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Effect of Blood Flow Restriction Resistance Training on Elbow Joint Muscle Strength

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Abstract

Blood flow restriction training combined with low-intensity resistance training is associated with increases in muscle strength and size. The effect of blood flow restriction resistance training on muscle strength at the elbow joint is unknown. The purpose of this systematic review was to explore the effects of blood flow restriction resistance training compared with traditional low or high-intensity resistance training on muscle strength at the elbow. Relevant literature from 3 databases was searched. Risk of bias was assessed using the PEDro scale. Eventually, 1502 literatures were retrieved, and 11 of these high-quality literatures were included in the review after screening out. blood flow restriction resistance training significantly increased elbow flexor and extensor muscle strength and muscle size. Blood flow restriction training combined with low-intensity resistance training was superior to low-intensity resistance training alone in terms of muscle strength and size during long-term training and achieved a similar level of traditional high-intensity resistance training, which was applicable during both isometric and isotonic training. It can be carried out in healthy adults or patients who are significantly weakened and unable to perform conventional strength training.

Keywords: resistance training; blood flow restriction training; elbow muscle; muscle strength; systematic review;

Introduction:

Kaatsu training, also known as blood flow restriction training (BFRT), is an emerging training method. During BFRT, physical compression methods such as elastic band compression and pneumatic compression band compression are often used to apply appropriate pressure to the proximal limb[1], allowing part of the arterial blood to flow and restricting venous reflux, and combining with means such as resistance training or aerobic training, so as to efficiently achieve the purpose of training, such as increasing muscle volume, improving muscle strength, and improving aerobic capacity [2]. Its advantage is that through the small intensity resistance exercise with the way of pressurization to fully stimulate the muscle mechanical stress and metabolic stress of the body of both stimulation, to strengthen the effect of exercise, and then reduce the traditional large load (≥ 70% 1RM) resistance training to promote the increase in strength may be brought about by the risk of injury[3], thus become a hotspot in the field of athletic training and medical rehabilitation research.

For an emerging training method, diversified validation analyses are required to assess the application of various pressurized positions on the limbs. The elbow joint, being one of the most susceptible parts of the human body to subluxation, is evidently crucial for related muscle strength exercises and post-injury rehabilitation treatments for patients with a variety of shoulder or elbow joint disorders. The purpose of this paper is to summarize previous empirical studies on the effects of blood flow restriction resistance training (BFRRT) on elbow flexor and extensor muscles, to explore the differences between BFRRT and resistance training of varying intensities, with the aim of providing a reference for subsequent research.

Research Methodology

To search the literature on applied BFRRT of the elbow joint published in PubMed, Cochrane Library and Web of Science Core Collection databases, the database search strategy was (using pubmed as an example): ((Blood Flow Restriction) OR (Blood Flow Restriction Therapy)) OR (vascular occlusion training)) OR (Blood Flow Restriction Exercise)) OR (Blood Flow Restriction Training)) OR (KAATSU)) AND ((Upper Extremity) OR (Upper Limb)) OR (Arm)) OR (Forearm)) OR (Elbow)). Literature related to applied BFRRT of the elbow joint of the upper extremity included in each database from its construction to November 6, 2024 was selected and the resulting literature was screened according to the inclusion and exclusion criteria.

The inclusion criteria included that (1)Subjects were independent, with no age or health status requirements; (2)included in the experimental intervention were BFRRT and the intervention had to include upper extremity elbow flexion/extension resistance training; (3) the control group of the experimental design was resistance training without blood flow restriction, or no exercise intervention group; (4)included outcome measures that reflected biceps or triceps muscle strength, muscle cross-sectional area; (5)A randomized controlled trial or quasi-experimental study design with an intervention period of greater than or equal to 2 weeks and with a minimum of five sessions.The exclusion criteria criteria included that (1) exclude duplicate publications; (2) exclude case reports, registry protocols, and reviews; (3) exclude publications where the duration of the pressurized antihistamine training intervention at the elbow is too short; (4) exclude publications that cannot be downloaded to read the full text; and (5) exclude publications that contain only controls of their own limbs.

