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Restricted Blood Flow versus Resisted Training in Elderly Women with Sarcopenia

Alaa Ali Esmail Sultan*[1], Akram Abd El-Aziz Sayed[1], Dina Mostafa Mohamed El-Maleh[2], Saif Mehmed[1]
[1]Department of Physical Therapy for Cardiovascular, Respiratory Disorder and Geriatrics,
Faculty of Physical Therapy, Cairo University, Egypt
[2]Department of Geriatric and Gerontology, Faculty of Medicine, Ain Shams University, Egypt
***Corresponding author:** Alaa Ali Esmail Sultan, **Mobile:** (+20) 01090462528, **E-mail:** aalaaalisultan@gmail.com

ABSTRACT

Background: A decrease in muscle mass, muscle strength, and muscle function is a hallmark of sarcopenia. The best training method for treating and preventing sarcopenia is resistance training (RT). Traditional high-load resistance training (CRT), which is recommended by the American College of Sports Medicine is difficult for older people with sarcopenia. Low-load RT with blood flow restriction (LRT-BFR), a novel training approach, has the potential to increase muscle development and strength similarly to CRT but with less effort.

Objective: This study aimed to determine which type of exercises (high load resisted exercises or LRT-BFR) obtaining the best improvement in elderly patients with sarcopenia.

Subjects and methods: A total of forty older women (65–75 years old) diagnosed with sarcopenia through medical or radiological means were randomly assigned to one of two matched groups: The study group (I) received low load RT combined with restricted blood flow training (RBF), while the study group (II) received high load resistance exercise, for 18 sessions every other day, each session for 20 min for each group. All patients were evaluated with one-repetition maximum strength [1RM] test, SARC-F questionnaire and six-minute walk test pre and post-treatment.

Results: A statistically significant difference was seen between the two groups, with a p-value of 0.001. This suggested that patients in study group I reported a greater improvement in muscle power compared to those in study group II.

Conclusion: This study showed that six weeks of low load RT combined with restricted blood flow training (RBF) revealed to be an effective method for treating sarcopenia in older female patients.

Keywords: Sarcopenia, Elderly women, HRT, LRT, Restricted blood flow.

INTRODUCTION

Sarcopenia is a disorder in which the skeletal muscle gradually and extensively deteriorates, leading to a sudden loss of muscular mass and function. This illness is associated with an increased risk of unfavorable outcomes, including falls, a decline in physical capacity, frailty, and even death. Due to aging, which is impacted by a person's lifetime genetic and lifestyle factors in addition to current risk factors, it is a common occurrence in older adults [(1)]. Sarcopenia has a deleterious effect on function, metabolism, morbidity, and mortality. Thus, functional problems, QoL impairments, falls, osteoporosis, dyslipidemia, an increased risk of cardiovascular illnesses, metabolic syndrome, and immunosuppression are associated with sarcopenia. There is an independent relationship between muscle mass and mortality and muscular function, such as walking speed and strength. A two-fold increase in the chance of falling, a 3.7-fold increase in mortality, and a greater likelihood of confidence are all associated with reductions in both muscle mass and muscular function [(2)].

Sarcopenia is caused by several pathophysiological mechanisms, some of which are connected. This syndrome is characterized by a low-inflammatory state known as inflame-aging, which includes not only the loss of muscle tissue and dysfunction of muscular contraction, but also endocrine and metabolic issues [(3)].

It is well acknowledged that RT is the best method for increasing elderly people's strength and muscular mass. The effectiveness of RT in improving muscle mass, strength, balance, and endurance in older persons has been repeatedly shown by extensive study. In physically fragile older adults, RT can dramatically boost the rate of mixed muscle protein synthesis [(4)].

Previous study has shown that the most effective non-pharmacological method for building muscle growth and strength is exercise, particularly RT. Additionally, it maintains muscular function as one matures [(4-6)].

