff. Additionally, blood pressure rose throughout the blood flow-restricted exercise rest periods. Other than localised tingling or numbness, which disappeared rapidly following cuff release, no ischaemia-related symptoms were seen. This correlates with this study's findings where subjects reported numbness and tingling five minutes after exercising [24].

This study's results are consistent with a previously published study by Filippou S et al., where there was an increase in BP (SBP and DBP) when exercise routines were used in conjunction with ongoing BFR. The SBP and DBP values showed an increasing trend that progressively grew from one break to the next but were not statistically significant [25]. Another previous study by Bonorino SL et al. showed that unilaterally flexing the elbow (concentration curls) with BFR led to an increase in SBP and DBP (9.60% and 11.75%, respectively) when compared to physical activity done without BFR. The findings of this work demonstrate that even a stimulus that may be of lower intensity ("low-intensity exercise for elbow flexion") when combined with BFR may induce greater cardiovascular stress than just exercise alone (without BFR). They also stated that, even though the acute elevations in SBP and DBP in reaction to BFR exercise were more apparent than those in response to exercise without BFR, these increases were not durable and returned to pre-exercise values (their baseline levels) within 15 minutes of recovery [26].

However, the outcomes of this study contradict a previously done study by Picón MM et al., whose results showed that there were no changes in SBP or DBP during the exercise. The employed total arterial occlusion was 30% (47.6 mmHg). The eccentric phases were tested with a digital metronome, and every repetition took about one second for the concentric phase and one second for the eccentric phase. SBP significantly decreased 15 minutes after exercise, which was likely brought on by the effect known as Post-Exercise Hypotension (PEH). The effect was attributed to a drop in cardiac output that was not entirely offset by an increase in systemic peripheral vascular resistance. In addition, they hypothesised that the low restrictive pressure (47.65 mmHg) utilised in the protocol, in addition to being released during the breaks between sets, may have contributed to the lower BP responses during the BFR-LI protocol [27].

Furthermore, consistent with present study observation, a study carried out by Gujral T et al., also looked at how young adults' muscle strength and muscle girth were affected by moderate-intensity resistance exercise combined with BFR. They found that there wasn't any discernible improvement in the three groups' muscle girth in the investigation. Despite this, following the four weeks of exercise, there was a noticeable increase in muscle girth in each group. This implied that either the training period or the occlusive pressure used was insufficient to produce muscle hypertrophy, or the exercise intensity in conjunction with that occlusive pressure was insufficient [21].

A prior study done by Abe T et al., showed that BFR combined with slow walk training increased the girth rise of the thigh muscles which was measured by an inch of tape after exercise [28]. A study was done by Ke J et al., to explore the effect of "BFRT on the recovery of knee function in patients after Arthroscopic Partial Meniscectomy (APM). The findings of the study stated that the thigh circumference of patients in the BFRT+RR group significantly increased after the procedure. However, the thigh circumference of the BFRT was substantially larger and greater before the surgical procedure and demonstrated that BFRT dramatically increases the patient's thigh circumference which used a standard tape to measure the patient's thigh circumference [2].

Also, Tennet DJ et al., demonstrated in a study that looked at how adding BFR-based exercise to conventional physical therapy techniques affected hypertrophy, strength, and functional results, along with patients' self-reported outcomes after postoperative non reconstructive knee surgery. At 6 cm and 16 cm proximal to the patella, the BFR group experienced statistically significant increases in thigh girth. Additionally, the BFR group's increases in thigh girth were considerably larger than those in the conventional therapy group at the 6 cm level [29]. Similar studies from the literature have been tabulated in [Table/Fig-4] [2,21,23-29].

