The Efficacy of Blood – Flow Restricted Compared with Heavy – Load Strength Training on Muscle Strength: A Systematic Review and Meta – Analysis

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Abstract. Background: Blood-Flow Restricted (BFR) and Heavy-Load Strength Training (HLT) are exercises beneficial for muscle strength. Many opinions or studies conclude that one of them is superior. Therefore, this study aims to compare the effects of BFR and HLT exercises on muscle strength. Method: Systematic research was conducted in five databases (MEDLINE, EmbaseMBASE, CINAHL, Web of Science, and SportsDiscus). A systematic review and meta-analysis were carried out on a Randomized Controlled Trial (RCT) comparing BFR and HLT exercises on muscle strength. Then, the assessment of study quality utilized the PEDro scale. Results: Six studies were presented in the review. The meta-analysis performed on the leg press exercise using one repetition maximum (1RM) uncovered evidence that the BFR exercise had no significant change compared to the HLT exercise, with statistical results (95% CI, -1.27 [-8.57, 6.03]). Conclusion: BFR and HLT exercises are beneficial interventions for individuals and produce the same effect on muscle strength.

Keywords: Blood Flow Restricted · Heavy Load Strength Training · Muscle Strength

1 Introduction

Strength is one of the human abilities needed to perform movements during daily activities and is one of the essential factors in sports since it is related to agility, speed, and accuracy. Factors affecting muscle strength include individual factors such as exercise training, food intake, sports supplements, and musculoskeletal health [1–4]. In addition, muscle strength has excellent benefits, i.e., not easy to feel tired, reducing the risk of injury, reduced body fat, muscle degradation prevention, and can increase energy to carry out daily activities [3, 5–7].

In this case, Heavy-Load Strength Training (HLT) is a form of weight training or resistance training that can help to increase skeletal muscle strength [8–10]. The American College of Sports Medicine (ACSM) suggests that adults do Heavy-Load Strength

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Training (HLT) regularly with an external load of 60%-90% of 1-Repetition Maximum (1RM) so that the muscles work to maximize their strength [11]. Heavy-Load Strength Training (HLT) exercise with a load of 60–80% of 1RM is further enormously beneficial for increasing muscle strength, muscle size, and neural adaptation [12–14].

On the other side, a systematic review and meta-analysis of recent years have shown that Blood – Flow Restricted (BFR) is highly efficient for increasing skeletal muscle strength and muscle hypertrophy in healthy adults [15–17]. Blood-Flow Restricted is a way in which the restriction of blood flow enters through the arteries and limits some of what goes out through the veins when the muscles contract during exercise [17, 18]. The latest meta-analysis revealed that strength training with 10–40% of 1RM with BFR could increase muscle mass, the same as strength training with 70–92% of 1RM without BFR [15, 19, 20].

Several previous studies have demonstrated that Blood-Flow Restricted (BFR) exercise is superior to Heavy-Load Strength Training (HLT) training in generating muscle hypertrophy and promoting muscle growth. As opposed to the previous argument, a recent meta-analysis assessing BFR exercise in a mixed group of clinical patients and healthy adults and elders revealed that BFR was less effective than HLT [21–23].

Therefore, this study aims to ascertain the difference between the effect of Blood-Flow Restricted and Heavy-Load Strength Training on muscle strength.

2 Method

This study utilized a systematic review and meta-analysis method based on the Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA).

2.1 Search Strategy

The following electronic databases were searched to find relevant studies: MEDLINE, EmbaseMBASE, CINAHL, Web of Science, and SportsDiscus, with a publication period from 2011 to 2018. The following terms were applied to multiple search databases: "Heavy Load Strength Training," "Blood-flow restricted," and "muscle strength."

2.2 Eligibility Criteria

The study was conducted with the following inclusion criteria: (1) a Randomized Controlled Trial (RCT), (2) individuals aged 18 years, and (3) a comparison between the effect of Heavy-Load Strength Training and Blood-Flow Restricted on muscle strength. Meanwhile, the exclusion criteria in this study were as follows: (1) unhealthy individuals and (2) articles not available in English.

2.3 Study Selection

The study search process was carried out in two steps: title or abstract screening and reading the full text. The study was excluded if it did not meet the inclusion criteria or if there were exclusion criteria. The screening process was approved by researchers and inspected by two reviewers (SSP and ANA).

