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Literature Review

# Physical exercise with aerobic predominance associated with blood flow restriction in the elderly: are there enough evidence for it clinical application?

## Exercício físico com predominância aeróbia associado a restrição de fluxo sanguíneo em idosos: há evidências suficientes para sua aplicação clínica?

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**ABSTRACT**

**Introduction:** Physical exercise with aerobic predominance is already a known strategy with benefits for the elderly population, and the use of blood flow restriction (BFR) can be a promising and effective alternative to bring vaster benefits with lower training loads when compared to physical exercise without restriction. **Objectives:** To review the scientific literature regarding the effects of aerobic physical exercise using blood flow restriction in the elderly. **Methods:** Searches were performed in three databases (PEDro, Pubmed, and Scielo). As descriptors, the combination of the terms *blood flow restriction/KAATSU, endurance/aerobic/walking aged people/elderly* was used. **Results:** Eight articles were included in the review. Three studies investigated muscle adaptations, two studies investigated aerobic capacity, three studies addressed cardiovascular and hemodynamic responses, two articles analyzed oxidative stress and hormonal responses, and one article assessed physical function. **Conclusion:** Aerobic exercise in the elderly with BFR seems to be superior to without BFR in this population. However, the low number of studies does not allow a definitive conclusion. It should be noted that no study has shown adverse effects or contraindications for the application of the BFR.

**Key-words:** Exercise, Aged, Review.

**RESUMO**

**Introdução:** O exercício físico com predominância aeróbia já é uma estratégia conhecida com benefícios para a população idosa, e o uso da restrição de fluxo sanguíneo (RFS) pode ser uma alternativa promissora e eficaz para trazer benefícios maiores com cargas de treino menores, quando comparado ao exercício físico sem a restrição. **Objetivos:** Revisar a literatura científica a respeito dos efeitos do exercício físico aeróbico com uso da restrição de fluxo sanguíneo em idosos. **Métodos:** Foram realizadas buscas em três bases de dados (PEDro, Pubmed e Scielo). Como descritores, foi utilizada a combinação dos termos *blood flow restriction/KAATSU, endurance/aerobic/walking aged people/elderly.* **Resultados:** Foram incluídos oito artigos na revisão. Três estudos investigaram adaptações musculares, dois estudos investigaram a capacidade aeróbica, três estudos abordaram as respostas cardiovasculares e hemodinâmicas, dois artigos analisaram o estresse oxidativo e respostas hormonais, e um artigo avaliou a função física. **Conclusão:** O exercício físico aeróbico em idosos com a RFS parece ser superior que o mesmo realizado sem RFS nessa população. Entretanto, o baixo número de estudos encontrado não permite uma conclusão definitiva. Deve-se ressaltar que nenhum estudo mostrou efeitos adversos ou contraindicação para a aplicação da RFS.

**Palavras-chave:** Exercício, Idoso, Revisão.

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## Introduction

The World Health Organization (WHO) defines the elderly from their chronological age, that is, elderly is any individual aged 60 or over in underdeveloped countries, as is the case in Brazil [1]. According to the WHO, by the year 2025, Brazil will be the sixth country in the world in the number of elderly people, as a consequence of the increase in average life expectancy. Thus, the quality of life of the elderly has been the subject of discussions for the aspects that it involves and interferes with.

The regular practice of physical exercise reduces the risk of developing chronic diseases, brings benefits to mental health and social integration. According to the American College of Sports Medicine, long-term adaptive responses in non-frail older adults are qualitatively similar to those seen in young individuals. Although there may be a long time for adaptation, the elderly also have benefits such as improved $VO_{2max}$, submaximal metabolic responses, exercise tolerance, muscle strength, resistance, and hypertrophy when undergoing training [4].

Recently, interest in physical activity associated with blood flow restriction (BFR) has grown. BFR consists of restricting part of the blood flow to a specific limb by applying a cuff to the proximal portion of the upper or lower limbs. This technique, also known as KAATSU, does not generate ischemic conditions in the muscles, but an accumulation of blood in the capillaries, making the flow turbulent [5].

