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EDUCAÇÃO FÍSICA / PHYSICAL EDUCATION

# Effects of aerobic exercise with blood flow restriction on cardiorespiratory and functional capacity in the elderly: a systematic review

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**ABSTRACT.** This study systematically reviewed the available scientific evidence regarding the chronic changes promoted by aerobic exercise (AE) combined with blood flow restriction (BFR) on cardiorespiratory capacity (CC) and functional capacity (FC) in the elderly. Search in PubMed, Web of ScienceTM, Scopus, and Google Scholar databases was carried out considering the period from January 1990 to November 2020. To this end, the following descriptors were used in English: ((blood flow restriction training) OR (blood flow restriction exercise) OR (vascular occlusion training) OR (vascular occlusion exercise) OR (kaatsu training)). Out of the 3,091 articles identified, 3,073 were excluded based on title and abstract, accounting for 99.41% of the total. Thus, 18 articles were obtained and read in full. Of the 18 articles, 16 were excluded as they did not meet the criteria for methodological quality analysis. Two articles were selected for critical consideration. Both studies found that AE combined with BFR improved CC and FC after six weeks of training. Aerobic training performed with RFS for six weeks improves FC and suggests an improvement in CC in the elderly.

**Keywords:** aerobic exercise; therapeutic occlusion; elderly.

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## Introduction

The elderly population has shown accelerated growth in recent decades, the World Health Organization (WHO) defines the elderly by their chronological age, that is, the elderly is any individual aged 60 years or more in underdeveloped countries, as is the case in Brazil (WHO, 2015). Human aging is increasingly understood as a process influenced by several factors, such as gender, social class, culture, and individual and collective health standards of society, among others (Schneider & Irigaray, 2008). According to Ferrarri, Forechi, Barauna and dos Santos (2020), the regular practice of physical exercise reduces the risk of developing chronic diseases and brings benefits to mental health and social integration. Aging is a natural process in which there is a decrease in physiological functions and responses, especially from the third decade of life onwards, when a progressive decline in functional capacity begins (Leite et al., 2008). Aging seems to have a profound implication on the functional capacity (FC) to perform activities of daily living that can seriously compromise performance in numerous daily tasks.

The reductions in muscle strength and cardiorespiratory capacity (CC) resulting from aging are crucial for the loss of functional autonomy in the elderly, in addition, there is a decline in cardiorespiratory fitness (Krause, Buzzachera, Hallage, Pulner, & Silva, 2007; Mazzeo et al., 1998), due to the decrease in the maximum heart rate and maximum ejection volume during effort, which causes a reduction in blood flow to the muscles in activity during vigorous exercise (Locks, Ribas, Wachholz, & Gomes, 2012). Consequently, the maximum capacity of the individual to absorb, transport, and metabolize oxygen in skeletal muscles (VO2max) declines, decreasing the capacity of the elderly to sustain prolonged exercise (Mazzeo et al., 1998).

With the increase in the number of elderly people at risk of functional disability, different protocols/programs of physical activity have emerged, to understand their effects on FC and CC, highlighting weight training (Dias, Gurjão, & Marucci, 2006), dance (Coelho, Junior, & Gobbi, 2008; Sebastião, Hamanaka, Gobbi, & Gobbi, 2008), and general physical activity (Silva & Gobbi, 2006; Zago, Polastri, Villar, Silva,

&Gobbi, 2012), each of these modalities is composed of activities/protocols, with principles that greatly distinguish them from one another. However, many older people do not support the practice of intense physical activities that may require a lot of physical effort, and different studies suggest that low-load aerobic training combined with Blood Flow Restriction (BFR) has been a viable strategy in improving aerobic fitness, cardiorespiratory and muscular endurance, and functional capacity of elderly individuals (Abe et al., 2010; Clarkson, Conway, & Warmington, 2017; Gomes-Silva et al., 2019; Patterson et al., 2019). Interestingly, walking stimuli with BFR is capable of generating important cardiorespiratory changes during the exercise session, such as an increase in VO2 and a reduction in systolic volume (Abe, Kearns, & Sato, 2006). In the relevant literature, some studies evaluated the chronic effect of AE with BFR on cardiorespiratory capacity and functional capacity. However, so far, there has not been a consensus that sets the real effectiveness of this type of intervention on the chronic alterations promoted by AE with BFR on CC and FC. This study considers opportune to highlight the results, given the established interventions and to dictate effective discussions so that the referred theme is established in the scientific environment in question.

