Journal of Biosciences and Medicines, 2025, 13(7), 356-367
https://www.scirp.org/journal/jbm
ISSN Online: 2327-509X
ISSN Print: 2327-5081

Effect of Blood Flow Restriction Training on Knee Function Rehabilitation after Anterior Cruciate Ligament Reconstruction Research Progress

Luo Su[1,2,3], Junxiu Zhou[4], Mingxuan Liu[1,2,3], Haidong Zhou[1,2,3], Yongfu Chen[1,2,3], Xuanfei Su[1,2,3], Huang Zhang[1,2,3*]

[1]Affiliated Hospital of Youjiang Medical University for Nationalities, Baise, China
[2]Biomedical Materials Engineering Research Center for Bone and Joint Degenerative Diseases, Guangxi Zhuang Autonomous Region, Baise, China
[3]Graduate School of Youjiang Medical University for Nationalities, Baise, China
[4]Department of Pharmacy, Baise Maternal and Child Health Hospital, Baise, China
Email: *1695573477@qq.com

How to cite this paper: Su, L., Zhou, J.X., Liu, M.X., Zhou, H.D., Chen, Y.F., Su, X.F. and Zhang, H. (2025) Effect of Blood Flow Restriction Training on Knee Function Rehabilitation after Anterior Cruciate Ligament Reconstruction Research Progress. *Journal of Biosciences and Medicines*, **13**, 356-367.
https://doi.org/10.4236/jbm.2025.137028

Received: February 20, 2025
Accepted: July 26, 2025
Published: July 29, 2025

Abstract

Purpose: This paper summarizes the development of blood flow restriction training and its effect on the rehabilitation of knee joint function in patients after anterior cruciate ligament reconstruction, provides a reference for the rehabilitation methods after anterior cruciate ligament reconstruction in the future, and also promotes the rehabilitation effect of blood flow restriction training technology. **Method:** The data sources included CNKI, Wanfang, VIP, Web of Science and PubMed. The search terms were blood flow restriction training, pressure training, anterior cruciate ligament reconstruction rehabilitation training, blood flow restriction training and BFRT. The literature on the application of blood flow restriction training in knee joint rehabilitation after anterior cruciate ligament reconstruction in recent years was extensively reviewed, and the mechanism and clinical efficacy of this technique were summarized. **Result:** Blood flow restriction training adopts the method of limiting the proximal blood flow of the limb and combining low-intensity resistance training, which achieves the training effect similar to that of traditional high-load training, and improves the problems of postoperative muscle atrophy and joint function weakening. The clinical application shows good curative effect. **Conclusion:** Blood flow restriction training can significantly improve knee joint function by promoting skeletal muscle metabolism emergency and promoting muscle fiber collection, which provides a new idea for the functional rehabilitation of knee joint after anterior cruciate ligament reconstruction. The technology is still in its infancy in China, and the sample size is small. The later application effect and standardization scheme need to be further studied.

Keywords

Blood Flow Restriction Training, Anterior Cruciate Ligament Reconstruction, Quadriceps Femoris, Muscle Strength, Knee Function Rehabilitation

1. Research Background

Anterior cruciate ligament (ACL) plays an important role in the activities of the knee joint. Anterior cruciate ligament injury is the most common sports injury. In severe cases, it can involve the meniscus and cartilage of the knee joint, and even produce joint distortion [1]. Anterior cruciate ligament reconstruction (ACLR) is the most common repair surgery, which mainly reconstructs the anterior cruciate ligament by using autologous tendon, allogeneic tendon or artificial ligament [2]. With the development of sports and the promotion of national fitness, the number of patients with ACL injury is increasing. More than 175,000 patients in the United States need ACLR surgery every year [3]. Because of the pain and swelling caused by local microcirculation disorder of ACL injury before operation and the toughening of graft in the early stage after operation, the degree of muscle atrophy is aggravated. Therefore, solving the problems of muscle strength decline and muscle atrophy after operation is the focus of postoperative rehabilitation, and it is also an important guarantee for patients to restore normal physiological function [4] [5].

