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Review Article

Blood Flow Restriction (BFR) Therapy to Rehabilitate Muscle Injuries in Post-operative Knee Patient

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A B S T R A C T

KAATSU is a blood flow restriction training that was developed in Japan in the 1960s as a low-intensity strengthening exercise. It involves the wrapping of a tourniquet or pneumatic cuff over the muscle at a quick repetition rate during low-intensity muscle contractions. It is a muscle-strengthening technique used in physical therapy clinics to help patients regain muscle function following an injury or surgery. This is performed by temporarily cutting off blood flow to the muscles during the exercise.

There were no linguistic or regional limitations in the literature searches for this article. This review contains a total of 25 records. Other resources were used to define additional elements. 4 records were duplicated and removed from the database. A total of 21 documents were found, with two being ruled out based on the title and abstract. Only 19 full-text items were authorised, and among these, 7 were eliminated because they were urgent research, case studies, and in a few studies, physical characteristics were not examined. This review article finally contained a total of 12 papers.

Low-intensity exercise is used in blood flow restriction strengthening to achieve strength improvements similar to those seen in high-intensity training. BFR is a novel approach to physical therapy (PT). According to a preliminary study, this can result in adequate strength improvements during low-intensity exercise.

Keywords: Blood Restriction, Vascular Obstruction, Geriatric, Sarcopenia, Muscle Atrophy, Strength Training, Exercise Training

Introduction

KAATSU (blood flow restriction training) was developed in Japan in the 1960s as a low-intensity strengthening exercise. A tourniquet or pneumatic cuff is wrapped over the muscle at a quick repetition rate during low-intensity muscle contractions in this process. Blood Flow Restriction (BFR) training is a muscle-strengthening technique which is used in various physical therapy clinics. It helps the patients regain the muscle function that they had lost because of an injury or surgery. As the name suggests, this training involves cutting off blood flow temporarily to the muscles during exercise.[1]

It was earlier becoming more popular in gyms and lately, it has become quite common in physiotherapy clinics. This

is because low-intensity exercise can result in significant strength and growth. Muscles are mechanically stressed during blood flow restriction training (mechanical stress is also present during high-intensity muscle strengthening). These two variables (strength and growth) are present during high-intensity exercise, but they can also be achieved during low-impact training by restricting blood flow to the muscles. These limitations create an environment in which muscle growth can occur even with low training loads, which can be substantial following a surgery or injury. The body may not be able to put much tension on the muscles or ligaments as it is recovering from surgery. Blood flow restriction training maximises strength growth with minimal and safe exertion, and low-impact exercise may be required.

A doctor or physical therapist may allow the client to return to work or sports if the general condition and range of motion have improved. To maintain a healthy knee range of motion, strengthening and stretching during rehabilitation may be required. A therapist can use KAATSU, commonly known as blood flow restriction, in this scenario.

After recovery, using BFR on the post-operative knee is the best way to improve strength and stability. Knee strengthening is necessary for returning to the normal activity of daily living (ADL).

Methodology

Selection of Articles

There were no linguistic or regional limitations in the literature searches; the language included Spanish and Japanese which were translated into English through Microsoft translation extension. All the papers that reported the application of BFR were identified. Full texts of peer-reviewed publications in PubMed, Scopus, Google Scholar, Web of Science, CINAHL, CENTRAL, SPORTDiscus, EMBASE, and SciELO between January 1, 1998, and February 25, 2022, were included in the study. The search was made using the keywords blood restriction, occlusion, vascular obstruction, muscle atrophy, strength training, resistance training, exercise training, and lower limb. The University Ethics Committee approval was obtained for this study.

Study Design and Patients

The database contained a total of 25 records from 1998 to 2021. 4 records were duplicated and hence removed from the database. A total of 21 documents were found, with two being ruled out based on the title and abstract. Only 19 full-text items were approved, and among these, 7 were eliminated because they were acute studies, case studies, and in a few studies, physical characteristics were not examined to reduce variation. The final sample of this review article was twelve.