The BFR as a viable strategy to be used in different sports practices (walking, cycling, resistance exercises) has become an important topic of study. BFR exercises have shown promising results in increasing muscle strength, hypertrophy, cardiorespiratory, and muscle resistance. During resistance training, results of muscle hypertrophy and increased strength are observed similar to those of a high-intensity exercise but using a lower intensity [6,7]. However, there are restrictions to BFR not directly linked to the aging process, but specific circulatory diseases, hemodynamic or clinical issues.

Studies with aerobic predominance exercises associated with BFR bring several chronic and acute adaptations in the general population. The acute adaptations of this type of exercise with BFR are mainly the increase in energy expenditure, oxygen consumption and increase in excessive oxygen consumption after exercise (EPOC), increased intracellular signaling, and increased growth hormone (GH). However, there is still no consensus specifying which is the best protocol to be followed in the use of BFR with aerobic exercise for each determined type of population. Therefore, this study aimed to review the effects of aerobic exercise with the use of blood flow restriction in the elderly [8].

## Methods

In this study, there was a systematic narrative review of scientific articles on the topic chosen. To conduct this study, articles published in the databases Pubmed, PEDro, and Scielo were selected, from January 2000 to May 2019, using the descriptors, in English: "blood flow restriction endurance elderly"; "blood flow restriction endurance aged people"; "blood flow restriction aerobic elderly"; "blood flow restriction aerobic aged people"; "kaatsu endurance elderly"; "kaatsu endurance aged people"; "kaatsu aerobic elderly"; "kaatsu aerobic aged people"; "kaatsu walking aged people"; "kaatsu walking elderly".

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Two researchers performed the searches independently and compared the results found. A third researcher supervised the selection and collaborated with the identification following the inclusion and selection criteria. Subsequently, an analysis of the references of the selected studies was carried out to identify other studies not included in the searches. The exclusion criteria for this study were: studies not performed in the elderly, literature review, studies addressing caloric restriction, studies using animal models, and studies that did not perform aerobic exercise.

## Results

There were found 113 articles in the three selected databases. In PubMed, 109 articles were found, in PEDro 4, and in Scielo, no study was found. Then, there were verified duplications, 75 studies were excluded.

Thus, 38 articles were analyzed with information obtained through the title and abstract. Eleven studies were identified as able to enter this work and later read in their entirety, with only eight selected in the end. The flow chart below summarizes the article selection process.