According to the guidelines of the American Physical Therapy Association, the resistance load of a single progressive resistance training should be greater than 60% 1RM (One-Repetition Maximum) is the best parameter to improve muscle strength [6]. However, ACLR cannot achieve this load training early after surgery, and traditional rehabilitation methods such as strength training and neuromuscular training have limited therapeutic effects on ACLR patients. Studies have shown that if limb training is carried out under the condition of moderate restriction of blood flow at the proximal end of the limb, even low load resistance muscle training may cause similar training effects to high load resistance muscle training [7]. Bood flow restriction training (BFRT), also known as compression training, is a method of exerting pressure on the proximal end of the limb by means of special devices such as inflatable cuffs to achieve partial occlusion of the blood flow of the pressurized limb, resulting in local hypoxia. At the same time, it is supplemented by a lower intensity of 1RM (20% - 30%) to produce a training effect similar to high-load resistance exercise [8]. Low-intensity resistance training can not only achieve the same training effect as high-load resistance exercise, but also promote muscle hypertrophy, increase muscle strength and hormone secretion. Combined with low-load resistance exercise, it can also effectively improve cardiopulmonary function. Compared with high-load resistance exercise, BFRT produces less mechanical stress and cardiovascular system pressure, which is safer than traditional high-load exercise, and is suitable for people with musculoskeletal diseases and chronic diseases. Therefore, BFRT is expected to provide a new method for clinical ACLR postoperative patients to increase muscle and reduce muscle atrophy, and promote knee function rehabilitation training. At the same time, it is beneficial to the exercise of cardiopulmonary function in middle-aged and elderly patients with ACLR.

2. BFRT Research Status

2.1. Overview and Origin of BFRT

Blood flow restriction training was first discovered and popularized by Sato. The use of BFRT in the early stage was mainly concentrated in the field of sports, which could effectively improve the muscle strength and quality of athletes [9]. In recent years, the application of BFRT in the field of clinical medical rehabilitation has become more and more extensive. With the wide spread of the effectiveness of BFRT, this training method has been gradually applied and promoted in many countries, providing a new way of functional recovery during rehabilitation for subjects who are not clinically suitable for high-load exercise.

2.2. Exploring the Mechanism of BFRT

It has been reported that the biggest advantage of blood flow restriction training is that it can improve muscle strength and endurance without applying high-intensity load, and achieve the same effect as high-load training [10]. Many scholars have carried out a series of studies on the physiological mechanism of its role, but there is no clear conclusion. Mechanical tension and metabolic changes are considered to be the main reasons for muscle hypertrophy adaptation after BFRT.

2.2.1. Changes in Metabolic Levels

Studies have shown that during the process of blood flow restriction, the muscle produces a microenvironment of ischemia and hypoxia. When combined with exercise, the degree of ischemia and hypoxia is aggravated [11]. Substances such as carbon dioxide, lactic acid and adenosine can stimulate vasodilation. At the same time, these substances are easy to diffuse through the cell membrane to the intercellular space, acting on vascular smooth muscle to produce a strong vasodilation effect, which increases blood flow and provides the required oxygen and nutrients for the tissues in the ischemic area. Under the stimulation of reperfusion after repeated ischemia and hypoxia, the vascular compliance, wall tension and endothelial cell shear stress were enhanced, and the changes of carbon monoxide/endothelin levels were regulated, so that the internal circulation function was improved [12] [13]. Pan Ying's experiment [14] showed that BFRT not only had low energy consumption, small degree of muscle micro-damage, but also had better intervention effect on microvascular function, which was related to the change of microcirculation function. At the same time, the change of endothelial cell shear stress will promote the expression of vascular endothelial growth factor, stimulate capillary regeneration, and further increase the blood perfusion of microvessels [15]. It has been reported that muscle groups can significantly increase the concentration of adrenaline, lactic acid, growth hormone, interleukin and other hormones when performing BFR combined with low-intensity training. Growth hormone can be as high as 290 times the static level in 15 minutes after exercise [16]. Li Zhuoqian's research [17] points out that the effect of BFR combined with low-intensity resistance training on the increase of hormone concentrations such as growth hormone and testosterone is more significant than that of BFR combined with high-intensity training. Similar studies showed different results. There was no significant change in hormone concentration in BFR combined with low-intensity resistance training, which was considered to be due to the difference in the BFRT scheme used.