2.4 Data Extraction

Each article's data was extracted, including the study author, study design, year, sample size, population, intervention, and outcome measure. The mean value, standard deviations, and samples were extracted to calculate the influence value obtained using review manager software version 5.4 and reviewed by two reviewers (SSP and ANA).

2.5 Quality Assessment

Assessment of the risk of bias from each study used the PEDro scale. In general, study quality in the PEDro scale is related to specific eligibility criteria, random allocation of participants or subjects, hidden allocation, similar groups at baseline regarding prognostic indicators, blind review, outcome measures obtained by more than 85% of participants or subjects with treatment intention, and statistical comparison results. The risk of bias was carried out to evaluate the studies' quality. (See Table 2).

2.6 Data Synthesis

The meta-analysis was processed utilizing Review Manager version 5.4 using continuous data: the mean, standard deviation, and total. The data needed were (1) 95% confidence interval data changes between pre- and post-intervention in each group; (2) when the value is $p > 0.05$, there is a substantial difference; conversely, when it is $p > 0.05$, there is no substantial difference.

3 Results

In the initial search, 3301 articles were identified. A total of 63 were left after duplicate removal, title filtering, and abstract. The remaining articles included and were eligible to enter the analysis were six articles. The PRISMA flowchart is depicted in Fig. 1.

3.1 Study Characteristics

In this study, the total number of participants was 207 healthy people. The measurement appliance used to calculate muscle strength was 1 RM, and the entire study discusses BFR and HLT exercises for muscle strength. (See Table 1).

3.2 Meta-analysis

3.2.1 Muscle Strength

Three studies provided data on the 1RM assessment of BFR and HLT exercises. Results from those studies showed no significant differences in patients who did BFR exercise compared to HLT exercise: MD: (95% CI, -1.27[-8.57, 6.03]); p-value = 0.73 (Chi2 = 0.85, df = 2, and p-value = 0.65; I 2 = 0%). (See Fig. 2).

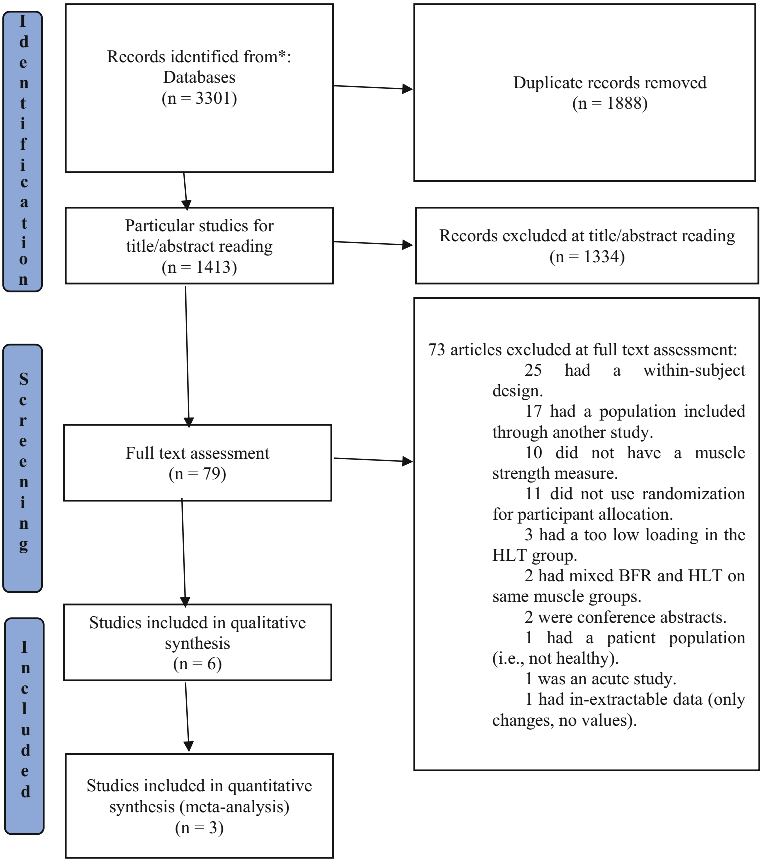

Fig. 1. The flow of studies through the review with PRISMA

3.3 Systematic Review

3.3.1 Leg Curl

Similar research regarding this topic has already been written and conducted by Cook et al. (2017). Their research explains that there is no difference in leg curl strength after BFR and HLT exercises using maximum voluntary contraction (MVC) ($p = 0.12$).