For each study, the rate of change in muscle strength and muscle mass [((MEAN $_{post}$ − MEAN $_{pre}$) / MEAN $_{pre}$) × 100] was calculated.

Figure 1 shows the steps by which the final 12 articles were selected.

Table 1 displays some information regarding the articles included in this review.

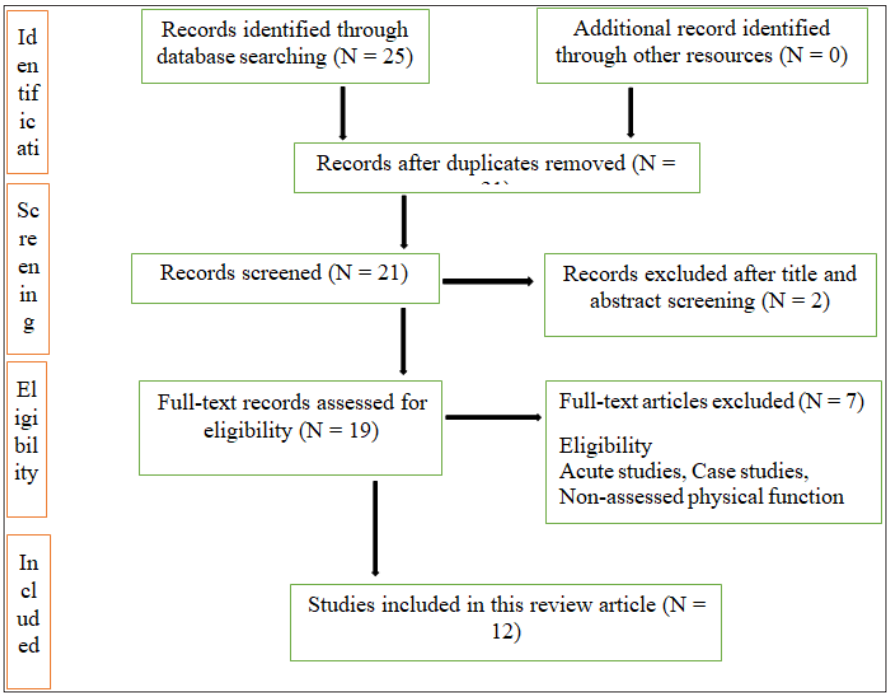

Figure 1.Flowchart of the Search Process (Search Criteria, Articles Selected and Excluded at Each Stage)

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Table 1.Overview of Studies included in this Review

Year/ DOI	Authors	Objective	Study Design/ Occlusion Pressure/ Cuff Width	Parameters	Method/ Duration	Conclusion
Published October 2014. (doi:10.1186 /s13075-014-0473-5)	Melina Andrade Mattar, Bruno Gualano, Luiz Augusto Perandini, Samuel Katsuyuki Shinjo, Fernanda Rodrigues Lima, Ana Lúcia Sá-Pinto, Hamilton Roschel	The researchers wanted to see if a low-intensity resistance training programme combined with partial blow flow restriction (BFR training) was safe and effective for a group of individuals with polymyositis (PM) and dermatomyositis (DM)	Prospective, longitudinal, quasi-experimental 70% left occipito-posterior position (LOP)/ 17.5 cm	Creatine kinase and aldolase were taken as laboratory measures.	4 weeks of 4 × 15 reps of bilateral leg press and knee extension exercises with BFR at 30% 1RM, 2 days/week, then 8 weeks of 5 × 15 reps, 2 days/week. It took a total of 12 weeks to complete the project.	In individuals with polymyositis (PM) and dermatomyositis (DM), a 12-week supervised low-intensity resistance exercise programme combined with partial blood flow restriction may be safe and effective in improving muscular strength, function, muscle mass, and health-related quality of life.[2]
Published June 2008. [Bioscience Trends, 2(3), 117-123]	Yoshiharu Yokokawa, Minoru Hongo, Hiroaki Urayama, Tazuko Nishimura, Ichiro Kai	Physical function in healthy elderly persons after low-intensity resistance exercise with vascular occlusion	Randomised controlled trial 70–150 mm Hg/ 4.5 cm	In 11 people, biochemical parameters, growth hormone levels in the blood, and lactate levels were analysed.	45 minutes of a combination of six different bodyweight movements. The period was 8 weeks in total.	Muscle strength in lower extremities was greatly raised in the moderate vascular occlusion (LIO) group, but not in the dynamic balance exercise (DBE) group. LIO resulted in a considerable increase in growth hormones. The 8-week LIO programme enhanced physical function, particularly muscle strength, which could be linked to growth hormone release produced by exercise.[3]

