Low-intensity with Practical Blood Flow Restriction Strength Protocols Successfully Increases Maximal Isometric Strength in Both Upper and Lower Muscles : A Pilot Study

Ratanyoo Longrak[1,*] , Wirat Sonchan[1] and Watanya Jaidee[2]

[1]Faculty of Sport Science, Burapha University, Chon Buri, Thailand
[2]Faculty of Medicine, Burapha University, Chon Buri, Thailand
[*]Corresponding author: E-mail: Addmuscleclinicz@gmail.com

Received 28 February 2024; Revised 9 April 2024; Accepted 29 April 2024

Abstract: This pilot study investigated the efficacy of a short-course minimal strength-protocol utilizing practical blood flow restriction, aiming to optimize muscle strength gains within a limited timeframe. The participants included 8 healthy undergraduate individuals undergoing the training intervention, and whose baseline strength levels were evaluated before the study. The intervention spanned three weeks, with a single session per week, and comprised a combination of high-intensity and low-intensity exercises with practical blood flow restriction. The results revealed significant improvements in both elbow flexor and knee extensor muscle strength postintervention ($p < 0.05$), with notable percentage increases recorded. Specifically, participants demonstrated enhancements of approximately 24.94% in elbow flexor strength and 23.08% in knee extensor strength in the limited timeframe. These findings demonstrated the practical applicability of the protocol in diverse settings, emphasizing its potential as a time-efficient strategy for maximizing muscle strength gains within a limited training period.

Keywords: Strength training, Blood flow restriction, Maximal isometric strength, Low-intensity training, High intensity training

INTRODUCTION

Strength training is important for inducing muscular adaptations and enhancing physical performance (1). The American College of Sports Medicine underscores the significance of structured resistance training programs aimed at optimizing muscle strength development (2). Central to these guidelines is the manipulation of training intensity, often expressed as a percentage of 1 repetition maximum (%1RM), to elicit targeted physiological responses conducive to strength gains. Higher intensity training, typically performed at 70–85% of the 1RM, is advocated for maximizing muscle strength and hypertrophy (2). Conversely, lower intensity training, ranging from 40–60%1RM, may be employed to enhance muscular endurance and metabolic conditioning (2). Furthermore, the principle of progressive overload is emphasized, wherein training intensity and volume must be increased to continually challenge the musculature and stimulate further strength adaptations (3). By adhering to these evidence-based principles, individuals can design effective strength training programs tailored to improve muscular strength.

Blood flow restriction (BFR) training has emerged as a promising strategy for enhancing muscular adaptations, particularly in contexts where traditional high-intensity resistance training may be impractical (4). This novel approach involves the application of a tourniquet or specialized cuffs to restrict blood flow to working muscles during low-intensity resistance exercise (5). Proponents of BFR training suggest that this technique induces metabolic stress and muscle fatigue (6), stimulating heightened muscle activation (7) and muscle growth (8). Moreover, the utilization of low-intensity loads in BFR training may offer advantages such as reduced joint strain and a lower risk of injury, making it an appealing option (9). However, while existing meta-analyses indicate that BFR training alone may not yield maximal strength gains compared to high-intensity resistance training (10), the potential synergistic effects of combining heavy-load exercises with BFRs remain relatively unexplored. Considering the impracticality and inherent risks associated with consistent training with heavy loads, exploring the integration of BFR into resistance training protocols holds promise for optimizing muscle strength development while mitigating potential drawbacks (11).

Given the potential benefits of both traditional resistance training and BFR, there is interest in investigating the effects of combined protocols on muscle strength development. The purpose of this pilot study was to test the efficacy of a short-course strength-protocol with practical blood flow restriction (pBFR) that combines heavy-load sets with low-load sets incorporating BFRs. This minimal protocol, wherein participants engage in training sessions only once a week for 3 weeks, aims to determine whether the synergistic effects of combined training can lead to significant increases in muscle strength within a relatively short timeframe.

MATERIALS AND METHODS

Experimental Approach to the Problem

To investigate the effectiveness of the short-course pBFR strength protocol, which was developed and adapted based on the guidelines of the National Strength and Conditioning Association, a single group experimental design was used. A mixed resistance protocol combining heavy-load sets and low-load sets under BFR conditions was constructed and implemented. Active healthy subjects received information about training purposes and agreed to provide informed consent before starting the short-term 3-week resistance training session once a week. Pre-test and post-test isometric strength test results were collected for both upper and lower body at one week before experiment and one week after completion. Ethical approval was granted by the Burapha University ethics committee (G-HS046/2566(C1)).