3.3.2 Quadriceps Cross-Sectional Area (CSAq)

Research conducted by Libardi et al. (2015) explained no significant difference between HLT or BFR training on muscle strength using magnetic resonance imaging (MRI) ($p = 0.13$).

Table 1. Characteristics of Included Studies

NO	AUTHOR	STUDY DESIGN	SAMPLE	POPULATION	INTERVENTION	COMPARISON	OUTCOME	RESULT
1	Tomohiro Yasuda et al. (2011)	RCT	N: 40	HLT: 10 BFR: 10 Combination of HL-BFR: 10 CON: 10	HLT: Leg Press (75% from 1-RM) BFR: Leg Press (30% from 1-RM) Combination: (BFR 2x a week, HLT 1x a week) CON: Non-training	control group (CON)	Strength: 1-RM	HLT: 47.3 BFR: 49.3 Combination: 49.8 CON: 52.8
2	FELIPE C. VECHIN et al. (2015)	RCT	N: 23	HLT: 8 BFR: 8 CON: 7	HLT: Leg Press (70–80% from 1-RM) BFR: Leg Press (20–30% from 1-RM) CON: Non-training	control group (CON)	Strength: 1-RM	HLT: 89 BFR: 43 CON: 93
3	Summer B. Cook et al. (2018)	RCT	N: 18	HLT: 6 BFR: 6 CON: 6	HLT: Leg Press (70% from 1-RM) BFR: Leg Press (20% from 1-RM) CON: Non-training	control group (CON)	Strength: 1-RM	HLT: 8.9 BFR: 7.7 CON: 9.1

(*continued*)

Table 1. (*continued*)

NO	AUTHOR	STUDY DESIGN	SAMPLE	POPULATION	INTERVENTION	COMPARISON	OUTCOME	RESULT
4	C. A. Libardi et al. (2015)	RCT	N: 25	HLT: 8 BFR: 10 CON: 7	HLT: leg Press (70–80% from 1-RM) BFR: leg Press (20–30% from 1-RM) CON: Non-training	control group (CON)	Quadriceps cross-sectional area (CSAq)	HLT: 7.3 BFR: 7.6 CON: -2.2
5	Summer B. Cook et al. (2017)	RCT	N: 36	HL: 12 BFR: 12 CON: 12	HLT: Exercises for knee extensors and flexors with weights (70% of 1-RM) twice per week for 12 weeks BFR: Exercises for knee extensors and flexors with weights (30% of 1-RM) twice per week for 12 weeks CON: Light upper body resistance and flexibility training	control group (CON)	Maximum voluntary contraction (MVC)	HLT: 19.3 (8.3–30.3) BFR: 11.2 (-2.7–25.0) CON: 3.5 (-7.3–14.3)

(*continued*)

Table 1. (*continued*)

NO	AUTHOR	STUDY DESIGN	SAMPLE	POPULATION	INTERVENTION	COMPARISON	OUTCOME	RESULT
6	Rubens Vinícius Letieri et al. (2018)	RCT	N: 56	HLT: 22 BFR: 22 CON: 12	HLT: Squats, Knee Extension and Leg Curl with weights, Leg Press (70–80% of 1-RM) BFR: Squat, Leg Press, Knee Extension, and Leg Curl with weights (20–30% of 1-RM CON: Non-training	control group (CON)	Maximum isokinetic torque (Nm)	HLT: 91.7 BFR: 93.51 CON: 80.54

BFR: Blood-Flow Restricted; HLT: Heavy-Load Strength Training; RCT: randomized controlled trials

Table 2. Risk of Bias Utilizing PEDro Scale

Author	Item											
	1	2	3	4	5	6	7	8	9	10	11	Total
Yasuda et al. (2011)	Y	Y	Y	Y	N	N	Y	Y	N	Y	N	6
Vechin et al. (2015)	Y	Y	N	Y	N	N	Y	Y	N	Y	Y	6
Cook et al. (2018)	Y	Y	Y	Y	N	N	N	Y	N	Y	Y	6
Libardi et al. (2015)	Y	Y	Y	Y	Y	N	N	N	N	Y	Y	6
Cook et al. (2017)	Y	Y	N	Y	Y	N	Y	Y	Y	Y	Y	6
Letieri et al. (2018)	Y	Y	N	Y	Y	N	N	N	N	Y	Y	5

Y: yes; N: no.
*1. Eligibility criteria; 2. Random allocation; 3. Hidden allocation; 4. Baseline comparability; 5. Blinding subject; 6. Blinding therapist; 7. Blinding assessors; 8. Outcome data obtained more than 85%; 9. Intention to treat; 10. Comparisons group result; 11. Point measures.
**Total 10-point PEDro scale score (items 2 through 11); 0–3 "poor," 4–5 "fair," 6–8 "good," 9–10 "excellent".