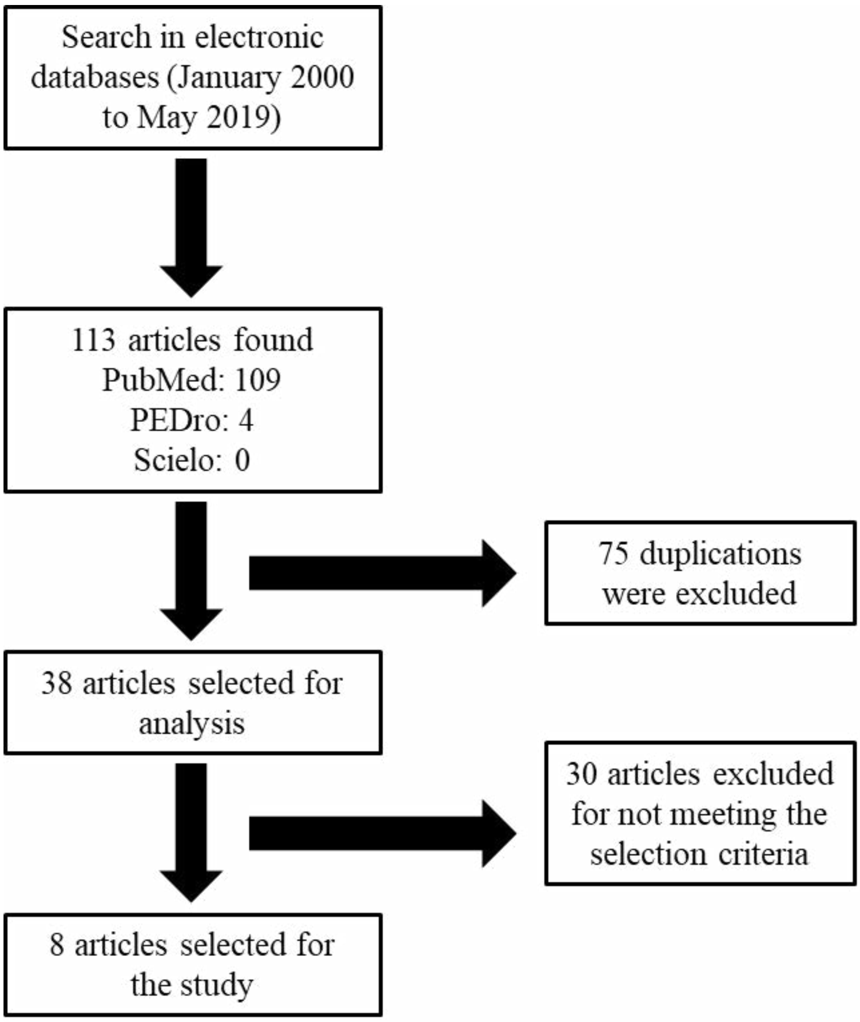


**Figure 1 –** Flow chart.

The presentation of the results was performed, according to the study outcome. Table I, at the end of the results, presents a summary of the studies.

### *Hypertrophy and muscle strength*

Regarding the increase in strength and hypertrophy, three studies investigated the effects of aerobic exercise with BFR.

Libardi *et al.* [9] concluded that muscle strength and hypertrophy increased similarly after 12 weeks with both traditional concurrent training and that associated with BFR. The only advantage observed in the groups with BRF was that the total training volume was lower to obtain a result like the group without BFR [9].

Abe *et al.* [10] concluded that walk training for six weeks associated with BFR improves muscle strength and functional capacity in both males and elderly females. The results showed that there were no significant changes in body mass and body mass index for any of the groups. However, the group with the BFR showed an increase in the perimeter of the thigh (5.8%) and the leg (5.1%). The maximum isometric torque of knee extension increased (11.8%) in the group with BFR. The same occurred with isokinetic knee extension and flexion, which increased (7.1 to 12.2% and 13.4 to 16.1%, respectively) in the presence of BFR. The only limitation of this study was that two participants did not support the 200mmHg occlusion pressure due to the perception of muscle fatigue during exercise with BFR [10].

The research by Ozaki *et al.* [11] concluded that walking with BFR performed 4 times a week for 10 weeks was an effective strategy to promote muscle hypertrophy and to increase the strength of knee flexors and extensors in the elderly population. The results showed a better response in muscle hypertrophy (3.2%), improvement in muscle strength of extensors (8.7%), and knee flexors (15%) in the group with BFR when compared to the control group [11].

### *Aerobic capacity*

Two studies investigated the effects of aerobic exercise with BFR on aerobic capacity. The study by Libardi *et al.* [9] found similar improvements in the cardiorespiratory capacity of both groups ($VO_{2max}$ increased from 9.5 to 10.3% with or without BFR) [9]. However, the study by Abe *et al.* [10] found no increase in $\%VO_{2max}$ in any of the groups, concluding that walking training with BFR for 6 weeks does not improve cardiovascular fitness in the elderly [10].

### *Physical function*

Clarkson *et al.* [12] concluded that walking 4 times a week for 6 weeks at a speed of 4 km/h associated with BFR brings beneficial results to improve physical fitness in sedentary elderly individuals. The results show that the BFR group increased the number of repetitions performed during the sitting and standing test in 30 seconds, compared to the group without BFR. The other measures of physical function, such as distance covered in the 6-minute walk test (6MWT), the time to complete the Timed Up and Go (TUG), and the steps of the Queen's College Step Test (QCST), showed similar improvement in both groups, with and without BFR [12].

