

From frailty to function: Effect of combined aerobic exercise with blood flow restriction on mobility and fatigue in elderly

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Article History

Received: 22.09.2025

Revised: 08.10.2025

Accepted: 15.10.2025

Published: 03.11.2025

Abstract:

Problem statement: Since physical therapy is crucial for helping older individuals restore their proper function and quality of life, contemporary approaches like blood flow restriction (BFR) have been used to enhance functional level in these patients. Objective: This study focused into how BFR affected older patients' functions. Methods: Sixty hypertensive older individuals aged from 65 to 75 years, were recruited, and divided randomly into two equal groups (30 participants in each group). Over 12 weeks, BFR group received treadmill moderate-intensity exercise in conjunction with BFR, whereas the control group received the same treadmill exercise only. Blood pressure (BP), Timed Up and Go (TUG) Test, and Fatigue Assessment Scale (FAS) were assessed before and after the intervention. Results: BP, TUG, and FAS showed significant reductions in both groups ($p < 0.001$). Furthermore, all assessed variables showed more significant improvements in favor of BFR group when compared to the control group ($p < 0.05$). Conclusions: BFR serves as a cost-effective, safe, and efficient way to reduce BP and enhances older patients' function and quality of life.

Keywords: Aerobic exercise; Blood flow restriction; Elderly, Fatigue, Hypertension, Mobility.

INTRODUCTION

Aging is a natural, progressive, and inevitable biological process characterized by a gradual decline of cellular function and progressive structural changes in many organ systems. In general, the rate of the physiologic decline is initially difficult to perceive; however, after certain age (late maturity), it undergoes acceleration. (Glasscock et al., 2012).

The world population is ageing rapidly. Since 1980, the number of people aged 60 years and over has doubled to approximately 810 million. The elderly population will continue to grow to approximately 2 billion in 2050. It has been predicted that 22% of the total population will be older than 60 years and around 5% will be older than 80 years in 2050. (Louie et al., 2010) Metabolic changes of aging like obesity are a significant contributor to sarcopenia (decrease in muscle protein synthesis) (Nagy et al., 2025) which suggests that muscle turnover and repair capacity is likely decreased with age. (Evans et al., 2010)

Moreover, Hypertension (HTN) which mean increasing blood pressure (BP) has adverse physiological alterations in the skeletal muscle response to an acute muscle contraction among individuals compared to those with normal BP that includes exaggerated sympathetic nervous activity, increased vasoconstriction, and a greater release of reactive oxygen species. (Greaney et al., 2014)

These alterations create a state of hypoxia in the skeletal muscle which augments oxidative stress, eventually leading to vascular wall thickening and skeletal muscle damage. This pathological chain of

events has been shown to be associated with decreased muscle strength specially in the elderly hypertensive patients. (Umbrello et al., 2013)

Blood flow restriction (BFR) and aerobic exercise with occlusion pressures between 40-60 mmHg and 50% maximum heart rate (HR Max), systolic and diastolic blood pressure (SBP and DBP) responses were found to be like those traditionally found with aerobic intensities of 62-85% HR max. (Sugawara et al., 2015). BFR became popular and effective rehabilitative medicine in hypertensive elderly individuals resulting in a decrease in vascular resistance and BP by increasing local blood flow. (Manini et al., 2009)

Empirical evidence indicates that low-load resistance training combined with BFR elicits hypertrophic adaptations and muscle activation levels that are comparable to those achieved through high-load resistance training. (Ferguson et al., 2018)

Moreover, when contrasted with low-load training performed without BFR, the BFR-enhanced produces significantly greater muscular responses, suggesting its efficacy as a potent alternative for inducing muscle growth under reduced mechanical load conditions. (Rolnick et al., 2022).

To address the existing gap in knowledge regarding the application of BFR training in older adults, the present study seeks to empirically evaluate the effect of BFR on functional outcomes within this population. The findings will help guide clinical practice by healthcare professionals' evidence-based recommendations for improving older people's physical performance.

MATERIALS AND METHODS

The study design

At Suez Canal University in Ismailia, Egypt, sixty hypertensive older individuals between the ages of 65 and 75 were recruited for this 12-week randomized controlled study. Following comprehensive clinical assessments, participants were randomly allocated into two equal groups: BFR group who engaged in a moderate-intensity aerobic exercise regimen incorporating BFR, while the control group B performed the same aerobic exercise protocol without BFR.