2.2.2. Collection of Muscle Fibers

The increase of type II muscle fiber recruitment is an important reason for the increase of muscle cross-sectional area. Studies have shown that low-intensity BFRT can cause more motor unit recruitment and activation of fast muscle fibers [18]. The reason may be due to the insufficient oxygen supply of slow muscle fibers after blood flow restriction, and the accumulated metabolites activate the afferent nerve, thereby inhibiting the innervation of α neurons to type I muscle fibers and increasing the recruitment of type II muscle fibers, which are more sensitive to the increase of muscle cross-sectional area. Schoenfeld [19] also found that during BFRT combined with low-intensity training, the aggregation of muscle fibers increased, and the cross-sectional area of fast muscle fibers increased more significantly than that of slow muscle fibers. At the same time, some scholars have proposed that BFRT-induced muscle hypoxia environment can accelerate the recruitment of fast glycolytic muscle fibers. The muscle fiber is one of the larger fiber subtypes, accounting for most of the muscle strength. These fibers have abundant contraction filaments, and the contraction force produced by them will have a direct impact on the increase of muscle strength and the increase of muscle cross-sectional area [20]. The above studies show that BFRT promotes the recruitment of muscle fibers is another important mechanism for muscle thickening and muscle strength enhancement.

2.2.3. Muscle Protein Synthesis and Muscle Cell Swelling

In addition to the above studies, BFRT-induced cell swelling may lead to another mechanism of cell hypertrophy. Yasuda [21] believed that after BFRT, intracellular hydration mediated cell swelling, increased cell protein synthesis and amino acid uptake, reduced protein hydrolysis, and promoted muscle growth. Therefore, cell swelling may be an important mechanism for promoting muscle hypertrophy. Xu S [22] found that muscle hypertrophy was mainly regulated by protein conversion rate when studying the mechanism of BFRT-induced skeletal muscle hypertrophy. BFR increased protein synthesis through signaling pathways to promote muscle hypertrophy and inhibited protein degradation through ubiquitin proteasome to prevent muscle atrophy. Manini [23] studied the expression of myogenic and proteolytic mRNAs after 8 hours of knee extension exercise in subjects under BFRT, and found that BFRT reduced transcripts related to the proteolytic pathway, that is, BFR unchanged muscle generation and reduced proteolytic genes related to muscle remodeling. Some scholars have suggested that the expression of anabolic genes and the long-term increase of protein synthesis will be an important reason for muscle strength enhancement and hypertrophy. For example, hypoxia-inducible factor 1-α (HIF-1α) and its downstream targets and its downstream target-driven angiogenesis are likely to play an important role in the enhancement of muscle endurance and oxidative capacity [24].

In summary, the mechanism of BFRT promoting muscle function recovery may involve many aspects. Most scholars believe that the level of metabolic stress and mechanical stress are the main mechanisms for low-intensity BFRT to play a role. The changes of the two will cause the increase of hormone concentration in the body, type II muscle fiber recruitment, cell swelling, etc., will promote protein synthesis and inhibit protein hydrolysis to cause muscle function enhancement.

3. Application Status of BFRT in Muscle Function Rehabilitation after ACLR

As a new treatment method, BFRT has achieved good application and promotion in foreign countries, and has been applied to all aspects of knee joint diseases. Knee joint diseases are mostly caused by pain, which leads to synovial joint-derived muscle strength inhibition. Patients often cause muscle disuse atrophy and decreased muscle strength due to protective braking after surgery [25]. BFRT combined with low-load resistance exercise can achieve similar rehabilitation effects as high-load resistance training, which is well reflected in the rehabilitation of knee joint diseases. Many foreign scholars have carried out experimental observation on the effect of BFRT on rehabilitation training after ACLR operation. Different treatment schemes and their therapeutic effects are shown in **Table 1**.

3.1. Foreign Research Status

As a new treatment method, BFRT has achieved good application and promotion in foreign countries, and has been applied to all aspects of knee joint diseases. Knee joint diseases are mostly caused by pain, which leads to synovial joint-derived muscle strength inhibition. Patients also often cause muscle disuse atrophy and decreased muscle strength due to protective braking after surgery. BFRT combined with low-load resistance exercise can achieve similar rehabilitation effects as high-load resistance training, which is well reflected in the rehabilitation of knee joint diseases. Many foreign scholars have carried out experimental observation on the effect of BFRT on rehabilitation training after ACLR operation. Different treatment schemes and their therapeutic effects are shown in Table 1.

Table 1. Foreign research status.