Research Results

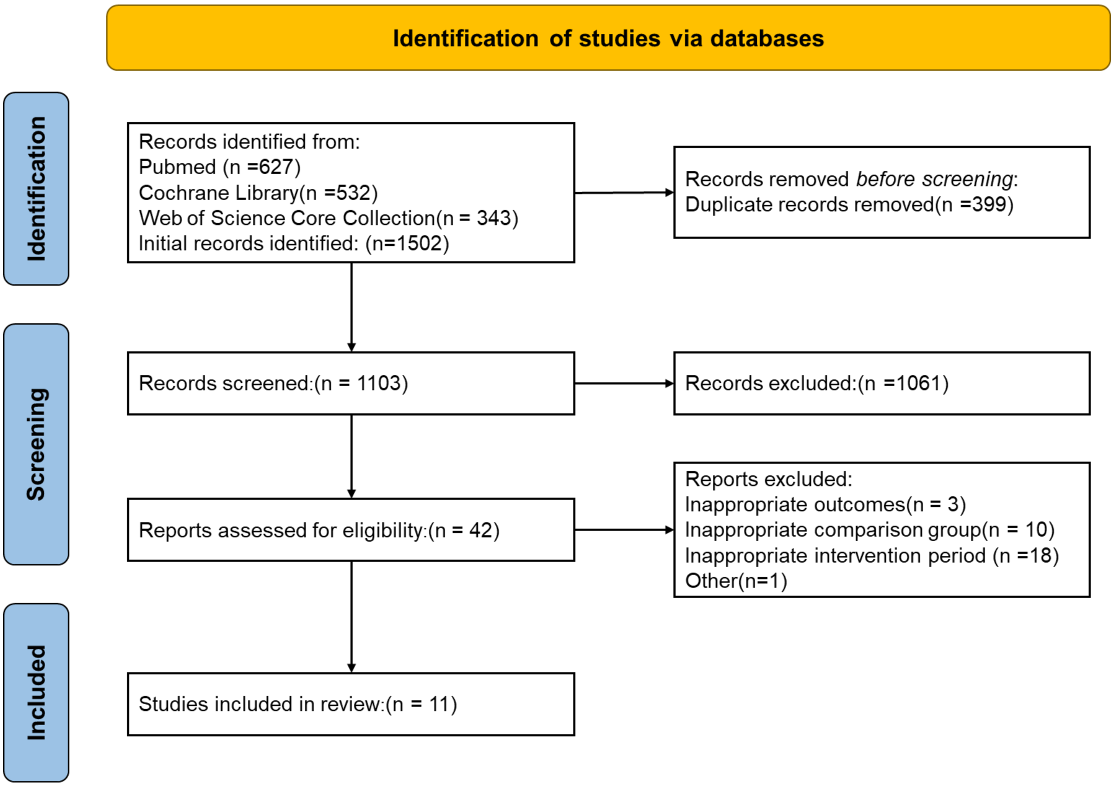

Figure 1 Flowchart of literature incorporation

The flow chart of literature inclusion is shown in Figure 1. Finally, 11 literatures were included for review .Literature quality was evaluated using the Physiotherapy Evidence Database (PEDro) scale[4]. The scale was evaluated by a score; if the score was ≤5, the literature was of low quality; if the score was >5, the literature was of high quality. The results of the methodological quality evaluation of the included literature are shown in Table 1, and the total score of the included literature was between 5 and 7, and the quality of the literature was high. A total of 11 literature met the inclusion criteria. In terms of exercise intensity, 5 literature explored the effect of low-intensity BFRRT versus traditional high-resistance training, 5 literature was a comparison of low-intensity BFRRT versus low-intensity resistance training, and 1 article was an exploration of the Eccentric and concentric training mode of BFRRT. In terms of exercise intensity, 3 articles were isometric resistance training and 8 articles were isotonic resistance training. The study population contained HIV patients, older adults, and healthy men and women. Basic information of the included literature are shown in Table 2.