The previously mentioned study by Abe *et al.* [10] also investigated the functional capacity. The results show an increase of approximately 13% in the TUG test and about 14% in the sitting and standing test in the BFR group [10].

### *Cardiovascular and hemodynamic responses*

Four of the selected studies aimed to investigate the cardiovascular and hemodynamic responses of aerobic exercise with BFR in the elderly.

The study by Staunton *et al.* [13] demonstrated that the use of BFR caused an increase in cardiac output (L/min: Rest: 4.2 ± 0.1 vs. Post-exercise: 8.4 ± 0.4) and systolic blood pressure (mmHg: Rest: 123 ± 3 vs. Post-exercise: 138 ± 3) in a similar way when BFR is absent. There was an increase in heart rate (bpm: BFR: 92 ± 5 vs. CON: 86 ± 3), mean arterial pressure (mmHg: BFR: 108 ± 3 vs. CON: 100 ± 2), and the double product (×103 bpm x mmHg: BFR: 12.3 ± 0.7 vs. CON: 11.0 ± 0.6) significantly higher after exercise in the BFR group. The authors concluded that walking associated with the use of BFR could be a viable alternative without overloading the cardiovascular system in an exacerbated manner [13].

Ferreira *et al.* [14] conducted a study to evaluate the autonomic cardiac effects and hemodynamic responses up to 30 minutes after aerobic exercise with the use of BFR in the elderly. The BFR group showed a tendency to reduce systolic blood pressure (mmHg: pre: 130 vs. post: 120) and diastolic blood pressure (mmHg: pre: 70 vs. post: 66), mean blood pressure (mmHg: pre: 94 vs. post: 87). A reduction in the double product (bpm x mmHg: BFR: 8000 vs. CON: 10100) was found when comparing the group with and without BFR 30 minutes after exercise. A reduction in HR (bpm: BFR: 66 vs. CON: 80) was also found in the post-exercise period. The authors concluded that low-intensity aerobic exercise with BFR is capable of generating autonomic and hemodynamic cardiac responses that cause less cardiovascular stress in this population. This study shows the safety, from the cardiovascular point of view, of performing the aerobic exercise with 50% BFR occlusion pressure [14].

Barili *et al.* [15] conducted a study to investigate the acute responses of the cardiorespiratory system in low-intensity aerobic exercise with BFR in aged women, however, hypertensive. The study demonstrated that there is a similar increase in HR, SBP, and MAP in the group with BFR versus without BFR, even in hypertensive aged people during exercise. The authors concluded that low-intensity aerobic exercise (30% of $VO_{2max}$) associated with BFR generates cardiovascular stress similar to high-intensity aerobic exercise (50% of $VO_{2max}$) [15].

Finally, the study by Ozaki *et al.* [11] observed an improvement in arterial compliance in both groups (with and without BFR) with no significant difference between them. This improvement in carotid artery compliance was observed after ten weeks of walking with BFR [11].

### *Hormonal responses and oxidative stress*

Ozaki *et al.* [16] conducted a study to investigate the acute effects of hormonal responses after walking with the use of BFR in the elderly. The study demonstrated that the levels of norepinephrine, insulin, and growth hormone (GH) were higher in the period immediately after exercise in the BFR group [16].

The study by Barili *et al.* [15], previously mentioned, also aimed to analyze oxidative stress in low-intensity aerobic exercise. The study showed that in the BFR group, there was an increase in the activity of antioxidant enzymes in the post-intervention period. Increases in the damage markers caused by oxidative stress after exercise were found in both groups with and without BFR in a similar way. The authors concluded that in addition to cardiovascular responses, low-intensity aerobic exercise with BFR in hypertensive aged women could trigger an increase in antioxidant enzymes [15].

