Effects of endurance training combined with blood flow restriction on functionality in older adults: a systematic review

Efeitos do treinamento de resistência combinado com restrição de fluxo sanguíneo na funcionalidade de idosos: uma revisão sistemática

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Abstract
The aim of this review was to verify the effects of aerobic exercise combined with blood flow restriction on older adult functionality. Systematic searches were performed in PubMed, Web of Science, and Embase between July and December 2023. Randomized studies with participants aged ≥ 60 years who were evaluated before and after the experimental protocols were included. We registered this systematic review at the International Prospective Register (PROSPERO CRD42022347205). The search strategy identified 2698 studies, four of which were included in the review, with 80 participants. The results suggested that aerobic exercise combined with blood flow restriction increased performance on specific functional tests. However, these results should be interpreted with caution due to the low-to-moderate study quality, as well as the low number of participants and studies. In conclusion, aerobic exercise and blood flow restriction may increase functional capacity in older adults. Further studies are needed to confirm such findings.

Keywords: physical activity; aerobic exercise; blood flow restriction therapy; physical condition; older people.
INTRODUCTION

Healthy aging is developing and maintaining the functional ability that enables well-being in older age. Functional ability is determined by the intrinsic capacity of an individual (i.e., the combination of all the individual's physical and mental capacities), the environment in which they live (understood in the broadest sense and including physical, social and policy environments) and the interactions among them. With increasing age, decreased physical activity and a progressive reduction in physical capacity have been observed, resulting in decreased functional aptitude. Functional fitness represents the physical capacity necessary to perform activities of daily living without the early onset of fatigue. Older adults with low functional fitness have an increased risk of falls and a greater chance of needing care and hospitalization.

For older adults who are beginning to exercise, the American College of Sports recommends intensities of ~40–50% a maximum repetition (1RM) (very light-to-light intensity) to improve strength and 20–50% 1RM to improve the power. The 2019 guidelines of the National Strength and Conditional Association recommended that strength training for healthy older adults should consist of 1–3 sets per muscle group with 8–12 or 10–15 repetitions, 70–85% of 1RM, at a frequency of 2–3 days per week. Finally, the International Exercise Recommendations in Older Adults suggests beginning strength training with loads equivalent to 30–40% 1RM and progressing to loads of 70–80% 1RM for optimal aging and functional capacity maintenance in older adults with a high risk of mortality.

However, aerobic exercise alone does not improve strength or muscle mass, which are essential components for increasing the functionality of older adults. Other studies have suggested that high-intensity strength training could overload the joints and cardiovascular system in most older adults, which could limit its application in this population. However, it has been shown that low-intensity aerobic training (~45% of the maximum reserve heart rate) involving walking on a treadmill at 67 m/min for 20 minutes combined with partial blood flow restriction (~160–200 mmHg) induced to greater increases in strength, muscle mass, and functional performance in older adults than aerobic exercise alone.

Although some studies have suggested that aerobic exercise combined with blood flow restriction (AEBFR) improves strength and muscle mass, there is no consensus about whether these adaptations would improve physical function in older adults. A previous review found no significant change in physical function when both resistance training with BFR and AEBFR training were performed, although strength and muscle mass increased. It is worth mentioning that only one AEBFR training study was included in the review and meta-analysis. In line with the previous studies, another meta-analysis showed that a BFR training program effectively increased strength and muscle mass but had no additional effects on performance in functional tests. Prior meta-analysis investigated the effects of training with and without BFR, including low load, high load, and walking. Previous studies have shown that aerobic training has beneficial effects on cardiovascular fitness and general health. AEBFR has also been shown to effectively increasing strength and muscle mass in both young and older adults. However, the effect of AEBFR on functional response in older adults is unclear.

In 2019, aiming to ensure the safety and uniformity of blood flow restriction, a group of researchers suggested using 40–80% of the individual occlusion pressure for BFR; however, some studies have used arbitrary pressures (i.e., ~160–200 mmHg) for all participants. The use of arbitrary pressures could lead to complete arterial occlusion in some participants, while others might not reach the minimum pressure levels needed to achieve a BFR training response, which could lead to inconsistent results. Therefore, the primary aim of this review was to verify the effects of AEBFR on functionality in older adults. The secondary aim of this review was to determine whether the level of blood restriction pressure applied to the limbs influences functional outcomes.

METHODS

Search strategy

This study was reported in accordance with the PRISMA guidelines for systematic reviews (Figure 1). The search was performed in 3 databases (PubMed, Web of Science and Embase) between July and December 2023. Studies published in English were searched from early 1960 to 2023 using the following combination of terms: (Aged [MeSH Terms]) AND (aerobic exercise [MeSH Terms]) OR (Walking) AND (blood flow restriction training) OR (Kaatsu) OR (Kaatsu training) OR (occlusion training) OR (partial occlusion training) AND (physical function) OR (Physical Conditioning) OR (functional ability).