Subjects

Eight active healthy male university students aged 20 to 22 years were recruited for a pilot study from the Faculty of Sport Science, Burapha University, Chon Buri, Thailand. These subjects were not engaged in regular strength exercise but did play sports such as football and basketball. The selection criteria also included having no prior experience with the use of pharmacological substances, ergogenic drugs, or steroids that could affect muscle strength.

Strength Testing

Subjects were required to complete tests to assess upper- and lower-body strength before and after the intervention. Pretesting and post-testing were conducted at the same time of day. The isometric strength test refers to the value of the maximum voluntary isometric contraction (MVIC) of both knee extension and elbow flexion. An isokinetic machine (ISOFORCE, Germany) was utilized in this study. Isokinetic machines are undeniably deemed to be the gold standard for maximal strength tests and were previously used in a number of studies. For the MVIC of knee extension, the knee extension force of the subjects was tested at a specific angle of 60 degrees of knee flexion (full knee extension = 0 degree of knee flexion). Each subject was asked to extend the knee as hard as possible to measure the force at this joint angle, which was maintained for 5 seconds for 3 repetitions and separated by 4 minutes of rest. The highest MVIC was recorded as the maximal isometric knee extension strength. For MVIC during elbow flexion, elbow flexion force was tested at a specific angle of 90 degrees of elbow flexion. Each subject was asked to flex the elbow as hard as possible to measure the force at this joint angle, which was held for 5 seconds for 3 repetitions and separated by 4 minutes of rest. The highest MVIC was recorded as the maximal isometric knee flexion strength.

Training Protocol

Within the initial phase of the practical strength protocol spanning the first and second weeks, the subjects engaged in structured resistance training targeting the biceps and quadriceps muscle groups. The exercises included machine preacher curls and machine knee extensions (Body Solid, USA). Each session comprised 2 sets of heavy-load exercises at 70%1RM, alongside one set of low-load exercises at 30%1RM, with pBFR applied using elastic wraps with a lock. This phase, termed accumulations, aims to induce varied adaptive responses while minimizing the physiological loading strain. After the third week, overreaching week, the training volume doubled to 6 sets, evenly distributed between heavy-load and low-load exercises with pBFR. Each set was provided with a 60-second rest interval and 4 minutes of rest between exercises starting from lower-body exercise first (Figure 1). In every training set, subjects were verbally encouraged to "try to perform as many repetitions as possible and feel the contraction and stretching of working muscle in every repetition" throughout the sets. The numbers of repetitions were not fixed in each set, and the set was taken to concentric muscle failure points and then terminated. Before starting every set of low intensities, the load was adjusted to 30% of the 1RM, and the elastic wraps were tightened and locked proximal to the training limbs and immediately released after each set terminated. This structured protocol contributed to the scholarly discourse on resistance training methodologies and strength adaptations.

Practical Blood Flow Restriction

Practical blood flow restriction was achieved by using elastic wrap tightened to a pressure of approximately 40% of the perceived arterial occlusion pressure (AOP). First, the subjects were fitted with a clinical pressure-adjustable cuff (H+CUFF, USA) and exposed to precise pressure capable of completely occluding arterial blood flow (AOP). The pressure was gradually increased in increments of 10-20 mmHg until reaching this AOP. The validity of AOP was confirmed using a portable vascular Doppler device. Next, the subjects were exposed to a pressure of 40% of their individual AOP. The pressure alternated between on and off fashion at a 12:22 second ratio for 5 cycles to allow participants to become acclimated to the perceived pressure. Once participants became comfortable with pressure, they were given the opportunity to use elastic wraps (GRIZZLY FITNESS, USA) to apply the same relative perceived pressure of approximately 40% AOPs.