Unlike traditional protocols that are higher intensity, previous studies have shown that BFR in conjunction with low intensity (LI) routines can induce hypertrophic and neural adaptations through a variety of endocrine, neural, and metabolic mechanisms. For those who find it difficult to tolerate severe strength training, using LI in addition to BFR may be a good choice [(7-9)].

According to studies, LRT-BFR can improve muscle strength in the upper and lower limbs, increase muscle mass, thickness, and cross-sectional area (CSA), decrease CSA of fat, and improve QoL in older adults, as measured by the 36-item Short-Form Health Survey [SF-36] [(10–15)].

So, the present study was designed to find out, which type of exercise (regular resisted exercises or LRT-BFR) obtains the best improvement in elderly patients with sarcopenia.

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SUBJECTS AND METHODS

This study was conducted through the period from May 2023 to December 2023. This study was a pre- and post-experimental research. Two equally matched groups of patients were assigned to the study (study I and study II groups):

- **Study group (I):** included 20 elderly female patients received low load RT combined with BFR.
- **Study group (II):** included 20 elderly female patients received high load resistance exercise. All patients were evaluated with one-repetition maximum strength [1RM] test, SARC-F questionnaire and six-minute walk test before and after 6 weeks of successive treatment program. The treatment period was 18 sessions, 3 times/week for 6 weeks, 20 minutes each session.

Inclusion criteria: Female patients with sarcopenia aged from **65** to 75 years old. Only patients who were medically and psychologically stable patients with no history of any neurological problems and with normal and stable vital signs (heart rate, blood pressure, temperature as well as respiratory rate) were included.

Exclusion criteria: Patients who had an artificial joint replacement in their lower extremities, post-bone fracture, recent surgery, history of deep vein thrombosis, severe cardiovascular conditions (unstable angina, advanced coronary heart disease, congestive heart failure and patients with existing arterial aneurysm or severe arterial hypertension), uncontrolled diabetes, severe psychiatric or cognitive impairment, neurological disorders, active infection, inflammation, autoimmune disorder, malignancy and medically unstable and uncooperative patients.

Data collection and intervention:

1. Assessment tools and procedures:

a. ***Prior to the program's commencement:*** All patients were told about the study's objectives, procedures, possible advantages, privacy, and data use. They were then requested to confirm and sign a permission form that detailed the program's purpose, nature, and any hazards.

b. One-repetition maximum strength (1RM) test:

A 1-rep max is the most amount of weight you can lift for one rep of a given exercise. It's proven as a reliable way to test muscular strength. To test the 1RM, following these steps [16]**:**

- *Warm up:* Using a weight that allows you to easily perform 6-10 repetitions, it was approximately 50% of your 1RM. Take a rest for a duration of 1 to 5 minutes. The duration of time required depends on when you feel completely restored and prepared to proceed with the subsequent stage.
- *Increase the weight:* To a weight that lets you do three reps, which is about 80% of your 1RM. Take a one- to five-minute break until you feel completely recovered.
- ***Do your heaviest lift:*** Lower the number of reps and raise the weight. Choose the largest weight that you can properly lift. Rest between sets and keep adding weight until you hit your limit. You've hit your new 1RM when you can lift the most weight for one rep.

c. SARC-F questionnaire: One potential quick diagnostic tool for sarcopenia is the SARC-F questionnaire. The five elements that make up SARC-F are as follows: strength, walking assistance, rising from a chair, climbing stairs, and falls. Each component contributes between zero and two points, for a total possible score of ten. Sarcopenia and bad results are predicted by a score of 4 or above. The specificity was 40% and sensitivity was 94.0 % [17]**.**

d. Six-minute walk test (6 MWT): Two plastic cones marked the edges of the hallway, and pieces of tape marked thirty-meter gaps between them. People were told to walk as quickly as they could along the path and to stop when they needed to. Over the course of six minutes, it tracks how far a person can walk on a hard, flat surface. The person has to walk as far as they can in only 6 minutes. The examiner walked with the subjects to make sure they were safe and told them regular things like "you are doing well" and "keep up the good work" every 1, 3, and 5 minutes. The test finished after 6 minutes, and it stopped right away if a participant said they had chest pain, dizziness, or shortness of breath. The total distance traveled was written down in meters [18]**.**