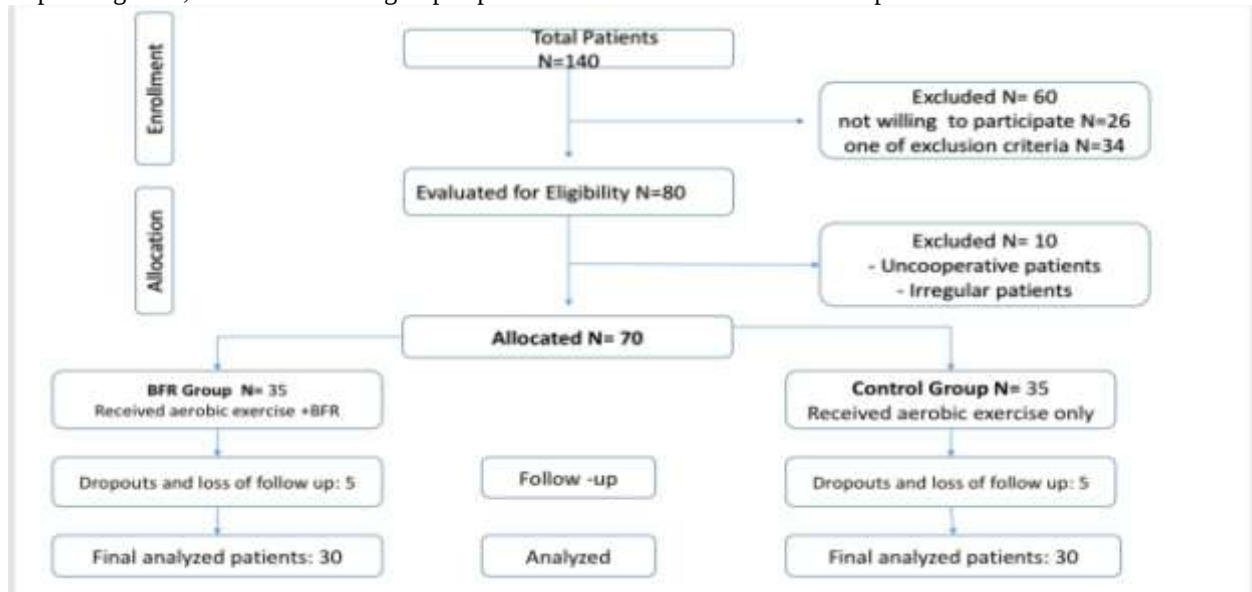


Figure 1. flowchart of the study

Every participant gave their consent after being fully informed about the intervention, including its possible benefits and drawbacks. This study was approved by the Ethics Committee Board of Cairo University's Faculty of Physical Therapy No: P.T.REC/012/005597, and it is listed on ClinicalTrials.gov with the registration No: NCT06877130.

Participants in this study were required to be of both sexes, be elderly (65–75 years old), had grade I and II hypertension (SBP 140:179 mmHg and/or DBP 90-109 mmHg) (Ramzy, 2019), as well as a body mass index between 30 and 34.9 kg/m² (class I obesity) (Bousslama et al., 2019).

Participants presenting with severe neurological, psychiatric, or cognitive impairments that could hinder adherence to the exercise protocol were excluded from the study. Additional exclusion criteria included the presence of significant pulmonary pathology (either obstructive or restrictive), clinical manifestations of advanced cardiovascular disease (e.g., severe atherosclerosis or congestive heart failure), uncontrolled diabetes mellitus, lower limbs peripheral arterial disease, and serious systemic illnesses such as malignancies. Furthermore, individuals with uncontrolled hypertension and those exhibiting severe tachycardia with resting heart rates exceeding 120 beats per minute were not eligible for inclusion.

Intervention

Moderate intensity exercise (MIE)

Both groups participated in a moderate-intensity aerobic exercise program utilizing a treadmill (Grand Fit Ac 88885- China) over a 12-week period. Each training session was structured into three distinct phases: warm-up, main exercise, and cool-down. According to Ebbeling et al., 1991, during the warm-up and cool-down phases, participants walked on a 0% incline treadmill for four minutes. The walking speed was individually adjusted to elicit a heart rate corresponding to approximately 50–70% of the age-predicted maximum, typically ranging between 2.0 and 4.5 miles per hour.