Research Author	number of cases	intervention time	control group	observer group	Degree of pressure/ Sleeve width	clinical effect
Kacin [26], 2021	18	After operation, for 3 weeks	Knee joint extension flexion resistance movement Training load: low load	Control group + LL-BFRT Control group + SHAM-BFRT Training load: low load	BFRT: 1800 mmHg Sham-BFRT: 20 mmHg/13.5 cm	LL-BFRT increased the cross-sectional area of quadriceps femoris and the ability of isokinetic peak torque of muscle, but it was less effective than other higher frequency training.
Curran [27], 2020	34	After operation, for 8 weeks	High load leg lift training load: high load (70% 1RM)	Control group + BFRT (HL-BFRT) Training load: high load (70% 1RM)	80% limb occlusion pressure	There was no significant difference in the measurement results between the two groups ($P > 0.05$). BFRT based on high-intensity exercise could not significantly improve the strength, activation and volume of the quadriceps.
Jack [28], 2022	32	After surgery, for a period of 12 weeks	Progressive rehabilitation Training load: low load	Control group + BFRT Training load: low load	80% limb occlusion pressure	After ACLR, BFRT can reduce muscle and bone loss and improve the time to return to exercise, and the functional results are comparable to those of standard rehabilitation.
Kilgas [29], 2019	18	Postoperative 5 ± 2 years, for 4 weeks	Single leg knee extension, half squat, walking Training load: low load	Control group + BFRT Training load: low load	50% limb occlusion pressure	The muscle thickness of rectus femoris, vastus lateralis and knee extensor in affected legs was significantly increased compared with that before training ($P > 0.05$), which proved that BFRT could improve the function of quadriceps femoris for a long time after ACLR.
Žargi [30], 2018	20	Preoperative, for 8 days	SHAM + knee extension resistance exercise Training load: low load	Control group + BFRT (occlusion 30 s, perfusion 45 s) Training load: low load	Experimental group: 150 mmHg/14 cm Control group: 20 mmHg/ 14 cm	There was no deterioration of quadriceps endurance in the BFRT group at 4 weeks after operation, while the muscle endurance in the sham stimulation group decreased by 50 %. There was no significant difference in muscle endurance between the two groups at 12 weeks after operation. The short-term preconditioning of BFRT can maintain the quadriceps endurance of ACLR patients.

Table note: HL-BFRT: high load blood flow restriction training; hL-RT: High load resistance training; lL-BFRT: low load blood flow restriction training; sHAM: False stimulus.

3.2. Domestic Research Status

At present, the application of BFRT is still in its infancy in the postoperative rehabilitation stage of knee joint diseases in China, and its application status is shown in Table 2.

Table 2. Domestic research status.

Research Author	number of cases	intervention time	control group	observer group	Degree of pressure /Sleeve width	clinical effect
Li Qi [31], 2019	36	After operation, for 3 months	Knee flexion and extension resistance training Training load: low load	Control group + BFRT Training load: low load (30% 1RM)	80 mmHg	Within 3 months of training, the muscle cross-sectional area and muscle strength were better than those of the control group (P < 0.05). The Lysholm score of the observation group was better than that of the control group at 2 months after operation, and there was no significant difference at 3 months. BFRT can improve muscle strength, muscle endurance and knee joint function in the early postoperative period compared with conventional resistance training.
Su Mingli [32], 2021	60	After operation, for 6 weeks	Routine training, straight leg raising, anti-gravity knee extension, resistance isometric contraction, isometric contraction Training load: low load	Control group + BFRT Training load: low load	80% limb occlusion pressure	After 6 weeks of intervention, there were significant differences in muscle thickness and thigh circumference between the experimental group and the control group. The Lysholm score of the experimental group was significantly improved compared with the control group (P < 0.05). BFRT can significantly improve knee function after ACLR.
Huang Wei [33], 2023	82	After operation, for 6 weeks	Routine rehabilitation training, straight leg raising, anti-gravity knee extension, resistance to isometric contraction, isometric contraction Training load: low load	Control group + BFRT Training load: low load (30% 1RM)	75 mmHg	The Lysholm score of the study group was higher than that of the control group, and the difference of thigh circumference was smaller than that of the control group. The average peak pressure of standing balance, knee bending and squatting in the study group was lower than that in the control group (P < 0.05). BFRT combined with routine rehabilitation training can improve knee joint function, quadriceps function and balance function.