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Published 2010 [Journal of Geriatric Physical Therapy, 33(1), 34-40]	Takashi Abe, Mikako Sakamaki, Satoshi Fujita, Hayao Ozaki, Masato Sugaya, Yoshiaki Sato, Toshiaki Nakajima	Effects of low-intensity walking with restricted leg blood flow on muscle strength and aerobic capacity in seniors	Randomised controlled trial 160–200 mm Hg/NA	Ultrasound-estimated skeletal muscle mass, and peak oxygen uptake (absolute and related to body mass).	5 days a week, 20 minutes of treadmill walking with a BFR of 67 m/min. The period was 6 weeks in total.	The current study's findings show that 6 weeks of KAATSU-walk training did not increase older participants' cardiovascular and muscular fitness at the same time. Active older men and women, on the other hand, saw a considerable gain in muscular size and strength, as well as functional capacity.[4]
Published 2011 (DOI: 10.1177/00033 197103 75942)	Hayao Ozaki, Motohiko Miyachi, Toshiaki Nakajima, Takashi Abe	Carotid arterial compliance and muscle size in elderly adults after 10 weeks of walk training with leg blood flow reduction	Controlled trial 140–200 mm Hg/ 5 cm	The effect of BFR walking on arterial compliance.	4 days a week, 20 minutes of treadmill walking with BFR at 45 per cent of HR reserve. The whole exercise lasted ten weeks.	In elderly persons, slow walk training with BFR can result in thigh muscle hypertrophy and greater knee joint strength. Unlike high-intensity weight training, carotid arterial compliance improved after 10 weeks of BFR walk training.[5]
2015 (DOI: 10.1177/2151-458515-583088)	Neil Segal, Maria D. Davis, Alan E. Mikesky	The study looked at the effects of blood flow-restricted low-load resistance training on quadriceps strength in males at risk of symptomatic knee osteoarthritis.	A randomized, double-blinded, controlled trial	This study covered parameters such as age, BMI, knee pathology, and muscle strength at baseline. 160-200 mmHg/6.5 cm	3 days/week, four sets (30, 15, 15, 15) of leg press at 30 per cent 1RM, either alone or with BFR. The whole thing lasted four weeks.	In older males with risks for symptomatic knee OA, adding BFR to 30 per cent 1RM resistance training for four weeks did not result in significantly larger improvements in leg press or quadriceps strength as compared to training without BFR.[6]

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Published 2016 (DOI: 10.1007/s00167-016-4064-7)	Flavio Fernandes Bryk, Amir Curcio dos Reis, Deborah Fingerhut, Thomas Araujo, Marcela Schutzer, Ricardo de Paula Leite Cury, Aires Duarte Jr., Thiago Yukio Fukuda	The goal of this research was to see if women with knee osteoarthritis who did a rehabilitation programme that included low-load exercises coupled with partial vascular occlusion (PVO) had the same results in terms of quadriceps strength, pain relief, and functional improvement as compared to women who did a programme that included high-load exercises without partial vascular occlusion (PVO).	Randomized, blinded, clinical trial 200 mm Hg/NA	To establish the homogeneity of the groups at baseline, age, body mass, height, body mass index (BMI), strength, functional scores, and pain scores were compared between both subgroups (pre-treatment).	3 days a week, 20 reps of sitting knee extensions at 30% 1RM. Stretching was also done regularly by the participants. The period was 6 weeks in total.	Using partial vascular occlusion (PVO) in conjunction with low-load exercise reduced anterior knee soreness during training sessions.[7]
Published 2010 (DOI: 10.1007/s00421-009-1204-5)	Murat Karabulut, Takashi Abe, Yoshiaki Sato, Michael G. Bemben	The goal of this study was to look into and evaluate the effects of two different types of resistance training protocols on skeletal muscle strength adaptation in older men.	Randomised controlled trial 16-240 mm Hg/ 5 cm	Including both training techniques parameters were, (a) strength values for upper and lower extremity exercises, and (b) total volume of exercises completed for lower extremity exercises.	Three sets (30, 15, 15 reps) of leg press and knee extensions at 20% 1RM with BFR, 3 days/week. The period was 6 weeks in total.	Except for dynamic leg extension, there were no significant differences between groups (greater in HL) (HL = high load).[8]