Table 1 Methodological quality of the included literature (PEDro scale)

PEDro meters	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**totals**
Alves et al.[5](2020)	√	√	0	√	0	0	0	√	√	√	√	7
Bowman et al.[6](2020)	√	√	√	0	0	√	0	√	√	√	0	7
Hill et al.[7](2020)	0	√	0	√	0	0	0	√	√	√	√	6
Keller et al.[8](2021)	0	√	0	0	0	0	0	√	√	√	√	5
Lowery et al.[9](2014)	0	√	0	√	0	0	√	√	√	√	√	7
Takarada et al.[10] (2000)	0	0	0	√	0	0	0	√	√	√	√	5
Yasuda et al.[11](2010)	0	√	0	√	0	0	0	√	√	√	√	6
Yasuda et al.[12](2011a)	0	√	0	√	0	0	0	√	√	√	√	6
Yasuda et al.[13](2011b)	√	√	0	√	0	0	0	√	√	√	√	7
Yasuda et al.[14](2015)	√	0	0	√	0	0	0	√	√	√	√	6
Hill et al.[15](2018)	0	√	0	√	0	0	0	√	√	√	√	6

Note：1. Eligibility criteria and source 2. Random allocation 3. Concealed allocation 4. Baseline comparability 5. Blinding of participants 6. Blinding of therapists 7. Blinding of assessors 8. Adequate follow-up (＞85%) 9. Intention-to-treat analysis 10. Between-group statistical comparisons 11.Reporting of point measures and measures of variability

Table 2 Basic information of the included literature

author (Year)	**participant**	**Experimental grouping/exercise intensity/ Content of the intervention**	**pressure**	**Training cycle/ frequency**	**reach a verdict**
Alves et al.[5] (2020)	AIDS patient 22	BFRRT (n=7) (30% 1RM) HI (n=7) (80% 1RM) CG (n=8) Bilateral elbow extension flexion	100% venous occlusion pressure Continuous pressurization	12 weeks 3 times a week	Low-intensity BFRRT achieves a similar level of traditional high-intensity resistance training
Bowman et al.[6] (2020)	Healthy Adults 24	BFRRT (n=14) (30% 1RM) LL-RT (n=14) own limb CG (n=10) 20 limbs Biceps curl while standing Triceps extension while lying on back	60% AOP continues to pressurize Pressure weekly adjustments	6 weeks 2 times per week	Low-intensity BFRRT is superior to low-intensity resistance training
Hill et al.[7] (2020)	Healthy Women 30	BFRRT (n=10) (30% peak torque) LI-RT (n=10) (30% peak torque) CG (n=10) Forearm flexion and extension muscles	40% AOP continues to pressurize	4 weeks 3 times a week	Low-intensity BFRRT is superior to low-intensity resistance training alone in terms of muscle strength
Keller et al.[8] (2021)	Healthy Women 20	BFRRT (n=10) (30% peak torque) LI-RT (n=10) (30% peak torque) Forearm flexion and extension muscles	40% AOP continues to pressurize	2 weeks Total 7 exercises	No significant difference between low-intensity BFRRT and low-intensity resistance training
Lowery et al.[9] (2014)	Healthy men 20	BFRRT-HI (n=10) (30%1RM-60%1RM) HI-BFRRT (n=10) (60%1RM-30%1RM) biceps curl	6-7/10 pBFR	8 weeks 2 times per week	Low-intensity BFRRT achieves a similar level of traditional high-intensity resistance training

Takarada et al.[10] (2000)	Older women 24	BFRRT (n=11) (50% 1RM) HI (n=8) (80% 1RM) CG (n=5) Seated one-arm dumbbell curls	110 mmHg continuous pressurization	16 weeks 2 times per week	Low-intensity BFRRT achieves a similar level of traditional high-intensity resistance training
Yasuda et al.[11] (2010)	Young men 10	BFRRT (n=5) (30% 1RM) LL-RT (n=5) (30% 1RM) Bench Press Exercise	Incremental intermittent pressurization: 100-160 mmHg (+10 mmHg/d)	2 weeks Six days a week. 2 times a day	Low-intensity BFRRT is superior to low-intensity resistance training
Yasuda et al.[12] (2011a)	Young men 30	BFRRT group (n=10) (30% 1RM) HI (n=10) (75% 1RM) CG (n=10) bench press exercise	Incremental intermittent pressurization: 100-160 mmHg (+10 mmHg/d)	6 weeks 3 times a week	Low-intensity BFRRT is not as significant a change as traditional high-intensity resistance training
Yasuda et al.[13] (2011b)	Young men 40	HI (n=10) (75% 1RM) LI-BFRRT (n=10) (30% 1RM) Combined training group (n=10) CG (n=10) bench press exercise	Incremental intermittent pressurization: 100-160 mmHg (+10 mmHg/d)	6 weeks 3 times a week	Low-intensity BFRRT is not as significant a change as traditional high-intensity resistance training
Yasuda et al.[14] (2015)	Healthy Older People 17	BFRRT (n=9) LL-RT (n=8) Bilateral arm curls and triceps press downs	120mmHg to 270mmHg, 10-20mHg each time	12 weeks 2 times per week	Low-intensity BFRRT is superior to low-intensity resistance training
Hill et al.[15] (2018)	Healthy Women 36	CON-BFRRT (n=12) (30% peak torque) ECC-BFRRT (n=12) (30% peak torque) CG (n=12) forearm flexors and extensors	40% AOP Continuous Pressurization	4 weeks 3 times a week	No significant difference between concentric and Eccentric low-intensity BFRRT