Continued

Zheng Qi [34], 2023	40	After operation, for 8 weeks	Routine rehabilitation training, knee flexion and extension muscle resistance training Training load: low load	Control group + BFRT Training load: low load	70% arterial occlusion pressure was (123 ± 11.23) mmHg	There was no difference in Lysholm score, flexor and extensor peak torque ratio and extensor peak torque between the two groups before treatment, and the difference was statistically significant after treatment ($P < 0.05$). Blood flow restriction training can effectively improve the quadriceps strength, knee stability and function of ACLR patients.
Liu Liping [35], 2023	80	After operation, for 8 weeks	Routine rehabilitation nursing, straight leg raising training, knee flexion and extension resistance training Training load: low load	Control group + BFRT Training load: low load	50% limb occlusion pressure /104.5*9 cm	There was no difference between the two groups before the intervention. After the intervention, there were statistically significant differences in Lysholm score, thigh circumference, joint mobility and VAS score. BFRT can significantly improve the postoperative knee function of patients with ACLR, which is of great significance for postoperative rehabilitation.

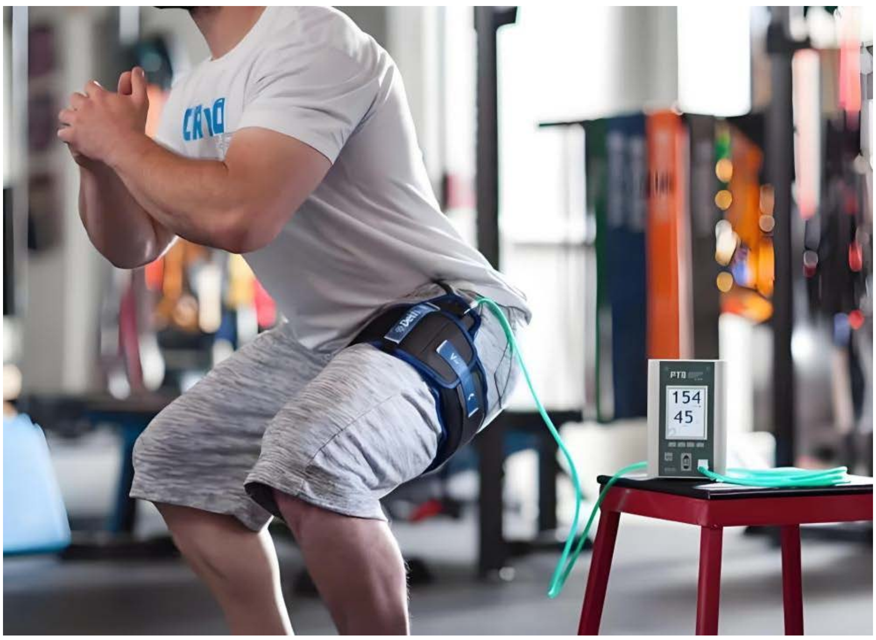

Figure 1. Quadriceps femoris.

Most of the clinical studies used low-load (30% 1RM) BFRT for intervention, and the results showed that it had a statistically significant improvement in the function of the quadriceps femoris, as shown in **Figure 1**. The intervention of high load (70% 1RM) BFRT showed no statistical significance in improving the strength and volume of quadriceps femoris, which further proved the effectiveness of blood flow restriction combined with low load exercise training. The above studies have shown that conventional low-load training combined with BFR is beneficial to further increase the knee muscle strength and volume of patients after ACLR. The role of low-load BFRT in improving muscle mass of patients after ACLR and the speed of high-load resistance training, but it can better reduce knee pain. The efficacy of BFRT may be related to the occupation, obstruction pressure and individual differences of the subjects. The preoperative or postoperative intervention of BFRT will also have different effects, indicating that the difference in intervention time may be a factor leading to different clinical efficacy.

4. BFRT Security Issues

Since the invention of BFRT, it has been reported that there are side effects such as limb numbness, pain and venous thrombosis, which are mostly related to the unreasonable setting of training parameters. The study found that [36], BFR had no significant effect on the level of muscle injury markers, and short-term low-load BFRT did not cause significant muscle damage. In 2006 and 2016, Japanese scholars carried out two safety surveys on the use of BFRT and found no serious adverse reactions caused by BFRT. In conclusion, there is no direct evidence that BFRT is more risky than traditional training methods. Under the guidance of scientific professionals, BFRT can be safe and effective regardless of the age, gender or physical condition of the subjects.