2. Treatment tools and procedures:

a. For study group I:

- **Low resistance training with restriction of blood flow (LRT-BFR):**
- In the LRT-BFR group, BFR was induced by inflating nylon cuffs attached to an inflator to a pressure equivalent to 50% of the limb occlusion pressure (LOP). To determine the individualized cuff pressure in mmHg, we used a vascular Doppler probe to assess the LOP of both the lower as well as upper limbs for every individual prior to the exercise intervention.
- The assessment approach employed for LOP involved positioning the individuals in a reclining position and using an ultrasonography probe to capture the auscultatory pulse of the tibial and radial arteries in the lower and upper limbs, respectively. The cuff was positioned at

the uppermost part of the patient's thigh for lower limb resistance and at the uppermost part of the arm for upper limb resistance, while the subject remained lying flat on their back. The cuff was inflated until the auscultatory pulse was completely blocked. The pressure applied to the cuff at this moment is known as the LOP (cuff pressure). At this point, the subjects began the LRT resistance training session, which included training for [(hip abductors, extensors (bridging ex.), flexors (SLR) and knee flexors and extensors (short and long arch quad ex)] and balance on one leg. The applied cuff pressure should not induce pain or discomfort in the subjects during training, and it can be modified as necessary based on the subject's level of comfort. The cuff remained continuously inflated during each training session, which included the rest intervals, as well as promptly deflated immediately after the completion of the final set.

b. For study group II:

- **High load resistance training (HRT):**
  RT for hip abductors, extensors (bridging ex.), flexors (SLR), knee flexors and extensors (short and long arch quad ex) and balance on one leg done using sandbags for 20 min. Three times weekly for a duration of six weeks.

Ethical approval: The Ethics Committee of Cairo University's Faculty of Physical Therapy accepted the study. Signed consent was provided by each participant. The Helsinki Declaration was adhered to at every stage of the investigation.

Statistical analysis

We performed all of the statistical analysis for this study using SPSS Version 25.0 for Windows. Relative percentages and frequencies were used to display the qualitative data. The statistical information was presented as mean ± SD. The Shapiro-Wilk test was utilized to evaluate the data for normal distribution. The homogeneity of variances between groups was evaluated using a Levene's test. The effects of the treatment on the SARC-F, 6 MWT, and 1 rep. max. test were investigated using a Mixed MANOVA. After that, post-hoc tests utilizing the Bonferroni correction were used to carry out multiple comparisons. For every statistical test, a significance threshold of $p \leq 0.05$ was used.

RESULTS

- **Subject characteristics:** Table (1) showed the subject characteristics of groups I & II. There was no substantial difference among groups regarding age, weight, height as well as BMI ($p > 0.05$).

Table (1): Comparison of subject characteristics between the group I and II

	Group I	Group II			
	Mean ±SD	**Mean ±SD**	**Mean difference**	**t-value**	**p-value**
Age (years)	69.10 ± 3.07	68.40 ± 2.78	0.7	0.75	0.45
Weight (kg)	72.50 ± 8.57	69.75 ± 5.34	2.75	1.22	0.23
Height (cm)	161 ± 6.37	159.60 ± 8.90	1.4	0.57	0.57
BMI (kg/m²)	28.05 ± 3.67	27.74 ± 4.66	0.31	0.24	0.81

- **Effect of treatment on SARC-F, 6 MWT and 1 rep. max. test:** According to a mixed MANOVA, time and treatment had a significant interaction impact ($F = 9.82$, $p = 0.001$). A significant main effect time was observed ($F = 218.38$, $p < 0.001$). Treatment had a significant main impact ($F = 3.66$, $p = 0.01$).