Sl no.	Author's name and publication year	Place of study	Number of subjects	Objective	Parameters assessed	Conclusion
1.	Brandner CR et al., (2015) [23]	New South Wales Institutes Of Sports	12 male subjects	This study aimed to compare the acute haemodynamic responses in the same young, healthy volunteers to unilateral bicep curl BFR exercise with both High Load Resistance Exercise (HLRE) and Low Load Resistance Exercise (LLRE). Additionally, two BFR workout methods were compared: intermittent high-pressure BFR application and continuous low-pressure BFR application	Cardiac parameters (Heart Rate), Blood pressures (SBP, DBP, MAP)	During BFR-I, HR and blood pressure were significantly higher. Which suggests that, in contrast to a low pressure restriction applied continuously without release (i.e., BFR-C), a high pressure restriction coupled with somewhat broad cuffs (i.e., BFR-I) increases myocardial work.
2.	Downs ME et al., (2014) [24]	Department of Health and Human Performance, University of Houston, Houston, TX	13 subjects (5 men, 8 women)	This study aimed to investigate the effects of four different loads on local vascular responses, tissue oxygen saturation (StO_2), and cardiovascular responses during supine unilateral leg press and heel raise exercise: high load (HL) without an occlusion cuff, low load (LL) without an occlusion cuff, and low load with an occlusion cuff pressure set at 1.3 times resting diastolic blood pressure (BFRDBP) or at 1.3 times resting systolic blood pressure (BFRSBP)	The systemic cardiovascular response, tissue oxygen saturation (StO_2), and local arterial blood flow	SBP and DBP were elevated during the BFR sessions, as opposed to the HL and LL sessions without an occlusion cuff. Additionally, blood pressure rose throughout the blood flow-restricted exercise rest periods. Other than localised tingling or numbness, which disappeared rapidly following cuff release, no ischaemia-related symptoms were seen.
3.	Filippou S et al., (2023) [25]	Department of Physiotherapy, Faculty of Health Sciences, International Hellenic University, Alexander Campus, Greece	The subjects were 12 healthy volunteers (n= 6 men and 6 women)	The purpose of this study was to examine and contrast, in healthy volunteers, the acute haemodynamic responses and muscle exhaustion following an isometric exercise session with and without BFR	Blood Pressure, Heart Rate (HR), Blood Oxygen Saturation, Rating of Perceived Exertion	When exercise regimens were combined with continuous BFR, there was an increase in blood pressure (both SBP and DBP). Though not statistically significant, the SBP and DBP data displayed a rising trend that steadily increased from one break to the next.