In this context, the objective of this review was to systematically analyze the available scientific evidence on the chronic changes promoted by AE + BFR on the cardiorespiratory and functional capacity of the elderly.

## Methods

The National Library of Medicine (PubMed), Web of ScienceTM, and Scopus electronic databases were searched to identify the articles, considering the period from January 1990 to October 2020. The study selection process is illustrated in Figure 1.

For the searches, the following descriptors/terms/operators were used in English: ((blood flow restriction training) OR (blood flow restriction exercise) OR (vascular occlusion training) OR (vascular occlusion exercise) OR (kaatsu training), (cardiorespiratory capacity) and (functional capacity). Additionally, the following inclusion criteria were adopted: original research developed in human beings, research published in journals indexed in the selected databases, research that contained individuals aged 60 to 90 years and that evaluated the acute/chronic alterations promoted by AE combined with RFS on FC and CC. Articles were excluded if (a) Review articles/meta-analysis, (b) Articles using protocols with isometric exercises, endurance exercises, and protocols without exercise, as well as (c) Articles of views/opinions, validation of studies; (d) Book chapters, theses or dissertations and (e) Case study articles.

Two groups of three investigators, Group 01 composed of MW, JR, and JS, and Group 02 composed of AL, JE, and ME, carried out the online search, simultaneously, independently, and blindly; for each group, a minimum of two researchers were present in each group at the time of the search; the same descriptors/terms/operators were used in the selected databases, and their findings were later compared and in case of disagreement, the third evaluator, supervisor of this study, established a consensus. During the screening, the title and abstract of the identified articles were read. Thus, studies in which the title and abstract provided sufficient information were obtained. All articles were read in full. The references of these articles were reviewed to identify other potentially relevant studies that were not identified in the electronic search.

### Methodological quality: PEDro scale

The PEDro scale (http://www.pedro.fhs.usyd.edu.au) was used to check the methodological quality of the studies, which is based on the Delphi list (Verhagen et al., 1998), which consists of a scale with 11 criteria. The score ranges from zero to ten, with criterion 1 (external validity) not used to calculate the score. This tool aims to identify randomized or quasi-randomized controlled studies with internal validity that may contain enough statistical information for results interpretation. In this study, for each criterion of the 11 items of the scale, two groups of three researchers evaluated the articles independently.

This study was conducted in accordance with Preferred Reporting for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Liberati et al., 2009). Data analysis was performed based on a critical review of the content using the following criteria: title, abstract, background, objectives, protocol, risk of bias between studies, study characteristics, results of individual studies, limitations, and conclusions.

## Results

The synthesis of the results of the studies was presented based on a structured script that considered the following components: (a) Author and year of the study; (b) Subjects; (c) Variable; (d) Duration and weekly frequency; (e) Intensity; (f) BFR pressure used during the exercise; (g) Blood flow restriction; (h) Cuff width, and (i) Main results. Of the 3,091 articles identified, 3,073 were excluded based on title and abstract, accounting for 99.41% of the total. Thus, 18 articles were selected for classification according to the PEDro Scale, and read in full. Of the 18 articles, 16 were excluded because they did not meet the methodological quality analysis criteria. Thus, 2 articles were selected for critical appreciation, performing a systematic assessment of the changes promoted by AE + BFR on the cardiorespiratory and functional capacities of the elderly (Figure 1).