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Published 2016 (DOI 10.1007/s00421-016-3328-8)	Ryosuke Shimizu, Kazuki Hotta, Shuhei Yamamoto,Takuya Matsumoto, Kentaro Kamiya, Michitaka Kato, Nobuaki Hamazaki, Daisuke Kamekaw, Ayako Akiyama, Yumi Kamada, Shinya Tanaka, Takashi Masuda	The goal of this study was to see how low-intensity resistance training combined with blood flow restriction affected vascular endothelial function and peripheral blood circulation.	Randomised controlled trial Systolic blood pressure/10 cm	Resistance training was done for four weeks at 20% of each expected one-repetition maximum. Lactate (Lac), norepinephrine (NE), vascular endothelial growth factor (VEGF), and growth hormone (GH) levels were measured before and after the initial resistance workout.	3 × 20 reps of leg press, leg extension, rowing, and chest press at 20% 1RM with BFR once a day, 3 days/week. The whole thing lasted four weeks.	In healthy elderly individuals, BFR resistance exercise increased vascular endothelial function and peripheral blood circulation.[9]
Published: 2016 [Oncotarget, 7(23), 33595]	Tomohiro Yasuda, Kazuya Fukumura, Takanobu Tomaru, Toshiaki Nakajima	They investigated how elastic band exercise with blood flow restriction (BFR) affected the size and function of thigh muscles in older women.	Controlled trial 180-270 mm Hg/ 3 cm	Hemodynamic, vascular function, coagulation system, and creatine kinase are all factors to take into account.	Two days a week, do four sets (30, 15, 15, 15) of arm curls and triceps pull-down exercises with BFR and an elastic band. It took a total of 12 weeks to complete the project.	The findings show that low-intensity elastic band BFR training could contribute to the development of safe and effective sarcopenia treatment and prevention approaches for older persons.[10]

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Published 2013 (DOI: 10.1007/s00421-012-2422-9)	Hayao Ozaki, Tomohiro Yasuda, Riki Ogasawara, Mikako Sakamaki-Sunaga, Hisashi Naito, Takashi Abe	They looked at how carotid arterial compliance was affected by high-intensity resistance training (HIT) and low-intensity blood flow restriction (LI-BFR) resistance training.	Randomised controlled trial 140-200 mm Hg/5 cm	Anthropometric characteristics, muscle size, and strength are all factors to consider.	4 days a week, 20 minutes of treadmill walking with BFR at 45 per cent of heart rate reserve (HRR). It took a total of 10 weeks to complete the experiment.	The high-intensity resistance training (HIT) group saw a reduction in carotid arterial compliance, but the low-intensity blood flow restricted (LI-BFR) group did not. As a result, the amplitude of blood pressure changes in response to exercise could be a determining factor in resistance training-induced central arterial stiffness.[11]
Published 2011 (DOI:10.1123/ japa.19.3.201)	Stephen D. Patterson, Richard A. Ferguson	Training with blood-flow restriction improves strength and post-occlusive calf blood flow in seniors	Randomised controlled trial 110 mm Hg/10 cm	The intensity of the plantar-flexor muscles was measured [1RM, mean corpuscular volume (MVC), and Isokinetic Torque].	Three sets of 25 per cent 1RM single-leg plantar flexion until failure. The whole thing lasted four weeks.	After a 4-week training session employing low-load resistance training (LLRT) with blood-flow restriction, both strength and blood-flow parameters in older persons can be increased more than that with low-load resistance training (LLRT) alone.[12]
Published 2013 (DOI: 10.1111/cpf.12033)	Robert S. Thiebaud, Jeremy P. Loennek, Christopher A. Fahs, Lindy M. Rossow, Daeyeol Kim, Takashi Abe, Mark A. Anderson, Kaelin C. Young, Debra A. Bemben, Michael G. Bemben	The impact of resistance training with elastic bands coupled with blood flow restriction on postmenopausal women's strength, total bone-free lean body mass, and muscle thickness	Quasi-experimental 80-120 mm Hg/ 3.3 cm	Muscle thickness, strength, and total bone-free lean body mass measurements	Three sets (30, 15, 15) of the lower body and upper body workouts with BFR utilising an elastic band at ~10%-30% 1RM, three times a week. The period was 8 weeks in total.	The study found that moderate-to-high-intensity EB training and low-intensity EB training with BFR produced equal gains in strength, total bone-free lean body mass, and muscle thickness (EB- Elastic band).[13]