5. Summary

The decrease of quadriceps muscle strength and muscle atrophy after ACLR are the most common clinical symptoms, which further leads to the decrease of knee joint function and increases the probability of re-injury. Due to the low tolerance of the knee joint with anterior cruciate ligament defect to mechanical stress, it is difficult for patients to carry out high-intensity strength training, which seriously affects the rehabilitation process. Blood flow restriction training is a new treatment technique. During exercise, limiting blood flow at the proximal end of the limb and supplemented by low-intensity strength training can produce a similar effect on muscles to high-intensity resistance training. It has been proven that it can increase the size and strength of muscles around the knee joint and prevent muscle atrophy. In addition, muscle atrophy after ACLR will cause changes in its joint movement pattern, and the wrong force line will aggravate complications such as cartilage wear, while BFRT improves the wrong movement pattern while increasing muscle strength, which is conducive to the recovery of knee joint function. At present, domestic ACLR patients are still mainly based on traditional training, BFRT is still not popular, prospective clinical trials and related reports are insufficient, most of them are small sample studies, lack of sample size, and are still in the exploratory stage. And the best training prescription of BFRT did not get the best parameters. The metabolic stress and mechanical tension caused by the difference of pressure size, aerobic exercise mode and exercise intensity in BFRT were also different, resulting in a certain difference in rehabilitation efficacy. Therefore, it is necessary to further study the different motion patterns during BFRT to determine the optimal combination of mechanical tension and metabolic stress. In the future, large sample experiments are still needed to determine the best parameters and training programs for BFRT in postoperative rehabilitation after ACLR.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Arundale, A.J.H., Bizzini, M., Giordano, A., Hewett, T.E., Logerstedt, D.S., Mandelbaum, B., *et al.* (2018) Exercise-Based Knee and Anterior Cruciate Ligament Injury Prevention. *Journal of Orthopaedic & Sports Physical Therapy*, **48**, A1-A42. https://doi.org/10.2519/jospt.2018.0303

[2] Zuo, H.W., Geng, Z.Z., Chen, P., *et al.* (2024) Meta-Analysis of Blood Flow Restriction Training on Knee Joint Function Recovery in Patients with Anterior Cruciate Ligament Reconstruction. *Tissue Engineering Research in China*, **28**, 1962-1968.

[3] Birchmeier, T., Lisee, C., Kane, K., Brazier, B., Triplett, A. and Kuenze, C. (2019) Quadriceps Muscle Size Following ACL Injury and Reconstruction: A Systematic Review. *Journal of Orthopaedic Research*, **38**, 598-608. https://doi.org/10.1002/jor.24489

[4] Li, X., Li, J., Qing, L., Wang, H., Ma, H. and Huang, P. (2023) Effect of Quadriceps Training at Different Levels of Blood Flow Restriction on Quadriceps Strength and Thickness in the Mid-Term Postoperative Period after Anterior Cruciate Ligament Reconstruction: A Randomized Controlled External Pilot Study. *BMC Musculoskeletal Disorders*, **24**, Article No. 360. https://doi.org/10.1186/s12891-023-06483-x

[5] Kochman, M., Kasprzak, M. and Kielar, A. (2022) ACL Reconstruction: Which Additional Physiotherapy Interventions Improve Early-Stage Rehabilitation? A Systematic Review. *International Journal of Environmental Research and Public Health*, **19**, Article 15893. https://doi.org/10.3390/ijerph192315893

[6] American College of Sports Medicine Position Stand (2009) Progression Models in Resistance Training for Healthy Adults. *Medicine & Science in Sports & Exercise*, **41**, 687-708.

[7] Loenneke, J.P., Wilson, J.M., Marín, P.J., Zourdos, M.C. and Bemben, M.G. (2011) Low Intensity Blood Flow Restriction Training: A Meta-Analysis. *European Journal of Applied Physiology*, **112**, 1849-1859. https://doi.org/10.1007/s00421-011-2167-x

[8] Wei, J., Li, B., Yang, W., *et al.* (2019) The Application Effect and Mechanism of Blood Flow Restriction Training. *Sport Science*, **39**, 71-80.

[9] Hu, R., Wang, W., Xie, M.M., *et al.* (2024) Research Progress of Blood Flow Restriction Training in Rehabilitation of Knee Joint Disease. *Sichuan Medicine*, **45**, 77-81.

[10] Dai, L.L., Gui, P.J., Xie, Y., *et al.* (2023) The Mechanism of Blood Flow Restriction Training Combined with Aerobic Exercise and Its Application Progress in the Field of Rehabilitation. *Chinese Journal of Rehabilitation Medicine*, **38**, 1459-1463.