According to the American College of Physicians (ACSM), the main exercise phase lasted 30 to 35 minutes and was conducted after the participant's heart rate reached 64–76% of their age-predicted peak heart rate (Riebe et al., 2018) which predetermined by Jackson formula [MHR = 206.9 - (0.67 x age)] (Jackson, 2007). Granzia pulse oximeter (Model No.: AS-304, Italy) was utilized to track the patients' changes in heart rate while exercising.

BFR training

During treadmill MIE, BFR was solely used for the BFR group in the previously mentioned manner. The thigh was subsequently wrapped with a wide cuff (18 cm wide cuff connected to GT001-110/111 aneroid sphygmomanometer, Zhejiang, China) and inflated until the blood pulse from the tibial artery was absent. The obstructed pressure was tracked at this point (Lorenz et al., 2021). According to Murray et al.

(2021), each lower limb underwent 60–80% of the limb occlusion pressure during treadmill training with lower limb BFR. If the exercise regimen causes chronic exhaustion, or continuous pain, the program was modified with special attention to the length and/or intensity of exercise for each participant.

Outcome measures

BP

Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured by Aneroid Sphygmomanometers: (Model Number: GT001-110/111 aneroid sphygmomanometer, Zhejiang, China)were used to obtain a BP reading according to **Pickering et al.,2005** recommendations.

Functional mobility and dynamic balance (TUG test)

To conduct the TUG test, a durable armchair with a back was placed at the end of a corridor. Three meters from the chair's front edge, a piece of tape was placed on the floor. After getting out of the chair, the patient was directed to walk three meters at a normal pace, turn around, walk back to the chair, and then sit down. A stopwatch was used to measure the test time from standing up to sitting down again; a score of more than 12 seconds often denotes a higher risk of falling and restricted mobility. (**Hayes et al., 2025**).

Fatigue level (FAS)

The FAS is a 10-item measure that assesses both mental and physical symptoms of chronic fatigue. A five-point rating system, with 1 denoting "never" and 5 denoting "always," is used to answer each FAS item. The scores for items 4 and 10 are reversed. The range of total scores is 10 for the lowest level of fatigue and 50 for the most. (**Bartholomew, et al., 2025**)

Statistical analysis

To compare subject characteristics between groups, the unpaired t-test was used. The chi-squared test was used to compare the distribution of sexes among groups. Using Levene's test and the Shapiro-Wilk test, respectively, the data were examined for homogeneity of variances between groups and for a normal distribution.

To examine the impact of therapy on BP, TUG, and FAS, a mixed MANOVA was performed. The Bonferroni correction for subsequent multiple comparison was used to do the post-hoc test. For every statistical test, the significance level was set at $p < 0.05$. The statistical software for social sciences (SPSS) version 25 for Windows (IBM SPSS, Chicago, IL, USA) was used for all statistical analyses.

RESULT AND OBSERVATION

Results From the entire sample, thirty participants each were selected and divided into two equal groups. The participants' age, sex distribution, anthropometric features, and BP levels did not differ significantly between the two groups. ($p > 0.05$). (Table 1)

Table 1. Characteristics of participants:

	BFR Group	Control Group	MD	t value	p value
	Mean $\pm$ SD	Mean $\pm$ SD			
Age (years)	65.77 $\pm$ 1.65	66.30 $\pm$ 2.18	-0.53	-1.07	0.29
Weight (kg)	87.70 $\pm$ 8.81	86.74 $\pm$ 8.63	0.96	0.43	0.67
Height (cm)	168.63 $\pm$ 7.92	167.07 $\pm$ 7.37	1.56	0.79	0.43
BMI (kg/m ²)	30.86 $\pm$ 2.56	31.03 $\pm$ 1.55	-0.17	-0.31	0.76
Blood pressure (BP)					
Systolic BP (mmHg)	150.17 $\pm$ 6.50	148.67 $\pm$ 8.60	1.5	0.76	0.45
Diastolic BP (mmHg)	101.67 $\pm$ 6.06	102.00 $\pm$ 7.50	-0.33	-0.19	0.85
Sex, n (%)					
women	15 (50%)	15 (50%)			
Men	15 (50%)	15 (50%)			

BMI: Body mass index, BP: Blood pressure. SD, Standard deviation; MD, mean difference; p value, Probability value. *Statistically significant at $P < 0.05$.

Differences in BP (systolic and diastolic) within groups

There was a significant decrease in SBP in BFR group post treatment compared with pretreatment ($p = 0.001$) with mean difference about 18 mmHg and a percent of change by 11.99%.