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Discussion

History of BFR - Japan

By 2014, it was predicted that one-quarter of Japan's population will be 65 years or older.[14] Because of the large potential load of government healthcare costs associated with a rise in the number of old people, Japanese people are becoming increasingly concerned. The administration has made treating age-related health issues a top priority. Furthermore, changes in federal healthcare laws are made in expectation of an increase in the number of seniors designated as needing nursing care, resulting in a rise in the number of bedridden elderly persons because the reclassification will increase the number of physically inactive older people who will later rely more heavily on Japan's healthcare system in future. [1]

The KAATSU training approach has gained popularity in the sports world, and many athletes have shown that it may help them improve their performance. At the same time, Professor Naokata Ishii has begun collaborating on a similar research project.[1] Low-intensity KAATSU exercise has been studied for its effects on blood growth hormones and chronic impacts on muscular hypertrophy and enhanced strength as well as the impact of KAATSU training on athlete size and strength.[1,3] The findings are published in peer-reviewed journals. The moderate vascular occlusion (LIO) group saw a significant gain in lower limb muscle strength, however, the dynamic balance exercise (DBE) group did not. Immediately after the low-intensity exercise, growth hormone levels increased considerably. The LIO programme improved physical function, particularly muscle strength, which could be linked to increased exercise-induced growth hormone release. To assess the content and duration of the LIO programme for older persons, more research is needed.[3]

BFR - Walking Parameters

Isokinetic plantar-flexion torque was determined by completing three single, maximal repetitions in the same position as during isometric mean corpuscular volume (MVC). Five warm-up contractions were performed before the maximal repetitions to acclimate the individual to the requisite velocity. Only the concentric portion of the movement was studied, with three distinct contraction velocities of 0.52, 1.05, and 2.09 rad/s (30, 60, and 120 °/s).[7]

Before training, there was no significant difference in age, standing height, body mass, body mass index, or circumference between the two groups (KAATSU walk and control). For participants aged 60 to 78 years, this study reveals two new and noteworthy findings: (1) After 6 weeks of low-intensity KAATSU walk training (walking speed of 67 m/min), isometric and isokinetic muscular strength and leg muscle size increased; however, (2) estimated VO_2 peak did not improve with this low-intensity KAATSU walking workout.[4] The primary result of this study was an increase in knee strength and thigh muscle size in older persons after 10 weeks of gait training combined with BFR. In addition, BFR gait training improved carotid compliance, suggesting that BFR gait training can improve arterial compliance and muscle hypertrophy at the same time. Since blood pressure does not vary as a result of exercise, changes in arterial compliance are mostly due to changes in arterial tension.[5]