**Table I -** Summary of articles according to the order of appearance in the text.

| Authors | Sample description | Results |
|---|---|---|
| Abe *et al.* (2010) [7] | n=19 (4M e 15W).<br>Intervention: 6 weeks.<br>K-walk: n=11, walking: 20 min., 67m/min, 5x/week, with BFR.<br>Control: n=8, no exercise. | - Strength:<br>K-walk: ↑ isometric (11%); ↑ isokinetic (7% extension, 16% flexion).<br>- Muscle size:<br>K-walk: cross-sectional area: ↑ 5.8% thigh and 5.1% leg;<br>K-walk: ultrasound: ↑ 6% total mass and 10.7% thigh.<br>- Functional capacity:<br>K-walk: ↑ (timed up and go test). |
| Libardi *et al.* (2015) [9] | n=25.<br>Intervenção: 12 semanas.<br>CT: n = 8, aeróbico: 2x/semana, 30-40 min, 50 -80% $VO_{2pico}$ e resistência: 2x/semana, 4x10 reps, 70-80% de 1-RM.<br>BFR-CT: n = 10, semelhante a CT, porém, com RFS.<br>CG: n=7, grupo controle, nenhum exercício. | - Área transversal do quadríceps:<br>CT: ↑ 7.3%;<br>BFR-CT: ↑ 7.6%.<br>- 1-RM:<br>CT: ↑ 38.1%;<br>BFR-CT: ↑ 35.4%.<br>- $VO_{2pico}$:<br>CT: ↑ 9,5%;<br>BFR-CT: ↑ 10.3%. |
| Ozaki *et al.* (2011) [11] | n=23.<br>Intervention: 10 weeks<br>BFR-W: 20 min., 4x/week, 45% of HRR.<br>CON-W: like BFR-walk, but, without BFR. | - Maximum strength (knee joint):<br>BFR-W: ↑ ± 15%.<br>- Cross-thigh area:<br>BFR-W: magnetic resonance: ↑ 3%.<br>- Carotid artery compliance:<br>BFR-W: 50% improvement.<br>CON-W: 59% improvement. |
| Clarkson *et al.* (2017) [12] | n=19 (11M e 8W).<br>Intervention:<br>CON: walking: 4x/week, 10 min, 4 km/h, for 6 weeks.<br>BFR-W: like CON, but, with BFR. | Sit-and-stand test for 30s:<br>BFR-W: 3.5x more.<br>Queens College Bank Test:<br>BFR-W: ↑ 4x more.<br>Six-minute walk test:<br>BFR-W: 4.5x more.<br>Sit-and-stand test:<br>BFR-W: ↑ 2.5x more. |
| Staunton *et al.* (2015) [13] | n=24H (11 jovens e 13 idosos)<br>Intervenção: 2 sessões.<br>CON: resistência: leg press, 1x30 reps + 3x15 reps, 20% 1RM e aeróbico: esteira, 4Km/h, 4x2 min.<br>BFR: semelhante a CON, porém, com RFS. | Pressões Arteriais (sistólica, diastólica e média):<br>BFRE > CON.<br><br>Débito Cardíaco:<br>BFR semelhante CON, porém, com ↑ FC e ↓ VS no aeróbico.<br><br>Obs.: respostas hemodinâmicas semelhantes em jovens e idosos com RFS. |
| Ferreira *et al.* (2016) [14] | n=24M (11 young and 13 elderly)<br>Intervention: 2 sessions.<br>CON: resistance: leg press, 1x30 reps + 3x15 reps, 20% 1-RM and aerobic: treadmill, 4km/h, 4x2 min.<br>BFR: like CON, but with BFR. | Arterial pressures (systolic, diastolic, and mean):<br>BFRE > CON.<br>Cardiac Output:<br>BFR like CON, however, with ↑ HR and ↓ SV in aerobic.<br>Note: similar hemodynamic responses in young and elderly people with BFR. |