There was a significant decrease in DBP of BFR group post treatment compared with pretreatment ($p = 0.001$) with mean difference about 9 mmHg and percent of change by 8.85%.

There was a significant decrease in systolic BP in the control group post treatment compared with pretreatment ($p = 0.001$) with mean difference about 11.5 mmHg and percent of change by 7.74%. In addition, there was a significant decrease in DBP in the control group post treatment compared with pretreatment ($p = 0.001$) with mean difference about 5.17 mmHg and the percent of change by 5.07%.

Table 2. Mean systolic and diastolic BP pre and post training of both groups:

BP (mmHg)	BFR Group	Control Group	MD (95% CI)	P value	d
	Mean $\pm$ SD	Mean $\pm$ SD			
Systolic BP					
Pre training	150.17 $\pm$ 6.50	148.67 $\pm$ 8.60	1.5 (-2.44: 5.44)	0.45	
Post training	132.17 $\pm$ 7.15	137.17 $\pm$ 8.48	-5 (-9.05: -0.95)	0.01	0.64
MD (95% CI)	18 (14.86: 21.14)	11.5 (8.36: 14.64)			
	p = 0.001*	p = 0.001*			
Diastolic BP					
Pre training	101.67 $\pm$ 6.06	102.00 $\pm$ 7.50	-0.33 (-3.86: 3.19)	0.85	
Post training	92.67 $\pm$ 6.26	96.83 $\pm$ 7.27	-4.16 (-7.67: -0.66)	0.02	0.61
MD (95% CI)	9 (7.27: 10.73)	5.17 (3.44: 6.89)			
	p = 0.001*	p = 0.001*			

BP: Blood pressure. SD, Standard deviation; MD, Mean difference; CI, Confidence interval; p-value, Probability value; d, Effect size. *Statistically significant at P<0.05.

Differences in TUG between within groups

There was a significant decrease in TUG in BFR group post treatment compared with pretreatment (p = 0.001) mean difference was 8.2 sec, and the percentage of change was 45.48%.

There was a significant decrease in TUG in the control group post treatment compared with pretreatment (p = 0.001) with mean difference about 5.07 sec, and the percentage of change was 28.37%.

Differences in FAS within groups

There was a significant decrease in FAS in BFR group post treatment compared with pretreatment (p = 0.001) mean difference was 22.17, and the percentage of change was 55.15%. There was a significant decrease in FAS in the control group post treatment compared with pretreatment (p = 0.001) with mean difference about 15.10, and the percentage of change was 38.20%.

Table 3. Mean TUG and FAS pre and post training of both groups:

	BFR Group	Control Group	MD (95% CI)	P value	d
	Mean $\pm$ SD	Mean $\pm$ SD			
TUG (sec)					
Pre training	18.03 $\pm$ 2.57	17.87 $\pm$ 3.18	0.16 (-1.33: 1.66)	0.82	
Post training	9.83 $\pm$ 2.84	12.80 $\pm$ 2.54	-2.97 (-4.36: -1.57)	0.001	1.10
MD (95% CI)	8.2 (7.36: 9.04)	5.07 (4.23: 5.91)			
	p = 0.001*	p = 0.001*			
FAS					
Pre training	40.20 $\pm$ 2.25	39.53 $\pm$ 2.26	0.67 (-0.50: 1.83)	0.26	
Post training	18.03 $\pm$ 3.27	24.43 $\pm$ 2.66	-6.4 (-7.94: -4.86)	0.001	2.15
MD (95% CI)	22.17 (21.08: 23.25)	15.10 (14.01: 16.19)			
	p = 0.001*	p = 0.001*			

FAS: Fatigue assessment scale, TUG: Time up and go. SD, Standard deviation; MD, Mean difference; CI, Confidence interval; p-value, Probability value; d, Effect size. *Statistically significant at P<0.05.

DISCUSSION

The study's findings demonstrated that following the intervention, participants' TUG, FAS, and BP were significantly reduced (p < 0.001). Additionally, the BFR group demonstrated significant improvements in all evaluated parameters when compared to the control group (p < 0.05).

Regarding BP, in line with our findings, Crisafulli et al. (2018) found that BFRT decreased BP during handgrip exercises, which may indicate a hypotensive effect of

this training method. Exercise training has been shown to improve baroreceptor regulation, which may reduce sympathetic activity.