- **Within group comparison:** Post-treatment, both groups' SARC-F levels dropped significantly, and their 6 MWT and 1-rep max tests improved significantly compared to their pre-treatment levels ($p < 0.001$). The % of change in SARC-F and 6 MWT as well as right and left 1 rep. max. test in group I were 33.64, 47.16, 41.32 and 48.05% respectively and that in group II was 21.24, 27.21, 25.37 and 39.68% (Tables 2-3).

- **Between group comparison:** There was no substantial difference among groups pre-treatment ($p > 0.05$). When comparing the two groups post-treatment, it was found that group I had a much lower SARC-F and significantly higher 6 MWT and 1-rep max than group II ($p < 0.01$) (Tables 2-3).

Table (2): Mean SARC-F and 6MWT pre and post treatment of group I and II

	Pretreatment	Post treatment			
	Mean ±SD	Mean ±SD	Mean difference	% of change	p value
SARC-F					
Group I	5.35 ± 0.99	3.55 ± 0.76	1.80	33.64	0.001
Group II	5.65 ± 0.93	4.45 ± 0.94	1.20	21.24	0.001
MD	-0.3	-0.9			
	p = 0.33	***p = 0.002***			
6MWT (m)					
Group I	194.88 ± 27.04	286.78 ± 41.11	-91.90	47.16	0.001
Group II	200.75 ± 22.88	255.38 ± 37.54	-54.63	27.21	0.001
MD	-5.87	31.40			
	p = 0.46	***p = 0.01***			

Table (3): Mean 1 rep. max. test pre and post treatment of group I and II

Strength (kg)	Pretreatment	Post treatment			
	Mean ±SD	Mean ±SD	Mean difference	% of change	p value
1 rep. max. test of right limb					
Group I	3.63 ± 0.86	5.13 ± 0.67	-1.50	41.32	0.001
Group II	3.35 ± 0.75	4.20 ± 0.59	-0.85	25.37	0.001
MD	0.28	0.93			
	p = 0.29	***p = 0.001***			
1 rep. max. test of left limb					
Group I	3.33 ± 0.77	4.93 ± 0.78	-1.60	48.05	0.001
Group II	3.10 ± 0.68	4.33 ± 0.44	-1.23	39.68	0.001
MD	0.23	0.6			
	p = 0.33	***p = 0.005***			

DISCUSSION

A significant difference was identified in this research when comparing the pre-treatment and post-treatment mean values of measuring variables for the two groups: study (I) and study (II). Specifically, the patients in study group (I) who received low load RT in conjunction with BFR exhibited a substantial improvement in muscle power as well as functional performance when compared to those in study group (II) who received HRT.

The muscular hypertrophy response to HRT may be compromised in older persons due to reduced muscle neuron activity [19]**.** According to **Verdijk and colleagues** [20], different types of muscle fibers (such as Type 1 and Type 2) respond differently to high intensity RT. They discovered that after 12 weeks of RT in older individuals, Type 2 muscle fibers showed an increase in satellite cell contents, while Type 1 muscle fibers did not experience any changes in satellite cell contents. These factors may contribute to the recent findings of reduced muscle growth with high-intensity exercise in older individuals. Therefore, when comparing BFRE to high intensity resistance exercise, it is evident that BFRE not only enhances strength but also promotes muscular growth in older individuals.

The efficacy and safety of LRT-BFR have been investigated as a potential strategy to build muscle mass in older individuals, aiming for a less intense approach [21]**.** Research indicates that LRT-BFR can enhance muscle size and strength by stimulating the release of hormones such as GH [22], and IGF-1 [23], as well as boosting protein synthesis through the activation of mTOR (mammalian target of rapamycin) [24], and reducing MSTN [25]**.**

The reason behind this is that growth hormone (GH) is activated to produce IGF-1, which controls growth as well as metabolism also, it is important for the development of skeletal muscle [26]**.** This was supported by research by **Takarada *et al.*** [7] who discovered that GH levels were 290 times greater following BFR compared to controls without flow restriction. Furthermore, these explanations are consistent with research carried out by **Sharifi *et al.*** [22], who affirmed that LL-BFR stimulates the secretion of GH. Additionally, **Yinghao *et al.*** [27] found that LL-BFR effectively raises levels of GH, IGF-1, as well as testosterone in young men, thereby raising cuff stress and boosting muscular anabolic potential, which raises hormone production levels.