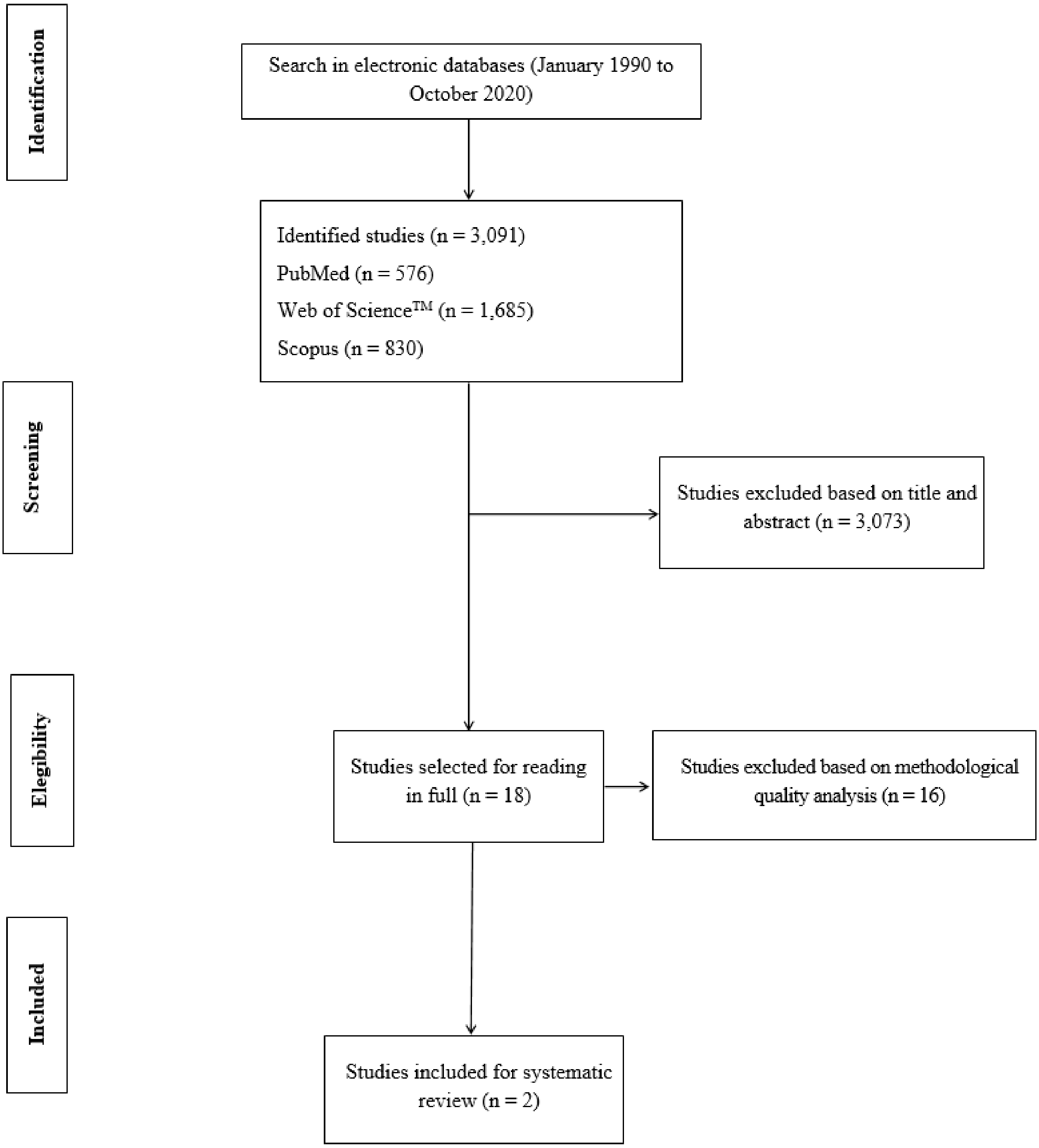


**Figure 1.** Flowchart of the study selection process

## Cardiorespiratory capacity

The study by Clarkson, Conway and Warmington (2017) was carried out with 20 elderly people, including 11 men and 9 women (60-80 years old) randomly divided into two groups: walking with BFR (BFR, n = 10; 6 men and 4 women), and a walking group without BFR (control, n = 9; 5 men and 4 women), once a day, 4 days a week, for 6 weeks, with the group walking with BFR continuously (10 minutes). A possible CC analysis was proposed through tests, 6-minute walk (6MWT) and the modified version of the Queen's College Step (QCST) in both groups. When analyzing the CC, in this study, an increase in VO2 max (maximum oxygen consumption) was suggested as a consequence of the improvement in the CC during the 6MWT. An increase in walking time was observed for the group subjected to BFR, compared to the control. The study carried out by Abe et al. (2010), with 19 elderly people, including 4 men and 15 women (60-78 years old) randomly divided into two groups: walking with BFR (BFR, n = 11; 2 men and 9 women) and a walking group without BFR (control, n = 8; 2 men and 6 women), reported the VO2max in both groups, using an estimated value of 45% of the maximum heart rate (HR) reserve, with duration and frequency protocol, a once a day, 5 days a week, for 6 weeks, with the group walking with BFR continuously (20 minutes). CC was checked through the walking test on a motorized treadmill at 67m/min. When analyzing the CC in the study, there were no significant differences between groups, with and without BFR.