Miller et al., 2009 also agreed with our results through study conducted to examine the levels of BP after aerobic exercise at chronic kidney diseases patients and showed an improvement at kidney function tests and the number of antihypertensive agents needed to control BP decreases after aerobic exercise training.

Jessee et al., 2018 observed dropping in BP after BFR exercise in athlete trainer as adaptation process which

result of several interconnected physiological mechanisms. Although BFR involves low-load resistance training, the cardiovascular responses it triggers are significant and resemble those seen in high-intensity workouts. The main causes of post BFR exercise hypotensive response is building up of metabolites such as lactate, hydrogen ions, and adenosine which stimulate the vasodilation once the cuffs are released.

Moreover, Desanlis et al., 2024 founded that exercise typically shifts the autonomic balance toward sympathetic dominance. However, after BFR exercise, there is a rapid shift back toward parasympathetic activity. This shift reduces heart rate and vascular tone, contributing to lower BP. Enhanced baroreflex sensitivity may also play a role in stabilizing BP at a lower level post-exercise.

In terms of functional mobility, our results align with those of Clarkson et al. (2017), who randomized sedentary older men and women to a non-BFR walking group and a low-intensity BFR walking group. The 30-second sit-to-stand test, the 6-minute walk test, the timed up-and-go test, and a modified Queen's College step test were used to evaluate the participants at baseline, three weeks, and six weeks. When compared to the non-BFR group, BFRT generally produced a larger improvement in performance on all physical function measures. This highlighted how adding BFRT can improve mobility for this population, who isn't an appropriate candidate for heavy-load resistance training.

Clarkson et al. (2019) also found that BFR is linked to higher improvements in muscle mass and strength compared to identical training that does not involve BFR. In a variety of clinical and chronic illness populations, BFR has been suggested as a potential substitute for physically demanding exercise. According to the current data, BFR exercise enhanced objective physical function measures that are representative of everyday life activities.

Additionally, Letieri et al. (2019) examined how the BFR affected the functional capacity of older women after 16 weeks, even though their Muscle Mass Index improved. Using physical activity as an auxiliary technique to reduce sarcopenia and provide a physical profile during the aging process, the BFR method can be a successful intervention process.

These promising findings may rely on the BFR training beneficial effect through promoting hypoxic intramuscular condition, encourage capillarization growth, enhance localized muscle endurance performance and in turn improve functional performance, balance, and mobility (Larkin et al. 2012)

Additionally, our results are in line with those of Rodríguez-Bautista et al. (2024), who assessed the

effects, safety, and viability of an aerobic training program using BFR for women with fibromyalgia. Tests such as the six-minute walk test, incremental shuttle walk test, dynamometer knee extension and handgrip test, 30-second chair stand test, and timed up-and-go test were used to evaluate functional capacity. According to Rodríguez-Bautista et al., BFR aerobic training may be a more effective, safe, and practicable physical exercise prescription technique than unconstrained aerobic training for enhancing the strength, balance, stiffness, and cardiorespiratory fitness of women with fibromyalgia.

Also, Schwiete et al. (2021) assessed the effects of BFR during resting intervals that were comparable to continuous BFR training on the maximum strength, hypertrophy, fatigue resistance, and perceived discomfort among participants who had received recreational training. They concluded that resting BFR training could offer a significant substitute for contentious BFR because they demonstrated comparable structural and functional changes along with less discomfort.

CONCLUSION

The present study demonstrated the positive effects of BFR on older persons' TUG, FAS, and BP. According to the results, BFR may be a useful tool for populations who could have mobility problems or other health limitations since it is a safe and efficient substitute for high-load exercise. Standardized training procedures and recommendations for incorporating BFR into clinical practice—particularly for managing cardiovascular health in older adults—should be developed through more research. Further studies are recommended to overcome the current study limitations such as assessment of the cost-effectiveness of BFR aerobic exercise compare to traditional therapy or exercise programs, evaluation of the long term adherence and quality of life and investigation of the safety and effectiveness of BFR aerobic exercise in elderly subjects with other sever co-morbidities (eg: Heart failure).

Declarations

Conflicts of interest: The authors have no conflict of interest.

Funding: This study received no funding from any institutions.

Data availability: Data of this study are available under request.

REFERENCES

1. American College of Sports Medicine (ACSM) (2018). ACM's Guidelines for Exercise Testing and Prescription, 10th ed.; Riebe, D., Ehrman, J.K., Liguori, G., Magal, M., Eds.; Wolters Kluwer: Philadelphia, PA, USA, 2018; ISBN 9781496339065.