According to **Centner *et al.*** [28] LRE-BFR is a recommended type of exercise for older people who require immediate attention but are unable to participate in HRT because of contraindications. Type II muscle fiber atrophy and a reduction in satellite cells are characteristics of sarcopenia [29]. The insufficient distal muscle oxygenation brought on by BFR on the proximal limb led to the quick activation of type II fast muscle fibers, which depend less on aerobic metabolism [8]. Increased calorie expenditure and a faster metabolism are directly linked to higher muscle mass, which in turn causes a notable decrease in body fat [30]. It has been discovered that LRE-BFR increases muscle growth and strength and is linked to the production of muscle protein, MSTN [31], and mammalian target of rapamycin [9].

One of the measures used in this study was the 6-minute walk test, which is in line with the results of **Letieri *et al.*** [32] who discovered a 6-minute walk distance improvement in patients receiving LI-BFR treatment where after 8 weeks of training, the LI-BFR group showed a greater improvement in 6-minute walk distance than the HRT group.

The present study's findings showed that women who used LI-BFR workouts had significant improvements in every measure that was examined. This result emphasized the possibility of using this approach with elderly individuals. These findings are consistent with **Yokokawa *et al.*** [15] who found that an eight-week exercise program with BFR can enhance the physical function of older individuals residing in the community. The improvements, particularly in strength as well as muscle mass, are believed to be a result of exercise-induced secretion of GH. Additionally, **Hughes *et al.*** [21] concluded that BFR exercise could be beneficial for enhancing bone health as well as reducing muscle atrophy. Furthermore, our study findings align with those of **Kim *et al.*** [33] who propose that in young adults, long-term BFRE is beneficial for increasing vascularity, muscle growth, and strength. However, BFRE training outperforms high intensity resistance exercise in terms of growing forearm girth in older individuals by primarily boosting muscle strength and size. These findings are consistent with our own results. Furthermore, **Yasuda *et al.*** [34] documented an increase in muscle mass subsequent to a six-week period of low intensity (20% of 1RM) BFRE incorporating exercises such as knee extension and leg press, as well as upper body [12]**.** This discovery aligns with our study's findings.

Our study findings contradict the conclusions of **Teixeira *et al.*** [35] who concluded that despite a higher metabolic load, adding BFR to HL-RT during rest or muscular contraction had no further effect on muscle strength or hypertrophy.

In order to place this study in context, a few limitations must be noted. This study was limited by the following factors: The personal differences between patient's lifestyle, the psychological state of patients at the time of evaluation or therapy as well as the non-cooperative patients also, the infrequent attendance of patients in the treatment sessions, patients who might not follow the instructions of the training procedures carefully and the absence of a long-term effectiveness evaluation of the therapy program.

CONCLUSION

From the obtained findings of the present study, it could be concluded that both LL-BFR as well as high load resistance (HRT) training had some potential to improve sarcopenia in older adults, in favour to the LL-BFR which has greater improvements in muscle strength. The LL-BFR could be used as a safe and effective method for improving muscle power and function outcomes in elderly female patients with sarcopenia. This improvement of muscle power may help those patients to walk more efficient without falling and improving their performance in their daily living activities. So, the LL-BFR could be used in the rehabilitation of elderly patients with sarcopenia.

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- **Conflict of Interest:** Nil.