4.	Bonorino SL et al., (2019) [26]	Instituto Federal do Paraná, Physical Education Course. Palmas, PR. Brazil.	10 male subjects	This study aimed to examine the acute haemodynamic reactions to small muscle group strength training with Blood Flow Restriction (BFR)	Blood pressure (BP), Haemodynamic responses, HR, Mean Arterial Pressure (MAP), and Pulse Pressure (PP)	The study's findings showed that SBP, DBP, and MBP only rose in response to strength training with BFR, and that these measurements returned to baseline 15 minutes after the exercise. Furthermore, PP values following exercise with BFR show that the extra load encouraged by BFR did not pose a cardiovascular danger to the research participants.
5.	Picón MM et al., (2018) [27]	Department of General and Specific Didactics, University of Alicante, Alicante, Spain	24 subjects	The study aimed to look into how BFR-LI affected cardiovascular responses in the short-term	Blood oxygen saturation (SpO_2), HR, blood pressure (BP), and double product (DP)	During the exercise, neither SBP nor DBP changed. Fifteen minutes after exercise, SBP drastically dropped, most likely due to the phenomenon known as Post-Exercise Hypotension (PEH). The cause of the effect was identified as a decrease in cardiac output that was partially compensated by an increase in peripheral vascular resistance within the system. Furthermore, they postulated that the protocol's low restrictive pressure (47.65 mmHg), which was also released during the intervals between sets, might have played a role in the protocol's lower blood pressure responses during the BFR-LI protocol.
6.	Gujral T et al., (2021) [21]	Physiotherapy Department, SMAS, Galgotias University, Gautam Budh Nagar, Noida, Uttar Pradesh, India	39 subjects	The study's objective was to investigate how young adults' muscle strength and muscle girth were affected by resistance training at a moderate intensity combined with Blood Flow Restriction (BFR)	Muscle strength, muscle girth	There has been no discernible improvement in any of the three groups' muscle girth. Though following the four weeks of training, there was a noticeable increase in the muscle girth in each group. This implies that either the training length or the occlusive pressure used were insufficient to produce muscle hypertrophy, or the exercise intensity combined with that occlusive pressure was insufficient.
7.	Abe T et al., (2006) [28]	Department of Exercise and Sport Science, Tokyo Metropolitan University, Tokyo, Japan	18 subjects	The aim of this study was to examine the effects of walk training paired with Kaatsu (Kaatsu-walk) on blood hormonal markers and muscle size and strength, both acutely and over time	Muscle size, maximal dynamic strength (one repetition maximum), isometric strength, and blood hormone levels	The main discovery of this study was that young men's thigh muscle volume and Cross-Sectional Area (CSA) increased after three weeks of twice-daily Kaatsu-walk training. Over the course of the training period, the Kaatsu-walk group's estimated muscle-bone CSA increased by 2% each week. This rise was consistent. Slow-walk training combined with leg muscle Blood Flow Restriction (BFR) (Kaatsu) causes strength increase and muscle hypertrophy even at the lowest workout intensity.
8.	Ke J et al., (2022) [2]	Sichuan Provincial Orthopedic Hospital, Chengdu, China	40 subjects	To investigate how Blood Flow Restriction Training (BFRT) affects patients' ability to regain knee function following an Arthroscopic Partial Meniscectomy (APM)	Quadriceps muscle strength, quadriceps thickness, and thigh circumference	According to the study's findings, participants in the BFRT + RR group had a substantial rise in thigh circumference following the operation. The patient's thigh circumference was measured with a standard tape measure, but the BFRT's was significantly higher and greater before to the surgical surgery, indicating that BFRT significantly increases the patient's thigh circumference.
9.	Tennent DJ et al., (2016) [29]	Department of Orthopaedics and Rehabilitation, San Antonio Military Medical Center, Ft Sam, Houston, Texas; and Center for the Intrepid, San Antonio Military Medical Center, Ft Sam, Houston, Texas.	17 subjects	The aim of this research was to assess the effects of incorporating BFR-based exercise into conventional physical therapy techniques to enhance functional results, strength, hypertrophy, and patient self-reported outcomes following nonreconstructive knee arthroscopy	Strength testing, thigh circumference, Veterans RAND 12-Item Health Survey (VR12), Knee Osteoarthritis Outcome Score (KOOS), and physical function assessments	The thigh girth of the BFR group increased statistically significantly at 6 and 16 centimeters proximal to the patella. Additionally, at 6 cm, this difference was noticeably greater in the BFR group when compared to the control group.
10.	Present study	Laboratory of Department of Physiotherapy at Galgotias University, Uttar Pradesh, India	30 subjects	This study aimed to provide insights into whether there is a major difference in the effect of single-bout exercise in BFRT on elbow flexors in terms of muscle girth and BP in terms of cardiovascular response	Muscle girth and blood pressure (SBP and DBP)	There was a significant increase in BP (both SBP and DBP). There was also a significant increase in muscle girth. No adverse effects were observed or reported by the subjects other than numbness and tingling which disappeared after the cuff was removed. So,it was concluded that BFRT is a safe and effective measure and it can also be used as a treatment intervention for hypotensive patients.

[Table/Fig-4]: Similar studies from the literature [2,21,23-29].

Limitation(s)

This study was a one-time study (single bout). More outcome measures like rate pressure product and HR were not studied and can be included in future studies.

CONCLUSIONS

In this study, there was a significant increase in muscle girth and both SBP and DBP following a single bout of BFRT. No adverse effects were observed or reported by the subjects other than numbness and tingling, which disappeared after the cuff was removed. Therefore, it can be concluded that BFRT is a safe and effective measure and can also be used as a treatment intervention for hypotensive patients. The study underscores the need for further research to elucidate the mechanisms underlying the observed changes in blood pressure and muscle girth following BFRT. Future studies should explore the long-term effects of BFRT on cardiovascular health, muscle adaptation, and its safety profile across diverse populations, especially for hypotensive patients.

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