[11] Mouser, J.G., Mattocks, K.T., Buckner, S.L., Dankel, S.J., Jessee, M.B., Bell, Z.W., *et al.* (2019) High-Pressure Blood Flow Restriction with Very Low Load Resistance

Training Results in Peripheral Vascular Adaptations Similar to Heavy Resistance Training. *Physiological Measurement*, **40**, Article ID: 035003. https://doi.org/10.1088/1361-6579/ab0d2a

[12] da Cunha Nascimento, D., Schoenfeld, B.J. and Prestes, J. (2019) Potential Implications of Blood Flow Restriction Exercise on Vascular Health: A Brief Review. *Sports Medicine*, **50**, 73-81. https://doi.org/10.1007/s40279-019-01196-5

[13] Zhu, H. and Gao, B.H. (2020) Research Progress on the Effect and Mechanism of Aerobic Exercise on Human Microvascular Reactivity. *Life Science*, **32**, 855-863.

[14] Pan, Y. and Zhao, Y. (2019) Effects of Blood Flow Restriction with Low-Intensity Resistance Exercise on Skeletal Muscle Microcirculation, Neuromuscular Activation and Subjective Fatigue in Low-Weight Women. *Chinese Journal of Sports Medicine*, **38**, 677-684.

[15] Machado, M.J.C., Boardman, R., Riu, F., Emanueli, C., Benest, A.V. and Bates, D.O. (2019) Enhanced Notch Signaling Modulates Unproductive Revascularization in Response to Nitric Oxide-Angiopoietin Signaling in a Mouse Model of Peripheral Ischemia. *Microcirculation*, **26**, e12549. https://doi.org/10.1111/micc.12549

[16] Zhu, B., Xie, C.G., Wang, Z.X., *et al.* (2024) Research Progress on Exercise Performance Effect and Mechanism of Blood Flow Restriction Training. *Sport Literature Search*, **32**, 265-270.

[17] Li, Z.Q., Wei, W.Z., Zhao, Z.G., *et al.* (2020) Effects of Different Degrees of Blood Flow Restriction on Serum Growth Hormone and Testosterone Secretion during Low-Intensity Resistance Exercise. *Sports Science and Technology in China*, **56**, 38-43.

[18] Chen, H.X. (2023) Research Progress on the Mechanism of Muscle Fiber, Cardiovascular Adaptive Changes and Hypoalgesia in Blood Flow Restriction Training. *Contemporary Sports Technology*, **13**, 5-7.

[19] Schoenfeld, B.J. (2013) Potential Mechanisms for a Role of Metabolic Stress in Hypertrophic Adaptations to Resistance Training. *Sports Medicine*, **43**, 179-194. https://doi.org/10.1007/s40279-013-0017-1

[20] Spranger, M.D., Krishnan, A.C., Levy, P.D., O'Leary, D.S. and Smith, S.A. (2015) Blood Flow Restriction Training and the Exercise Pressor Reflex: A Call for Concern. *American Journal of Physiology-Heart and Circulatory Physiology*, **309**, H1440-H1452. https://doi.org/10.1152/ajpheart.00208.2015

[21] Yasuda, T., Loenneke, J., Ogasawara, R. and Abe, T. (2013) Influence of Continuous or Intermittent Blood Flow Restriction on Muscle Activation during Low-Intensity Multiple Sets of Resistance Exercise. *Acta Physiologica Hungarica*, **100**, 419-426. https://doi.org/10.1556/aphysiol.100.2013.4.6

[22] Xu, S., Liu, X., Chen, Z., Li, G., Chen, Q., Zhou, G., *et al.* (2016) Transcriptional Profiling of Rat Skeletal Muscle Hypertrophy under Restriction of Blood Flow. *Gene*, **594**, 229-237. https://doi.org/10.1016/j.gene.2016.09.008

[23] Manini, T.M., Vincent, K.R., Leeuwenburgh, C.L., Lees, H.A., Kavazis, A.N., Borst, S.E., *et al.* (2011) Myogenic and Proteolytic mRNA Expression Following Blood Flow Restricted Exercise. *Acta Physiologica*, **201**, 255-263. https://doi.org/10.1111/j.1748-1716.2010.02172.x

[24] Ferguson, R.A., Hunt, J.E.A., Lewis, M.P., Martin, N.R.W., Player, D.J., Stangier, C., *et al.* (2018) The Acute Angiogenic Signalling Response to Low-Load Resistance Exercise with Blood Flow Restriction. *European Journal of Sport Science*, **18**, 397-406. https://doi.org/10.1080/17461391.2017.1422281

[25] DePhillipo, N.N., Kennedy, M.I., Aman, Z.S., Bernhardson, A.S., O'Brien, L.T. and