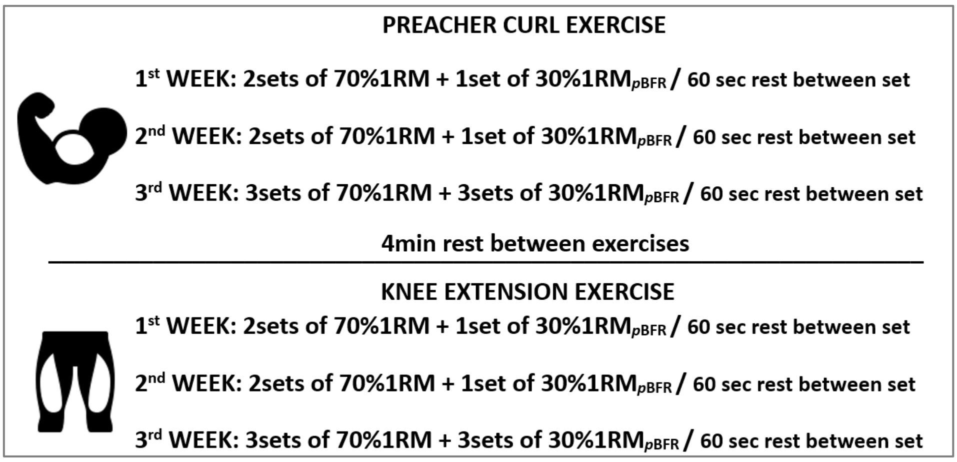

Figure 1. Practical blood flow restriction strength protocol. pBFR = Practical blood flow restriction; %1RM = % of the 1 repetition maximum

Statistical analysis

In the statistical analysis conducted using advance statistical Microsoft Excel 2023, descriptive statistics were first calculated for the mean and standard deviation of muscle strength values for both elbow flexion and knee extension exercises at the pre- and posttraining stages. Next, inferential statistics were employed to evaluate the significance of the pre to post changes in muscle strength. Specifically, a paired t-test was conducted within Microsoft Excel to compare the mean differences between pre- and posttraining muscle strength measurements for both exercises, with data representing with 95% Confidence Interval (95%CI). This analytical approach facilitated an examination of the effectiveness of the training intervention in inducing changes in muscle strength levels.

RESULTS

Repetition Volumes.

In the present study, the average number of repetitions performed for heavy sets of machine preacher curls was 12.4 ± 6.5, while the average number of repetitions performed for heavy sets of machine knee extensions was 14.3 ± 4.9. In contrast, the average repetitions performed for low-load sets with pBFRs were 25.1 ± 10.9 and 37.3 ± 15.9 repetitions for preacher curl and knee extension, respectively.

Maximal Isometric Elbow Flexion and Knee Extension Strength

This strength protocol was successful in increasing muscle strength following the training intervention for both elbow flexion and knee extension exercises. Specifically, the average elbow flexion isometric strength increased from 48.63 ± 10.29 N at pretest to 60.38 ± 13.71 N at posttest, indicating a significant improvement ($p = 0.029$). This increase corresponded to a notable increase of approximately 24.94% in elbow flexor strength. The effect size, as measured by Cohen's d, was large (1.02). Similarly, for knee extension isometric strength, participants exhibited significant progress, with the pretest average strength at 239.88 ± 62.91 N increasing to 295.25 ± 51.50 N at the posttest ($p = 0.002$). This improvement represented a considerable enhancement of approximately 23.08% in quadriceps muscle strength. The effect size, as measured by Cohen's d, was large (0.96) (Table1). These results underscored the efficacy of this short-course pBFR strength protocol in increasing substantial gains in both elbow flexion and knee extension strength in the limited short timeframe.

DISCUSSION

The primary significance of this pilot investigation lies in its examination of the potential gains in maximal isometric strength across both the knee extensor and elbow flexor musculature via a combined training protocol. This study effectively demonstrated substantial enhancements in these strength parameters. Previous studies have typically juxtaposed strength adaptations arising from disparate training protocols, such as comparisons between high-intensity resistance training in isolation and low-intensity resistance training coupled with BFR (12–14).

Previous meta-analyses revealed that while both low-intensity (<50%1RM) resistance training with BFRs and traditional high-intensity (>65%1RM) resistance training led to similar levels of muscle hypertrophy, traditional high-intensity training resulted in superior muscle strength gains (10). Our

Table 1. Change in maximal isometric strength

Maximal isometric strength	Pre-training Mean ± SD	Post-training Mean ± SD	Change(95%CI)	Cohen'*d*	*p* value
Elbow flexion (Newton)	48.63 ± 10.29	60.38 ± 13.71	11.75 (1.59;21.91)	1.02	0.029
Knee extension (Newton)	239.88 ± 62.91	295.25 ± 51.50	55.38 (27.81;82.94)	0.96	0.002

current study contributes to the existing body of research by demonstrating that over a brief 3-week training period, the combination of high-intensity and low-intensity training with pBFR significantly increased muscle strength gains, with improvements of +23% and +24% observed in knee extension and elbow flexion, respectively. This finding suggests that combining these approaches may address the limitations of low-intensity resistance training with BFR alone, which may not optimize strength gains to the same extent.