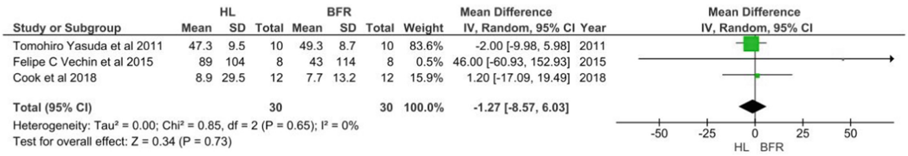

Fig. 2. Forest Plot: Blood-Flow Restricted and Heavy-Load Strength Training Score

3.3.3 Knee Extension

Letieri et al.'s (2018) research reported a substantial difference before and after treatment with $p < 0.05$ in knee extension strength. The HLT exercise exposed a more significant muscle strength difference than the BFR exercise.

4 Discussion

A systematic review and meta-analysis revealed that BFR and HLT exercises are effective interventions for increasing muscle strength in individuals. The main objective of this review is to ascertain whether BFR exercise results in a better increase in muscle strength than HLT exercise. Data from the three studies collected were then included in a meta-analysis, with the result that there was no substantial difference in BFR exercise and HLT exercise on muscle strength.

On the other hand, applying Blood-Flow Restrictions with Heavy Load Strength Training did not substantially improve muscle strength, according to Grondfelt et al. (2020), apart from the significant difference in the intensity of the external load used (BFR: 20% -30% 1RM vs. HLT: 60%-90% 1RM) [8, 24].

The fundamental reasons for doing BFR and HLT exercises for muscle strength are to minimize loss of muscle strength, avoid injury, and maintain and improve one's quality of life. One of the easiest alternatives to HLT exercises for the elderly is walking, which helps maintain muscle mass and strength in the elderly [25]. Meanwhile, BFR exercise is characterized by the movement of the limbs being given a pressure cuff to restrict the blood flowing towards the limbs during exercise [17, 26].

In a study, Grønfeldt et al. (2020) revealed that HLT exercise is considered one of the exercise modalities used to increase skeletal muscle strength. However, the appliance of weighty external loads cannot be given to weak people who are in rehabilitation after injury or surgery and have musculoskeletal disorders [27, 28]. To overcome the high risk of injury, it is recommended to do BFR exercises whose purpose remains the same, i.e., to strengthen muscles. BFR is also an alternative exercise since the risk of injury is very small, even though the effect of BFR training is smaller than HLT [29].

According to Cook et al. (2017), the beneficial effects of BFR and HLT exercises for leg curl strength did not change significantly but were distinct in studies by Elefsen et al. (2015) and Martín-Hernández et al. (2013), which disclosed an increase in leg curl strength after BFR and HLT workouts [30, 31, 32]. Meanwhile, in Cook et al.'s research (2018), there was no change because the patients given this exercise were weak and at risk for mobility due to limitations [30].

Furthermore, HLT and BFR exercises are equally beneficial to strengthen muscles during knee extension. However, Letieri et al.'s (2018) research stated that HLT exercise experienced significant changes compared to BFR [33]. It was due to the external burden factor, which significantly impacted healthy participants, so HLT had a substantial effect [34]. HLT workouts can also build muscle and improve strength in the lower limbs for young people and the elderly [35].

The advantage of this study is that it provides an overview of the effectiveness of the BFR intervention with HLT so that it can be considered for strengthening exercises. Nevertheless, this study has some limitations, including a lack of research comparing BFR with HLT training and a few discussing muscle strengths. Hopefully, in the future, there will be many studies discussing BFR and HLT, both subjectively and objectively.

5 Conclusion

This meta-analysis study was conducted to compare Blood-Flow Restricted (BFR) with Heavy-Load Strength Training (HLT) on muscle strength. The meta-analysis's outcome revealed no substantial distinction between BFR and HLT exercises for muscle strength.

Moreover, BFR and HLT exercises are beneficial for muscle strength. In clinical practice, it is recommended that the physiotherapist monitor the patient while doing this exercise, and for the elderly patients, they consider giving the load according to their ability. In addition, readers are expected to carry out exercises under the supervision of a physiotherapist or other person who is an expert in their field.

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