Note: BFRRT: blood flow restriction resistance training group; HI: high-intensity resistance training group; LI: low-intensity ;RT: resistance exercise; CG: no exercise intervention control group; 1RM: the maximum can be repeated once the weight; NA:: the text is not mentioned; AOP: resting arterial occlusion pressure; pBFR; practical blood flow restriction training (practical blood flow restriction); mmHg: millimeters of mercury （AOP: arterial occlusion pressure;

The Effects of Blood Flow Restriction Resistance Training on Elbow Elbow Joint Muscle Strength

Compared to the low-intensity resistance training, low-intensity BFRRT results in greater muscle strength and hypertrophy regardless of age[6,7,11,14] .increases in upper arm and forearm circumference and elbow flexion strength were observed in the pressurized limb compared to the non-pressurized limb, and low-intensity BFRRT was superior to low-intensity resistance training alone.[6] In addition, low-intensity BFRRT was superior to low-intensity resistance training alone. The bench press exercise combined with BFRRT also significantly increased muscle size and strength of the triceps and pectoralis major muscles[11] A 12-week period of BFRRT combined with elastic band training in healthy older adults[14] In healthy older adults, 12 weeks of BFRRT combined with elastic band training was found to be ineffective in leading to significant muscle hypertrophy without blood flow restriction resistance intervention, whereas BFRRT with elastic band training improved muscle cross-sectional area and maximal muscle strength without negatively affecting arterial stiffness in older adults, both demonstrating the superiority of BFRRT compared with low-intensity resistance training in elbow strength gains.

Compared to traditional high-resistance training, low-intensity BFRRT induced similar muscle hypertrophy in both healthy people and AIDS patients[5,9,10,12,13] In the case of AIDS patients, 12 weeks of BFRRT induced increases in muscle strength, cross-sectional area, and isokinetic muscle power.[5] In terms of muscle strength, low-intensity BFRRT training achieved a similar level of increase to conventional high-resistance training, and the positive effects on muscle hypertrophy, body fat reduction, and muscle strength in patients with AIDS further validate that resistance training, which restricts blood flow, is an effective alternative to conventional strength training in a patient population that is significantly weakened and incapable of conventional strength training. takarada et al.[10] through a 16-week training intervention of force exhaustion, found that BFRRT at 50% 1RM intensity also achieved a similar degree of muscle strength and muscle size as conventional high-resistance training in an elderly population. Notably, the increase in muscle strength after low-intensity BFRRT in previous studies was less than the increase in muscle size[10,11] , suggesting that increases in muscle strength were closely related to changes in muscle hypertrophy and that increases in relative strength did not occur.

Blood Flow Restriction Resistance Training Patterns and Mechanisms

In isometrics training, there are no differences in neuromuscular responses between 4 weeks of low-intensity BFRRT and low-intensity resistance training[7]. There is a greater increase in concentric force volume with low-intensity BFRRT, but there are no significant differences in biceps thickness. The mechanism leading to the greater increase in concentric force volume is not thought to be related to muscle size or myoelectricity. There is an increase in maximal voluntary isometric contraction force in the low-intensity BFRRT group, which is almost twice as much as that of the low-intensity resistance training (42.1% vs. 23.3%)[8]. In the same way, in the 2-week short-term isokinetic training with low-intensity blood flow restriction, there are no significant changes in perceptual response, performance fatigue, and muscle strength, indicating that short-term isokinetic BFRRT does not necessarily reflect the advantages of BFRRT. There are no significant changes in muscle hypertrophy and neuromuscular adaptations with low-intensity BFRRT, but it can increase concentric force volume. Long-term low-intensity BFRRT can better improve muscle strength compared with low-intensity resistance training.