One possible explanation for the inability of low-intensity resistance training with BFR, when not combined with high intensity, to maximize strength gains may lie in the reduced level of muscle activation. This phenomenon was observed in a previous study where surface electromyography (EMG), which is indicative of motor unit recruitment levels, demonstrated lower activity during BFR sessions than during high-intensity resistance training sessions (15). Additionally, it appears that low-intensity resistance training with BFR alone fails to sustain increased muscle activation over the long term. Evidence from a study spanning 12 weeks of training showed that only the high-intensity resistance training group achieved a significant increase in activation levels from 93.5% to 96.5%, whereas the low-intensity resistance training with BFR group did not exhibit such improvement (16). Therefore, the combination of heavy-load sets and low-load sets, as implemented in the current study, may serve to mitigate this effect and ultimately lead to greater strength gains compared to low-load sets alone.

Building upon the logical conclusions drawn from previous research, as proposed by Cognetti and team, the low-intensity nature of BFR training may serve as a means to mitigate the mechanical stress exerted on the joints, in contrast to high-intensity training, while still facilitating enhancements in strength (17). Our study appears to align with this assertion, as our data revealed notable increases in both elbow flexion and knee extension strength following just three weeks of training, but reduced some heavy sets to low-intensity sets. Additionally, Scott and colleagues recommended the incorporation of low-intensity resistance training with BFRs into appropriately designed stages of periodized athletic training plans as a strategy to mitigate potential adverse effects stemming from high overall training loads (9).

Despite the minimal number of training sessions, the substantial 23% increase in knee extension strength observed in the current pilot study stands out as remarkably impressive compared to similar studies conducted within similarly short timeframes. For instance, Clark and colleague reported a mere 8% increase in isometric knee extension force following 4 weeks of training using a low-intensity protocol combined with BFR, with a total of 12 sessions (18), which is four times more than the sessions conducted in our current pilot study. Similarly, Martin-Hernandez and colleagues structured a 5-week training regimen with BFR, wherein knee extension strength increased by only 2–6% following a total of 10 sessions conducted twice per week (19). Hence, the pBFR strength protocol employed in our study offers an attractive and feasible strategy for significantly enhancing knee extensor muscle strength within a very short timeframe and with a minimal number of sessions.

In a previous study, Moore and colleague investigated neuromuscular adaptations to low-intensity resistance training with BFR utilizing elbow flexion exercises at 50% of 1 RM (20). They found significant increases in maximal voluntary dynamic strength (up to 22%) and maximal voluntary isometric strength (up to 10%, approximately 6 newtons) after 8 weeks (20). Our study corroborates these findings, showing a substantial increase (approximately 12 newtons) in maximal isometric strength post-training, likely due to heightened neuromuscular activation. Notably, our protocol, which combined strength protocol, resulted in superior gains compared to the previous study focus solely on low-intensity training with BFR (20), suggesting that the rationale behind our strength-protocol, that structuring heavy and light load sets with pBFR could lead to superior gains in maximal strength within a shorter timeframe.

CONCLUSION

In conclusion, the findings of this study highlighted the efficacy of the short-course strength protocol in achieving significant improvements in muscle strength within a 3-week timeframe. Considering that pBFR was inexpensive and accessible to almost every practitioner, this enhancing technique was worthy of attention. The observed enhancements in both elbow flexion and knee extension strength underscored the effectiveness of training. It was evident that this approach yielded promising results. We suggested this protocol be optional in practical settings, offering a minimal strength protocol to maximize strength within a limited period of time.