REFERENCES

1. **Cruz-Jentoft A, Sayer A (2019):** Sarcopenia. The Lancet, 393 (10191): 2636-2646.
2. **Cheung C, Lam K, Cheung B (2016):** Evaluation of cut points for low lean mass and slow gait speed in predicting death in the national health and nutrition examination survey 1999–2004. J Gerontol A Biol Sci Med Sci., 71: 90–5.
3. **Curcio F, Ferro G, Basile C *et al.* (2016):** Biomarkers in sarcopenia: a multifactorial approach. Exp Gerontol., 85: 1–8.
4. **Giallauria F, Cittadini A, Smart N *et al.* (2016):** Resistance training and sarcopenia. Monaldi Arch Chest Dis., 84 (1-2): 738. doi: 10.4081/monaldi.2015.738.
5. **American College of Sports Medicine (2009):** American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. Med Sci Sports Exerc., 41 (3): 687–708.
6. **Larsson L, Degens H, Li M *et al.* (2019):** Sarcopenia: aging-related loss of muscle mass and function. Physiol Rev., 99 (1): 427–511.
7. **Takarada Y, Takazawa H, Sato Y *et al.* (2000):** Effects of resistance exercise combined with moderate vascular occlusion on muscular function in humans. J Appl Physiol., 88 (6): 2097–2106.
8. **Yasuda T, Fukumura K, Fukuda T *et al.* (2014):** Muscle size and arterial stiffness after blood flow-restricted low-intensity resistance training in older adults. Scand J Med Sci Sport., 24 (5): 799–806.
9. **Fry C, Glynn E, Drummond M *et al.* (2010):** Blood flow restriction exercise stimulates mTORC1 signaling and muscle protein synthesis in older men. J Appl Physiol., 108: 1199–1209.
10. **Loenneke J, Wilson J, Marín P *et al.* (2012):** Low intensity blood flow restriction training: a meta-analysis. Eur J Appl Physiol., 112 (5): 1849–1859.