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**Table 1** - Continuation

| Authors | Sample description | Results |
|---|---|---|
| Barili *et al.* (2018) [15] | n=16W hypertensive.<br>Intervention: 3 sessions.<br>HIAE: treadmill at 50% $VO_{2max}$.<br>LIAE: treadmill at 30% $VO_{2max}$.<br>LIAE+BRF: like LIAE, but, with BRF | Lipid peroxidation:<br>LIAE + BRF: ↑ recovery vs. rest.<br>Glutathione-S-Transferase:<br>LIAE + BRF: ↑ recovery vs. rest.<br>Superoxide Dismutase:<br>LIAE + BRF: ↑ recovery vs. rest.<br>Non-Protein Thiols:<br>LIAE + BRF: ↑ rest vs. recovery.<br>LIAE: ↑ recovery vs. other groups.<br>Hemodynamic responses (blood pressure and HR)<br>LIAE + BRF: ≅ HIAE |
| Ozaki *et al.* (2017) [16] | n=7W.<br>Intervention: acute: 20 min. and chronic: ≅ 6 months.<br>BFR-walk: 20 min., 45% of HRR, with BFR.<br>COM-walk: like BFR-walk, but, without BFR. | - Insulin:<br>↑ over time and ↑ BFR-walk.<br>- GH:<br>↑ over time.<br>- Noradrenaline:<br>↑ over time and ↑ BFR-walk.<br>- Muscular hypertrophy:<br>No correlation with the ↑ of the hormones. |

M = Men; W = Women; BFR = Blood Flow Restriction; RM = Repetition Maximum; HRR = Heart Rate Reserve; HR = Heart Rate; SV = Stroke Volume; GH = Growth Hormone.

## Discussion

According to the review, aerobic exercise with BFR appears to be as effective as a training alternative to improve cardiorespiratory fitness, muscle strength, hypertrophy, and physical function in elderly individuals. However, the effects still do not seem to be as superior to exercise without BFR. Besides, one must observe the broad heterogeneity between the study protocols. Among the 8 studies included, there are variations between acute and chronic, in the intensity of occlusion pressure, in the control group, and mainly in the results. However, one interesting point is that no study has had results that contradict the application of the BFR in the elderly population. Although there are possible side effects related to the inadequacy of the utilization of the restriction, uses under strict protocols solve this issue.

The mechanisms that allow these adaptations include: local hypoxia; recruitment of fast muscle fibers; increased metabolic acidosis time; stimulation of metabolic receptors; change in the muscular contractile mechanism and deformation of the sarcolemma; greater stimulation of the fast-glycolytic pathway, production of reactive oxygen species and hyperemia after removing the cuff. The study by Wenborn *et al.* [17] examined 3 series of unilateral knee extension of low intensity (30% of 1-RM) using BFR performed until failure. In the 3rd series, the electromyographic activity of the group with BFR was significantly higher in the eccentric phase when compared to the group that did not use the restriction [17].

Metabolic responses are due to the metabolic stress that restriction of blood flow promotes. Several studies have shown that ischemic and hypoxia conditions in muscle induce a higher demand for ATP hydrolysis, increase phosphocreatine depletion, and decrease pH. The research by Suga *et al.* [18] concluded that during low-intensity exercise (20% of 1-RM) associated with BFR, there was also higher metabolic stress when compared to the same exercise without restriction.

Regarding muscle strength gain and hypertrophy, three studies were found [9-11]. All of them detected an increase in strength or hypertrophy after the period of exercise with aerobic predominance associated or not with resistance exercises. In the study by Libardi *et al.* [9], the volume of training with resistance exercise in the BFR group was lower than the group without BFR, which is an advantage for the use of BFR as already described by Sakamaki *et al.* [19]. In this study, Sakamaki *et al.* also found improvement in muscle hypertrophy in the lower limbs (3.2%) of individuals who performed low intensity walking on a treadmill associated with BFR. The study by Abe *et al.* [10] showed that the practice of aerobic exercise with BFR improves muscle parameters, such as isometric and isokinetic strength, compared to the control group. However, since they compared only with the control group that did not perform physical exercise, it is hard to compare results regarding the addition of BFR. However, we highlight the favorable results found in this study in a short period and with low-intensity exercises, such as the 11.8% increase in maximal isometric torque of knee extension and isokinetic of knee extension and flexion with an addition of 7.1% and 13.4%, respectively.