### Functional Capacity

In this review on functional capacity (FC), two studies found that sessions of AE combined with BFR showed a significant increase compared to AE protocols without BFR (Abe et al., 2010; Clarkson et al., 2017). Abe et al. (2010) applied the Timed Up and Go test and the sit-to-stand test to assess FC, but Clarkson, Conway and Warmington (2017) used the tests of the modified version of the QCST, 6MWT, timed Up and Go test and the sit-to-stand for 30 seconds. The results reported by Abe et al. (2010) showed that 6-week walking training with BFR significantly improved FC compared to EA without BFR. The tests conducted by Clarkson, Conway and Warmington (2017) showed significant improvement in both groups with and without BFR, however, over the course of the six-week training period, they did not show significant differences.

**Table 1.** Summary of the results of studies evaluating the effects of aerobic exercise with blood flow restriction on the cardiorespiratory and functional capacity of the elderly.

| Author (year) | Subjects | Variable | Weekly duration and frequency | Intensity | PADE (mmHg) | BFR | CW (cm) | Results |
|---|---|---|---|---|---|---|---|---|
| Clarkson, Conway and Warmington (2017) | 11 men and 9 women | CC (6MWT and QCST) and FC (STS30 and TUG) | Once a day, 4 days a week, for 6 weeks | 45% maximum HR reserve in both groups, with and without BFR | 134 ± 4 | Continuous (10 minutes) | 10.5 | ↑ FC in both groups, no significant differences, suggesting ↑ VO2max, with possible improvement in CC |
| Abe et al. (2010) | 19 men and women | CC (VO2peak and HR) and FC (up and go and SS) | Once a day, 5 days a week, for 6 weeks | 45% maximum HR reserve in both groups, with and without BFR | 160-200 | Continuous (23 minutes) | 5.0 | ↑ FC in the BFR group, no significant differences in CC between groups |

BFR = Blood flow restriction; HR = Heart rate; PADE = Pressure applied during exercise; CW = Cuff width; - = Non-informed; ↑ = Increase; CC = Cardiorespiratory capacity; CF = Functional capacity, SS = Sit and stand, VO2peak = Peak oxygen consumption; 6MWT = 6-minute walk test; QCST = Modified version of the Queen's College step test; STS30 = 30-second sit-to-stand; TUG = Timed up and go test.

## Discussion

The present study systematized the available scientific evidence on chronic alterations promoted by AE + BFR on the cardiorespiratory and functional capacity of the elderly. Analyzing the methodology and results of the evaluated studies, AE with BFR resulted in higher values of FC compared to the AE protocols without BFR (Abe et al., 2010; Clarkson et al., 2017), however, the studies that compared CC showed no significant differences between groups with and without BFR (Abe et al., 2010; Clarkson et al., 2017).

Regarding FC, Clarkson, Conway and Warmington (2017) showed a significant improvement in all functional measures evaluated. The gain was approximately 4 repetitions in the sit-to-stand test (flexibility), which corresponds to 28% of the baseline value. These authors concluded that walking four times a week for 6 weeks at a speed of 4km/h associated with BFR improves functional fitness in elderly individuals. The TUG test demonstrated that both groups achieved significant improvement over the six weeks, although the walking group with BFR presented a greater reduction in time to complete the session, compared to the control group without BFR. The reduction in the time of the walking group with BFR may be associated with improvements in lower limb strength, and this is shown by Loenneke, Wilson and Wilson (2010), who stated that the strength of the lower limbs can be improved by walking with BFR because of the fast-twitch muscle fibers that are stimulated even using a low load.