BFR - Knee and Quadriceps

Knee discomfort can result from a variety of factors. However, as we become older, osteoarthritis (OA) can develop and become a source of knee pain. Many individuals with OA may need a knee replacement in the future, but there is frequently a lot we can do to control the pain and get back to the activities we enjoy before that happens. Strengthening the hip, thigh, and core muscles is frequently recommended to help support the knee joint and decrease pain. What if, on the other hand, the workouts that are supposed to strengthen the knee make the discomfort worse? Blood flow restriction exercise, on the other hand, can be a strong tool for strengthening the muscles around the knee without increasing the pain, not just for knee OA but for a variety of other conditions. [7]

As compared to a programme that uses traditional high-load exercises, a rehabilitation programme that combines PVO (partial vascular occlusion) with low-load workouts delivers equal benefits in quadriceps, whereas in cases of women with osteoarthritis of the knee, it delivers discomfort, function, and strength. However, combining PVO with low-load workouts can assist to decrease pre-workout knee soreness.[7]

Quadriceps strength is linked to a lower likelihood of symptomatic osteoarthritis in the knee (OA). However, high-risk factors for knee OA (such as a sedentary lifestyle, obesity, and knee injury) can lead to a 60% reduction in resistance training tolerance. A study was conducted to see if combining blood flow restriction (BFR) with low-load training is an effective and acceptable strategy to develop strength. Men at risk for symptomatic knee osteoarthritis should strengthen their quadriceps. Adding BFR to 30% 1RM resistance exercise for 4 weeks did not result in a significantly higher leg or quadriceps strength in older men with predisposing characteristics as compared to training without it. Symptomatic knee osteoarthritis is a possibility.[6]

For Speed, Strength, and Power Athletes

Rehab from Injury/ Surgery

For power and conditioning, the therapists use mild masses to teach injured athletes to enhance recuperation, minimising power, size, and function loss.

- Passive BFR (no activity) throughout mattress relaxation

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or immobilisation
- BFR combined with mild depth aerobic (biking or walking) exercise
- BFR paired with mild load resistance exercise
- BFR training blended with heavy load training and in the end, a go back to competition

For example, Todd Lodwick, an American Nordic skier, shattered his leg, and shoulder, and tore ligaments during practice just weeks before the 2014 Winter Olympics. He employed BFR training during his recuperation and went on to finish sixth in the finals after being named the flagbearer for the United States of America Olympic squad.[15]

Training and Competition while Travelling

Contributors in numerous sports activities have erratic training and competition schedules, which means that they're often far from their most reliable training facilities. While automatically pressurised gadgets and cuffs together with the ones utilised in research, are exceedingly luxurious and might typically be used with a single user at a time, elastic wraps and tourniquets are much less luxurious and time-investing equipment (albeit with much less control of the strain stimulus applied). Using BFR alongside frame weight workouts, weighted vests, or elastic resistance bands can assist, develop or keep muscle diversifications whilst travelling.

Decrease Training Loads and Time

Athletes may also gain from combining BFR with moderate hundreds to provide an anabolic schooling stimulus without the excessive mechanical hundreds and muscle harm related to excessive mechanical hundreds. Training classes are generally shorter than traditional training sessions due to the shorter intra-set relaxation periods (30-60 seconds), which reduces training time.

Pain Management

While pain and perceived exertion are regarded to be excessive at some stage in BFR exercise, it's also a less-recognised fact that BFR can alleviate soreness afterwards.

Athletes

A blood flow restriction cuff is inflated in conventional techniques till blood flowing toward the coronary heart is blocked, however, blood flowing far from the coronary heart is preserved. To keep away from adverse nerves near the skin, the cuff has to most effectively be worn at the top thigh or top arm. This is mainly proper if the cuff is overinflated. Inflate the cuff to 80% of the limb occlusion stress. When the cuff is used, stress of 6-7/10 is recommended.[16]

The 30/15/15/15 protocol is mostly applied clinically which includes 30 reps with 2-second concentric and 2-second eccentric contraction following 30 seconds rest and then 15 reps again followed by 30 seconds. This is performed with 3 sets of 15 reps for 5 times. This is split into 4 units of seventy-five reps each, with 30-60 seconds of recuperation in between. Start with 20% of the most weight and progressively boost if all seventy-five repetitions are completed, then record the time taken to complete these repetitions.[16]