11. **Loenneke J, Kim D, Fahs C *et al.* (2015):** Effects of exercise with and without different degrees of blood flow restriction on torque and muscle activation. Muscle Nerve, 51 (5): 713–721.
12. **Karabulut M, Abe T, Sato Y *et al.* (2010):** The effects of low-intensity resistance training with vascular restriction on leg muscle strength in older men. Eur J Appl Physiol., 108 (1): 147–155.
13. **Thiebaud R, Loenneke J, Fahs C *et al.* (2013):** The effects of elastic band resistance training combined with blood flow restriction on strength, total bone-free lean body mass and muscle thickness in postmenopausal women. Clin Physiol Funct Imaging, 33 (5): 344–352.
14. **Mattar M, Gualano B, Perandini L *et al.* (2014):** Safety and possible effects of low-intensity resistance training associated with partial blood flow restriction in polymyositis and dermatomyositis. Arthritis Res Ther., 16 (5): 473. doi: 10.1186/s13075-014-0473-5.
15. **Yokokawa Y, Hongo M, Urayama H *et al.* (2008):** Effects of low-intensity resistance exercise with vascular occlusion on physical function in healthy elderly people. Biosci Trends, 2 (3): 117–123.
16. **Yoo J, Kim J, Hwang B *et al.* (2022):** Estimation of 1-Repetition Maximum Using a Hydraulic Bench Press Machine Based on User's Lifting Speed and Load Weight. Sensors (Basel), 22 (2): 698. doi: 10.3390/s22020698.
17. **Krzymińska-Siemaszko R, Deskur-Śmielecka E, Kaluźniak-Szymanowska A *et al.* (2020):** Polish version of SARC-F to assess sarcopenia in older adults: an examination of reliability and validity. PLoS One, 15 (12): e0244001. doi: 10.1371/journal.pone.0244001
18. **Caballer V, Lisón J, Rosado-Calatayud P *et al.* (2015):** Factors associated with the 6-minute walk test in nursing home residents and community-dwelling older adults. J Phys Ther Sci., 27 (11): 3571-78.
19. **Unhjem R, Lundestad R, Fimland M *et al.* (2015):** Strength training-induced responses in older adults: attenuation of descending neural drive with age. Age (Dordr), 37 (3): 9784. doi: 10.1007/s11357-015-9784-y.
20. **Verdijk L, Gleeson B, Jonkers R *et al.* (2009):** Skeletal muse hypertrophy following resistance training is accompanied by a fiber type-specific increase in satellite cell content in elderly men. J Gerontol A Biol Sci Med Sci., 64: 332–339.
21. **Hughes L, Paton B, Rosenblatt B *et al.* (2017):** Blood flow restriction training in clinical musculoskeletal rehabilitation: a systematic review and meta-analysis. Br J Sports Med., 51 (13): 1003-11.
22. **Sharifi S, Monazzami A, Nikousefat Z *et al.* (2020):** The acute and chronic effects of resistance training with blood flow restriction on hormonal responses in untrained young men: a comparison of frequency. Cell Mol Biol., 66 (1): 1–8.
23. **Takano H, Morita T, Iida H *et al.* (2005):** Hemodynamic and hormonal responses to a short-term low-intensity resistance exercise with the reduction of muscle blood flow. Eur J Appl Physiol., 95 (1): 65–73.
24. **Bahreinipour M, Joukar S, Hovanloo F *et al.* (2018):** Mild aerobic training with blood flow restriction increases the hypertrophy index and MuSK in both slow and fast muscles of old rats: role of PGC-1α. Life Sci., 202: 103–9.
25. **Drummond M, Fujita S, Abe T *et al.* (2008):** Human muscle gene expression following resistance exercise and blood flow restriction. Med Sci Sports Exerc., 40 (4): 691. https://doi.org/10.1249/MSS.0b013e318160ff84.
26. **Kim H, Barton E, Muja N *et al.* (2005):** Intact insulin and insulin-like growth factor-I receptor signaling is required for growth hormone effects on skeletal muscle growth and function in vivo. Endocrinology, 146 (4): 1772-1779.
27. **Yinghao L, Jing Y, Yongqi W *et al.* (2021):** Effects of a blood flow restriction exercise under different pressures on testosterone, growth hormone, and insulin-like growth factor levels. J Int Med Res., 49 (9): 3000605211039564. 10.1177/03000605211039564.
28. **Centner C, Wiegel P, Gollhofer A *et al.* (2019):** Effects of Blood Flow Restriction Training on Muscular Strength and Hypertrophy in Older Individuals: A Systematic Review and Meta-Analysis. Sports Medicine, 49 (1): 95–108.
29. **Zhang X, Xie W, Chen L *et al.* (2022):** Blood Flow Restriction Training for the Intervention of Sarcopenia: Current Stage and Future Perspective. Front Med., 9: 894996. doi: 10.3389/fmed.2022.894996.
30. **Carey D, Pliego G, Raymond R (2006):** Body composition and metabolic changes following bariatric surgery: effects on fat mass, lean mass and basal metabolic rate: six months to one-year follow-up. Obes Surg., 16 (12): 1602–8.
31. **Santos A, Neves M, Gualano B *et al.* (2014):** Blood flow restricted resistance training attenuates myostatin gene expression in a patient with inclusion body myositis. Biol Sport., 31 (2): 121–4.
32. **Letieri R, Furtado G, Barros P *et al.* (2019):** Effect of 16-week blood flow restriction exercise on functional fitness in sarcopenic women: a randomized controlled trial. Int J Morphol., 37 (1): 59-64.
33. **Kim J, Lang J, Pilania N *et al.* (2017):** Effects of blood flow restricted exercise training on muscular strength and blood flow in older adults. Exp Gerontol., 99: 127-132.
34. **Yasuda T, Loenneke J, Thiebaud R *et al.* (2012):** Effects of blood flow restricted low-intensity concentric or eccentric training on muscle size and strength. PLoS One, 7 (12): e52843. doi: 10.1371/journal.pone.0052843.
35. **Teixeira E, Ugrinowitsch C, Painelli V *et al.* (2021):** Blood Flow Restriction Does Not Promote Additional Effects on Muscle Adaptations When Combined with High-Load Resistance Training Regardless of Blood Flow Restriction Protocol. Journal of Strength and Conditioning Research, 35 (5): 1194-1200.