In addition to short-term training, due to the design of the own-limb control, the BFRRT may not reflect the advantages compared with the non-pressurized training, the reason may be the same body exercise caused by the hormone level changes and other factors, some scholars in the upper limb carried out eight weeks of the own-limb control pressurized intervention[16,17] The same body's pressurized limb did not show any advantage in muscle strength compared to the non-pressurized limb, probably due to the cross-migration phenomenon induced by the pressurized training. Grip strength was significantly increased in the non-pressurized limb in the pressurized training group compared to the limb in the non-exercise group[6] . This idea was also corroborated laterally. Thus, contralateral limb pressurization training may lead to potential cross-migratory effects, either because BFRRT induces the expression of relevant cytokines in vivo, circulates hormones produced by exercise in vivo, or affects the neurogenicity[18] At present, the neural mechanisms associated with cross-migration are still difficult to determine, and fewer articles have been published on the induction of cross-migration phenomenon by BFRRT. In future applications and experimental designs, the possible benefits of cross-migration phenomenon should be taken into account, and the feasibility and utility of BFRRT induced cross-migration phenomenon can be explored as well.

Four weeks of isokinetic concentric and Eccentric training for elbow flexion and extension[15] The findings that Eccentric and concentric exercise at the same load resulted in similar strength gains in eccentric peak moment, concentric peak moment, and maximal voluntary isometric contraction are inconsistent with traditional high-intensity resistance training, where increases in muscle strength and hypertrophy are typically greater with Eccentric-only training than with concentric-only resistance training at similar relative intensities, and where Eccentric training should be more efficient in terms of increase muscle mass[19] . Traditionally, it has been assumed that neural adaptations increase strength during the first few weeks of exercise and that muscle hypertrophy occurs later in the training period. Some scholars have quantitatively analyzed low-intensity BFRRT of the lower extremity, and have hypothesized that low-intensity BFRRT may reverse the traditional paradigm of training adaptations[20] The initial increase in strength may be entirely due to muscle hypertrophy, and prolonged bench press training[13] and forearm flexion pressurization[15] No significant changes in EMG signal amplitude were observed after either, presumably low intensity BFRRT would not elicit comparable neural adaptations as high intensity resistance training. The effects brought about by the included literature at the elbow joint validate the conclusions of BFRRT in previous lower extremity muscle strength. Early muscle hypertrophy brought about an increase in absolute strength with no neural adaptation yet, and short-term low-intensity BFRRT did not enhance neural fitness[7,10] This may be due to the fact that the elbow flexion and extension is an uncomplicated maneuver with simple neurological control of the muscles involved, and no new neural adaptations have been established resulting in no significant change in relative strength.

Conclusion

In summary, this study found that BFRRT increases the strength, muscle thickness, and muscle cross-sectional area of elbow flexor and extensor muscles. Low-intensity BFRRT is superior to low-resistance training alone in terms of muscle strength and size in long-term training and achieves a similar level of conventional high-resistance training, which is applicable in both isometric and isotonic training. It can be performed in healthy adults or in patients who are unable to perform conventional strength training. The increase in muscle strength and size may be due to early muscle hypertrophy that brings about absolute strength gains, and the relative strength does not increase. Short-term isokinetic training has a greater advantage in concentric strength growth, and does not cause muscle hypertrophy. In the action mode of elbow extension and bending, low-intensity pressure training does not produce new nerve fitness. There is potential for future research regarding the design of cross-migration phenomena in BFRRT.

Disclosure

Author's contribution

Conceptualization: Qian Liu; methodology: XiongZhuang XU; check: Li Peng; datacuration: XiongZhuang XU; supervision: Li Peng

Authors have read and agreed with the published version of the manuscript.

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The authors deny any conflict of interest.

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