REFERENCES

1. Suchomel TJ, Nimphius S, Bellon CR, Stone MH. The Importance of Muscular Strength: Training Considerations. Sports Med. 2018;48(4):765–785. https://doi.org/10.1007/s40279-018-0862-z
2. American College of Sports Medicine. American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. Med Sci Sports Exerc. 2009;41(3):687–708. https://doi.org/10.1249/MSS.0b013e3181915670
3. Kasper K. Sports Training Principles. Curr Sports Med Rep. 2019;18(4):95–96. https://doi.org/10.1249/JSR.0000000000000576
4. Cuffe M, Novak J, Saithna A, Strohmeyer HS, Slaven E. Current Trends in Blood Flow Restriction. Front Physiol. 2022;13:882472. https://doi.org/10.3389/fphys.2022.882472
5. Wortman RJ, Brown SM, Savage-Elliott I, Finley ZJ, Mulcahey MK. Blood Flow Restriction Training for Athletes: A Systematic Review. Am J Sports Med. 2021;49(7):1938–1944. https://doi.org/10.1177/0363546520964454
6. Hwang PS, Willoughby DS. Mechanisms Behind Blood Flow-Restricted Training and its Effect Toward Muscle Growth. J Strength Cond Res. 2019;33 Suppl 1:S167–S179. https://doi.org/10.1519/JSC.0000000000002384
7. Pearson SJ, Hussain SR. A review on the mechanisms of blood-flow restriction resistance training-induced muscle hypertrophy. Sports Med. 2015;45(2):187–200. https://doi.org/10.1007/s40279-014-0264-9
8. Pope ZK, Willardson JM, Schoenfeld BJ. Exercise and blood flow restriction. J Strength Cond Res. 2013;27(10):2914–2926. https://doi.org/10.1519/JSC.0b013e3182874721
9. Scott RB. Using Blood Flow Restriction Strategies to Manage Training Stress for Athletes. J Aust Strength Cond. 2014;22(6):84-90.
10. Lixandrao ME, Ugrinowitsch C, Berton R, Vechin FC, Conceição MS, Damas F, et al. Magnitude of Muscle Strength and Mass Adaptations Between High-Load Resistance Training Versus Low-Load Resistance Training Associated with Blood-Flow Restriction: A Systematic Review and Meta-Analysis. Sports Med. 2018;48(2):361–378. https://doi.org/10.1007/s40279-017-0795-y
11. Schoenfeld BJ. Science and Development of Muscle Hypertrophy. Human Kinetics. 2020.
12. Yasuda T, Ogasawara R, Sakamaki M, Ozaki H, Sato Y, Abe T. Combined effects of low-intensity blood flow restriction training and high-intensity resistance training on muscle strength and size. Eur J Appl Physiol. 2011;111(10):2525–2533. https://doi.org/10.1007/s00421-011-1873-8
13. Laurentino GC, Ugrinowitsch C, Roschel H, Aoki MS, Soares AG, Neves M Jr, et al. Strength training with blood flow restriction diminishes myostatin gene expression. Med Sci Sports Exerc. 2012;44(3):406–412. https://doi.org/10.1249/MSS.0b013e318233b4bc
14. Thiebaud RS, Loenneke JP, Fahs CA, Rossow LM, Kim D, Abe T, et al. The effects of elastic band resistance training combined with blood flow restriction on strength, total bone-free lean body mass and muscle thickness in postmenopausal women. Clin Physiol Funct Imaging. 2013;33(5):344–352. https://doi.org/10.1111/cpf.12033

15. Cook SB, Murphy BG, Labarbera KE. Neuromuscular function after a bout of low-load blood flow-restricted exercise. Med Sci Sports Exerc. 2013;45(1):67–74. https://doi.org/10.1249/MSS.0b013e31826c6fa8
16. Kubo K, Komuro T, Ishiguro N, Tsunoda N, Sato Y, Ishii N, et al. Effects of low-load resistance training with vascular occlusion on the mechanical properties of muscle and tendon. J Appl Biomech. 2006;22(2):112–119. https://doi.org/10.1123/jab.22.2.112
17. Cognetti DJ, Sheean AJ, Owens JG. Blood Flow Restriction Therapy and Its Use for Rehabilitation and Return to Sport: Physiology, Application, and Guidelines for Implementation. Arthrosc Sports Med Rehabil. 2022;4(1):e71–e76. https://doi.org/10.1016/j.asmr.2021.09.025
18. Clark BC, Manini TM, Hoffman RL, Williams PS, Guiler MK, Knutson MJ, et al. Relative safety of 4 weeks of blood flow-restricted resistance exercise in young, healthy adults. Scand J Med Sci Sports. 2011;21(5):653–662. https://doi.org/10.1111/j.1600-0838.2010.01100.x
19. Martín-Hernández J, Marín PJ, Menéndez H, Ferrero C, Loenneke JP, Herrero AJ. Muscular adaptations after two different volumes of blood flow-restricted training. Scand J Med Sci Sports. 2013;23(2):e114–e120. https://doi.org/10.1111/sms.12036
20. Moore DR, Burgomaster KA, Schofield LM, Gibala MJ, Sale DG, Phillips SM. Neuromuscular adaptations in human muscle following low intensity resistance training with vascular occlusion. Eur J Appl Physiol. 2004;92(4-5):399–406. https://doi.org/10.1007/s00421-004-1072-y