2. Bartholomew, E. J., Medvedev, O. N., Petrie, K. J., & Chalder, T. (2025). Which fatigue scale should I use? A Rasch analysis of two fatigue scales in inflammatory conditions. *Rheumatology*, 64(1), 195-203.
3. Bouslama, M., Perez, H. J., Barreira, C. M., Haussen, D. C., Grossberg, J. A., Belagaje, S. R., ... & Nogueira, R. G. (2020). Body mass index and clinical outcomes in large vessel occlusion acute ischemic stroke after endovascular therapy. *Interventional neurology*, 8(2-6), 144-151.
4. Clarkson, M. J., Conway, L., & Warmington, S. A. (2017). Blood flow restriction walking and physical function in older adults: a randomized control trial. *Journal of science and medicine in sport*, 20(12), 1041-1046.
5. Clarkson, M. J., May, A. K., & Warmington, S. A. (2019). Chronic blood flow restriction exercise improves objective physical function: a systematic review. *Frontiers in physiology*, 10, 1058.
6. Crisafulli, A., De Farias, R. R., Farinatti, P., Lopes, K. G., Milia, R., Sainas, G., ... & Oliveira, R. B. (2018). Blood flow restriction training reduces blood pressure during exercise without affecting metaboreflex activity. *Frontiers in physiology*, 9, 1736.
7. Desanlis, J. (2024). Hemodynamic and cardiorespiratory acute and chronic responses to different blood flow restrictions at rest and during exercise (Doctoral dissertation, Université Paris-Saclay).
8. Ebbeling, C. B., Ward, A., Puleo, E. M., Widrick, J., & Rippe, J. M. (1991). Development of a single-stage submaximal treadmill walking test. *Medicine and science in sports and exercise*, 23(8), 966-973.
9. Evans WJ (2010). Skeletal muscle loss: cachexia, sarcopenia, and inactivity. *Am J Clin Nutr* 91:1123S-1127S.
10. Ferguson, R. A., Hunt, J. E., Lewis, M. P., Martin, N. R., Player, D. J., Stangier, C., ... & Turner, M. C. (2018). The acute angiogenic signalling response to low-load resistance exercise with blood flow restriction. *European journal of sport science*, 18(3), 397-406.
11. Glasscock, R. J., & Rule, A. D. (2012). The implications of anatomical and functional changes of the aging kidney: with an emphasis on the glomeruli. *Kidney international*, 82(3), 270-277.
12. Greaney, J. L., Matthews, E. L., Boggs, M. E., Edwards, D. G., Duncan, R. L., & Farquhar, W. B. (2014). Exaggerated exercise pressor reflex in adults with moderately elevated systolic blood pressure: role of purinergic receptors. *American Journal of Physiology-Heart and Circulatory Physiology*, 306(1), H132-H141.
13. Haas, D. C., Foster, G. L., Nieto, F. J., Redline, S., Resnick, H. E., Robbins, J. A., ... & Pickering, T. G. (2005). Age-dependent associations between sleep-disordered breathing and hypertension: importance of discriminating between systolic/diastolic hypertension and isolated systolic hypertension in the Sleep Heart Health Study. *Circulation*, 111(5), 614-621.
14. Hayes, L. D., Sanal-Hayes, N. E., Mclaughlin, M., Berry, E. C., & Sculthorpe, N. F. (2025). People with long COVID and ME/CFS exhibit similarly impaired balance and physical capacity: a case-case-control study. *The American Journal of Medicine*, 138(1), 140-147.
15. Jackson, A. S. (2007). Estimating maximum heart rate from age: Is it a linear relationship?. *Medicine and science in sports and exercise*, 39(5), 821-821.
16. Jessee, M. B., Mattocks, K. T., Buckner, S. L., Dankel, S. J., Mouser, J. G., Abe, T., & Loenneke, J. P. (2018). Mechanisms of blood flow restriction: the new testament. *Techniques in orthopaedics*, 33(2), 72-79.
17. Larkin, K. A., Macneil, R. G., Dirain, M., Sandesara, B., Manini, T. M., & Buford, T. W. (2012). Blood flow restriction enhances post-resistance exercise angiogenic gene expression. *Medicine and science in sports and exercise*, 44(11), 2077.
18. Letieri, R. V., Furtado, G. E., Barros, P. M. N., Farias, M. J. A. D., Antunez, B. F., Gomes, B. B., & Teixeira, A. M. M. B. (2019). Effect of 16-week blood flow restriction exercise on functional fitness in sarcopenic women: A randomized controlled trial. *International Journal of Morphology*, 37(1), 59-64.
19. Lorenz, D. S., Bailey, L., Wilk, K. E., Mangine, R. E., Head, P., Grindstaff, T. L., & Morrison, S. (2021). Blood flow restriction training. *Journal of athletic training*, 56(9), 937-944.
20. Louie, G. H., & Ward, M. M. (2010). Sex disparities in self-reported physical functioning: true differences, reporting bias, or incomplete adjustment for confounding?. *Journal of the American Geriatrics Society*, 58(6), 1117-1122.
21. Manini, T. M., & Clark, B. C. (2009). Blood flow restricted exercise and skeletal muscle health. *Exercise and sport sciences reviews*, 37(2), 78-85.
22. Mehboudi, M. B., Nabipour, I., Vahdat, K., Darabi, H., Raeisi, A., Mehrdad, N., ... & Ostovar, A. (2017). Inverse association between cigarette and water pipe smoking and hypertension in an elderly population in Iran: Bushehr elderly health programme. *Journal of human hypertension*, 31(12), 821-825.
23. Miller, W. G. (2009). Estimating glomerular filtration rate. *Clinical chemistry and laboratory medicine*, 47(9), 1017-1019.
24. Murray, J., Bennett, H., Boyle, T., Williams, M., & Davison, K. (2021). Approaches to determining occlusion pressure for blood flow restricted exercise training: Systematic review. *Journal of sports sciences*, 39(6), 663-672.
25. Nagy, E. N., Shafiek, M., Elsheimy, H., Mogahed, H. G., & Elsayed, M. M. (2025). High-intensity Interval Training and Mindfulness Breathing