LaPrade, R.F. (2018) The Role of Blood Flow Restriction Therapy Following Knee Surgery: Expert Opinion. *Arthroscopy: The Journal of Arthroscopic & Related Surgery*, **34**, 2506-2510. https://doi.org/10.1016/j.arthro.2018.05.038

[26] Kacin, A., Drobnič, M., Marš, T., Miš, K., Petrič, M., Weber, D., *et al.* (2021) Functional and Molecular Adaptations of Quadriceps and Hamstring Muscles to Blood Flow Restricted Training in Patients with ACL Rupture. *Scandinavian Journal of Medicine & Science in Sports*, **31**, 1636-1646. https://doi.org/10.1111/sms.13968

[27] Curran, M.T., Bedi, A., Mendias, C.L., Wojtys, E.M., Kujawa, M.V. and Palmieri-Smith, R.M. (2020) Blood Flow Restriction Training Applied with High-Intensity Exercise Does Not Improve Quadriceps Muscle Function after Anterior Cruciate Ligament Reconstruction: A Randomized Controlled Trial. *The American Journal of Sports Medicine*, **48**, 825-837. https://doi.org/10.1177/0363546520904008

[28] Jack, R.A., Lambert, B.S., Hedt, C.A., Delgado, D., Goble, H. and McCulloch, P.C. (2022) Blood Flow Restriction Therapy Preserves Lower Extremity Bone and Muscle Mass after ACL Reconstruction. *Sports Health: A Multidisciplinary Approach*, **15**, 361-371. https://doi.org/10.1177/19417381221101006

[29] Kilgas, M.A., Lytle, L.L.M., Drum, S.N. and Elmer, S.J. (2019) Exercise with Blood Flow Restriction to Improve Quadriceps Function Long after ACL Reconstruction. *International Journal of Sports Medicine*, **40**, 650-656. https://doi.org/10.1055/a-0961-1434

[30] Žargi, T., Drobnič, M., Stražar, K. and Kacin, A. (2018) Short-Term Preconditioning with Blood Flow Restricted Exercise Preserves Quadriceps Muscle Endurance in Patients after Anterior Cruciate Ligament Reconstruction. *Frontiers in Physiology*, **9**, Article 1150. https://doi.org/10.3389/fphys.2018.01150

[31] Li, Q., Li, R., Luo, C.L., *et al.* (2019) Effect of Blood Flow Restriction Exercise on Knee Joint Function after Anterior Cruciate Ligament Reconstruction. *Guangdong Medical Journal*, **40**, 1405-1408.

[32] Iversen, E., Røstad, V. and Larmo, A. (2016) Intermittent Blood Flow Restriction Does Not Reduce Atrophy Following Anterior Cruciate Ligament Reconstruction. *Journal of Sport and Health Science*, **5**, 115-118. https://doi.org/10.1016/j.jshs.2014.12.005

[33] Huang, W., Hu, L.Y., Luo, L.L., *et al.* (2023) Effects of Routine Muscle Strength Rehabilitation Training Combined with Blood Flow Restriction Training on Knee Joint Function, Quadriceps Function and Balance Function in Patients after Anterior Cruciate Ligament Reconstruction. *Progress of Modern Biomedicine*, **23**, 1929-1933.

[34] Zheng, Q., Shi, A.M., Li, X.L., *et al.* (2023) Effect of Blood Flow Restriction Training on The Stability of Quadriceps Femoris and Knee Joint in Patients Undergoing Anterior Cruciate Ligament Reconstruction. *Chinese Journal of Physical Medicine and Rehabilitation*, **45**, 633-636.

[35] Grapar Zargi, T., Drobnic, M., Jkoder, J., Strazar, K. and Kacin, A. (2016) The Effects of Preconditioning with Ischemic Exercise on Quadriceps Femoris Muscle Atrophy Following Anterior Cruciate Ligament Reconstruction: A Quasi-Randomized Controlled Trial. *European Journal of Physical and Rehabilitation Medicine*, **52**, 310-320.

[36] Alvarez, I.F., Damas, F., de Biazon, T.M.P., Miquelini, M., Doma, K. and Libardi, C.A. (2019) Muscle Damage Responses to Resistance Exercise Performed with High-Load versus Low-Load Associated with Partial Blood Flow Restriction in Young Women. *European Journal of Sport Science*, **20**, 125-134. https://doi.org/10.1080/17461391.2019.1614680