These sets are:[16,17]

- Set 1: 30 reps
- Rest 30 s
- Set 2: 15 reps
- Rest 30 s
- Set 3: 15 reps
- Rest 30 s
- Set 4: 15 reps

If there is any problem, the cuff stress must be maintained during the time of relaxation. If the stress cannot be maintained, it can be shifted to a different part, after shifting it is reinflated and reps are repeated. Leg presses, deadlifts, and lunges are mostly suggested.[17]

Minimal to no resistance must be utilised by folks who are in the usage of BFR post-operatively and are nonetheless within the early levels of rehab or have not been cleared for complete weight-bearing. When no weight is added, shorter relaxation times (15 s) among units are appropriate.[16,17]

BFR - Post-surgery

BFR training is a safe and effective strategy that may be used in both normal training and rehab settings for knee discomfort and post-operative recovery. Due to its capacity to rapidly enhance both strength and muscle growth while employing light resistance, BFR training can be a useful tool following knee surgery. Most knee procedures cause muscle atrophy and weakness as a side effect. The importance of regaining thigh musculature strength is critical for a successful surgical outcome and the prevention of future knee joint damage. When compared to a control group, BFR physical therapy for knee discomfort after surgery resulted in increased thigh muscular strength, muscle mass gain, and superior overall recovery.[18]

Muscle Strength

In a 2017 meta-analysis of numerous published trials, it was found that BFR training enhanced muscle strength in individuals with various diseases such as ACL repair and knee osteoarthritis when compared to low-intensity exercise alone. The damage was minimised when the blood flow restriction exercise was done correctly.[19] Another study looked at how BFR training affected the elderly. Researchers looked at 11 research and discovered that low-intensity exercise with restricted blood flow is a safe strategy to assist seniors to acquire strength and growth. If the exercise was carried out correctly, no risk was found.[20]

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In a group of polymyositis (PM) and dermatomyositis (DM) patients, this was the first study to look at the benefits of low-intensity resistance exercise paired with partial BFR. This exercise regimen has been demonstrated to be useful in the treatment of PM/ DM symptoms such as muscle weakness, muscle dysfunction, muscle atrophy, and low quality of life. It should be highlighted that no illness exacerbations were detected. These findings suggest that BFR training may be safe and useful for PD and DM patients who are sedentary.[2] This research has certain drawbacks. In this study, the male/ female ratio may have an impact on improvements in vascular endothelial function, peripheral blood flow, and muscle strength. As a result, more research is needed to see if gender differences influenced their progress after BFR resistance training. Hypoxic stress on skeletal muscle during BFR resistance training is one of the basic mechanisms for improving vascular endothelial function and peripheral blood flow, according to these researchers. They should have looked at the effects of BFRs without resistance training them, as shear stress caused by reperfusion after BFR resistance training has been shown to help with dysfunction.[9]

Conclusion

A muscle is mechanically stressed during blood flow restriction training (mechanical stress is also present during high-intensity muscle strengthening). There should be no stress on a muscle or ligament while the body is recuperating following surgery. Low-load workouts may be necessary, and blood flow restriction training allows for maximum strength development while using minimal, safe loads. When heavy training loads are not appropriate, such as after surgery, injury, or considerable muscle loss, this approach is the best option. Low-intensity exercise is used in blood flow restriction strengthening to achieve strength improvements similar to those seen in high-intensity training. BFR is a novel approach to physical therapy (PT). According to a preliminary study, this can result in adequate strength improvements during low-intensity exercise.

Despite the paucity of research on this subject, our findings give preliminary information for practitioners and physicians dealing with patients who are unable to handle near-maximal loads yet should be treated appropriately. Future research should look into potential modifiers (e.g., cuff pressure, gender, volume, or frequency) that may alter adaptation in muscle mass and strength in the elderly, which is outside the scope of this study. Finally, future studies should look into the effects of various training adaption measures on physical function and quality of life during rehabilitation.

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Conflict of Interest: None

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