Regarding aerobic capacity, only the study by Libardi *et al.* [9] observed a significant improvement in $VO_{2max}$, but with no difference between groups with and without BFR. This result may have been positive due to the protocol adopted being aerobic exercises + resistance exercises (concurrent training), while the study by Abe *et al.* [10] found no difference in either group. In another study by Abe *et al.* [7], low-intensity aerobic exercise (40% $VO_{2max}$) with BFR was performed in young adults, demonstrated an increase in $VO_{2max}$ in the BFR group (6.4%) when compared to the group that performed aerobic exercise without restriction (0.1%) [7]. Other studies have also observed an improvement in $VO_{2max}$ in young adults who were walking with BFR [20].

According to the American College of Sports Medicine, for an adaptation of the aerobic capacity of a healthy elderly individual, it is necessary to carry out an exercise program using at least 60% of $VO_{2max}$, ≥3 times a week with a minimum duration of 16 weeks [4].

As for physical function, the study by Clarkson *et al.* [12] showed significant improvement in all the functional measures evaluated. The gain was approximately 4 repetitions in the sitting and standing test, which corresponds to 28% of the baseline value. The improvements obtained in this study are even better than those in the study by Abe *et al.* [10], who found gains of 13% and 14% in the functional measures of TUG and in the sitting and standing test, respectively in the BFR group.

Regarding cardiovascular and hemodynamic responses, the four studies [13-16] presented favorable results in their findings regarding the use of BFR. The study by Cirilo-Sousa *et al.* [21] also found a reduction in BP, HR, and DP after aerobic exercise associated with BFR, with results similar to the study by Ferreira *et al.* [14]. The research by Kumagai *et al.* [22] found an increase right after the most relevant exercises of SBP, MAP, DBP, and HR during aerobic exercise associated with the use of BFR, demonstrating a cardiac stimulus similar to that without BFR [22]. These data confirm the findings in the studies by Staunton *et al.* [13] and Barili *et al.* [15]. From an autonomic cardiovascular point of view, Ferreira *et al.* [14] justify the lower cardiovascular stress due to the increase in parasympathetic reactivation that was found only in the BFR group.

## Conclusion

We can conclude that the use of BFR associated with aerobic exercise as a training alternative for the elderly resulted in improved muscle strength, hypertrophy, and physical function in elderly individuals. However, the evidence about its real effect on the cardiorespiratory capacity of this population is still unclear.

Finally, no study has shown adverse effects or contraindications for the application of physical exercises associated with BFR in this population. However, it is necessary to conduct new studies that seek results comparing aerobic training with BFR versus without BFR in the elderly, given the low number of studies and heterogeneous protocols. It is also important to emphasize the importance of studies for the establishment of protocols with safety criteria for the application of the method.

**Potential conflict of interest**
No conflicts of interest with potential potential for this article have been reported.

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Barauna VG is a CNPq productivity fellow; Santos L dos is a CNPq Post-Doctoral fellow.

**Authors' contributions***
Conception and design of the research: Ferrari MB, Forechi IC, Barauna VG. Data collection: Ferrari MB, Forechi IC. Analysis and interpretation of data: Ferrari MB, Forechi IC, Barauna VG, Santos L dos. Obtaining financing: Santos L dos, Barauna VG. Writing of the manuscript: Ferrari MB, Forechi IC, Santos L dos. Critical review of the manuscript for important intellectual content: Santos L dos, Barauna VG.
* Ferrari MB and Forechi IC also contributed to the study.

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