The study conducted by Abe et al. (2010) is similar to the research developed by Clarkson, Conway e Warmington (2017), demonstrating improvements in the FC of the elderly through the TUG tests and the sit and stand test, respectively. However, only the group subjected to BFR showed significant improvements in FC over the 6 weeks of activities, compared to the control group without RFS. These results indicate that training with BFR generates beneficial results in the tested areas with a period of approximately six weeks and that the improvement in FC in the elderly may be mainly due to strength gains induced by training. That said, Early et al. (2020) show that low-load activities combined with BFR suggest an increase in lactate and growth hormone (GH) levels. In turn, even with a low load, but a high intensity, there is an improvement in strength gain, which may be involved with processes of neuromuscular adaptation or even hypoxia, due to the BFR in the site, thus leading to cascade effects of the endothelial growth factor (VEGF). VEGF and the elevation of GH increase nitric oxide, all simultaneously, help in blood nutrition, mass gain, and muscle fiber recruitment, which may be correlated with the increase and improvement in strength gain in the elderly during CF tests (Baker, Stannard, Duren, Cook, & Stannard, 2020).

Regarding CC, Abe et al. (2010) found no difference in any of the groups, demonstrating a little increase in VO2max in the group with BFR, compared to the group that performed aerobic exercise without restriction; this may be because the AE program adopted occurred during only 6 weeks. According to Chodzko-Zajko et al. (2009), the adaptation of the aerobic capacity of an elderly individual requires an exercise program using at least 60% VO2 max, ⩾3 times a week with a minimum duration of 16 weeks.

Unlike the study by Clarkson, Conway e Warmington (2017), which suggests an increase in VO2Max in the 6-minute walk test (6MWT), due to the strong positive correlation between the 6MWT distance and the aerobic capacity tests, Cahalin et al. (1996) reported a strong correlation between the 6-minute walk test and the VO2 peak, although other tests determine the functional capacity, the 6-minute walk test provides prognostic information very similar to the maximum VO2. Nevertheless, no significant improvement was detected between walking with BFR and walking without BFR in the aerobic capacity of the elderly. Some authors believe that the improvement in CC in untrained subjects, especially in the elderly, is impeded by inadequate muscle strength associated with the aging process (Vincent, Braith, Feldman, Kallas, & Lowenthal, 2002) since the methods used to assess cardiorespiratory improvement require strength in the lower limbs. This is evidenced by Vincent et al. (2002), who found a correlation between the increase in the strength of the lower limbs and the increase in the time of strength to walking in the elderly, therefore, alterations found may be associated with the greater consumption of oxygen by the muscle. Another point to be highlighted is the duration of the walking session, according to Kumagai et al. (2012), during a 30-minute walk session with BFR, cardiovascular changes occur mainly in the first 10 minutes of exercise, stabilize during the rest of the training, and considering these data, cardiorespiratory changes resulting from exercises with BFR seem to depend on the protocol used in training.

The present review had some limitations such as few studies to be used as a sample, and limitations in the data presented. More studies on the topic are suggested to be carried out with different durations, age groups, percentages of intensity, and BFR on the CC and FC of the elderly. Further descriptions of the intervention are essential, which meet the methodological criteria as much as possible, to give more reliability and strength to the results.

Finally, the results of both studies indicate that in 6 weeks of training with BFR, an increase in muscle strength and size can be observed (Abe et al., 2010), and this may be correlated with the improvement in FC in the elderly. However, the study by Abe et al. (2010) demonstrates no significant differences in CC in the elderly, which may be related to the intervention time adopted by the authors, whereas Clarkson, Conway and Warmington (2017) suggest an increase in VO2 when associated with the 6-minute walk test.

## Conclusion

Aerobic training performed in six weeks with BFR improves FC and suggests an improvement in CC in the elderly. However, different methodological procedures were observed, suggesting the conduction of standardized studies employing other intensities with and without BFR. A point to be addressed is the limiting number of articles in the literature and the number of samples regarding the effect of AE with BFR on CC and FC in the elderly, which may not allow a precise conclusion. Therefore, studies on AE combined with BFR in the elderly should be carried out using different levels of pressure, duration, and intensity.

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