- Induce Hormonal, Metabolic, and Anticarcinogenic Effects in Obese Postmenopausal Women: A Randomized Controlled Trial. *Journal of evidence-based integrative medicine*, 30, 2515690X251372718.
<https://doi.org/10.1177/2515690X251372718>
26. Nordestgaard, B. G. (2017). A test in context: lipid profile, fasting versus nonfasting. *Journal of the American College of Cardiology*, 70(13), 1637-1646.
27. Pickering, T. G., Hall, J. E., Appel, L. J., Falkner, B. E., Graves, J., Hill, M. N., ... & Roccella, E. J. (2005). Recommendations for blood pressure measurement in humans and experimental animals: part 1: blood pressure measurement in humans: a statement for professionals from the Subcommittee of Professional and Public Education of the American Heart Association Council on High Blood Pressure Research. *Circulation*, 111(5), 697-716.
28. Ramzy, D. (2019). Definition of hypertension and pressure goals during treatment (ESC-ESH Guidelines 2018). *Eur. Soc. Cardiol. J*, 17.
29. Rodríguez-Bautista, J. C., López-Lluch, G., Rodríguez-Torres, P., López-Moral, Á., Quijada-Carrera, J., Bueno-Antequera, J., ... & Munguia-Izquierdo, D. (2024). Feasibility, safety, and effects of an aerobic training program with blood flow restriction on functional capacity, and symptomatology in women with fibromyalgia: a pilot study. *Biomedicines*, 12(8), 1895.
30. Rolnick, N., de Sousa Neto, I. V., da Fonseca, E. F., Neves, R. V. P., dos Santos Rosa, T., & da Cunha Nascimento, D. (2022). Potential implications of blood flow restriction exercise on patients with chronic kidney disease: a brief review. *Journal of exercise rehabilitation*, 18(2), 81.
31. Schwiete, C., Franz, A., Roth, C., & Behringer, M. (2021). Effects of resting vs. Continuous blood-flow restriction-training on strength, fatigue resistance, muscle thickness, and perceived discomfort. *Frontiers in physiology*, 12, 663665.
32. Sugawara, J., Tomoto, T., & Tanaka, H. (2015). Impact of leg blood flow restriction during walking on central arterial hemodynamics. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, 309(7), R732-R739.
33. Umbrello, M., Dyson, A., Feelisch, M., & Singer, M. (2013). The key role of nitric oxide in hypoxia: hypoxic vasodilation and energy supply-demand matching. *Antioxidants & redox signaling*, 19(14), 1690-1710.