We included the term ‘Kaatsu’, a method in which pneumatic cuffs are positioned on the upper and lower limbs to restrict blood flow, combined or not with exercise. Thus, the term Kaatsu is recognized as a synonym for BFR. The reference lists of studies involving BFR training and functional performance were also manually searched to identify further potential publications.
This systematic review was performed according to the PICO method: “P” (population): older adults aged ≥ 60 years; “I” (intervention): AEBFR; “C” (comparison): clinical trials with a control group or alternative form of training; and “O” (outcome): any of the following:
1. Physical performance;
2. Functional ability;
3. Balance;
4. Physical function/functionality; or
5. Functional ability.

This systematic review was approved by the International Prospective Register of Systematic Reviews (PROSPERO CRD42022347205).

Eligibility
The following studies were eligible for inclusion in this review:

a. those with an older adult population (aged ≥ 60 years; original studies published in a peer-reviewed journal);
b. controlled trials with or without randomization (parallel groups; crossover included); ≥ 1 group including AEBFR and ≥ 1 group including exercise without BFR (control intervention group) and/or a control group with no intervention, which was compared to the intervention with BFR at 2 time points (pre- and post-intervention);
c. BFR was applied using an external device to provide pressure to the proximal part of a limb (e.g., Kaatsu pneumatic or pressure control cuffs);
d. at least 1 functionality-related outcome was reported (e.g., the 30-second sit-to-stand test [30STS], the timed up and go test [TUG], the 6-minute walk test [6MWT]);
e. intervention studies lasting ≥ 4 weeks. Studies were excluded if the intervention group involved other forms of hypoxia training, such as a hyperbaric chamber or high-altitude training.

The following publication types were also excluded: conference abstracts, letters to the editor, theses, unpublished data, case studies, and review articles.

Selection process
Records identified in the database initially underwent title and abstract screening were subsequently imported into EndNote TM 20 (Clarivate, Philadelphia, PA, USA). Duplicate records were excluded, and the studies were screened for eligibility by two independent reviewers (RSO and RGB). The full texts of studies that passed screening stage were read independently by two reviewers (RSO and RGB). Differences between the reviewers were resolved by discussion and, when consensus could not be reached, a third reviewer (GCL or MLJM) was consulted. The reference lists of the included studies were manually searched to identify additional eligible studies.

Data extraction
The data were extracted independently by two reviewers (RSO and RGB).

The following categories were included:
a. authors and year of publication;
b. study design, test of type, sample size, and sex;
c. exercise training regimen for the intervention and control groups, the exercise protocols, duration, frequency, and type, the BFR protocol (for the intervention group), and the BFR pressure used during the protocol (Table 1).

We used the WebPlotDigitizer to extract the data from studies that only results in figures..

Quality assessment
Study quality was assessed using the TESTEX tool. This tool, which assesses the quality of studies involving exercise training, includes novel quality assessment criteria,
such as crossover from sedentary control to exercise, periodic adjustment of exercise intensity, physical training adaptation, and exercise program characteristics. TESTEX uses 12 criteria (some scoring more than 1 point), for a maximum score of 15 points (5 points for study quality and 10 points for reporting). Being developed for exercise interventions, it includes specific criteria, unlike more comprehensive tools, such as ROB, or tools used by physical therapists, such as PEDro. These tools do not include adequate criteria for determining the effectiveness and risks of interventions involving exercise (Table 2). 

Some examples of this include reports of withdrawal/adverse events, participation in sessions, exercise adherence, and features of the exercise program, which are important in physical training studies.

**RESULTS**

Figure 1 shows the study flow diagram, in which a total of 2698 records were retrieved from the searches: 2277 from PubMed, 205 from the Web of Science, and 216 from EMBASE. Two studies were removed (one duplicated and other out of scope). 2692 records during title/abstract screening, and four studies were considered eligible and selected for full-text reading (Table 1). A total of 80 participants aged ≥ 68 years were recruited; 47 were allocated to the intervention group, and 33 were allocated to the control intervention and control groups.

The first study reported 15% increases in TUG and 30STS results. The second study reported increases of ~10.7% and ~20.5% in TUG and 30STS results, respectively. Increases of ~12%, 28%, and 9% in the TUG, 30STS, and 6-minute walk test, respectively, were observed in the third study. The fourth study found increases of ~10.7% and ~20.5% in the TUG and 30STS results, respectively. Further details about these results are shown in Table 3. Blood flow restriction pressure (arbitrary vs individualized pressure) had no additional effect on functionality in older adults. Further details about the results are available in Table 1.

**DISCUSSION**

The primary aim of this study was to investigate the effects of AEBFR on physical function in older adults, and the secondary aim of this review was to determine whether the level of blood restriction pressure applied to the limbs influenced functional outcomes. The results of this review indicated that AE combined with partial BFR effectively increased functional test performance in older adults.

### TABLE 1. Overview of the characteristics of the studies included in review.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Participants (n)</th>
<th>Age (yr) Mean (SD)</th>
<th>Groups</th>
<th>Exercise intensity</th>
<th>Protocols</th>
<th>Training period</th>
<th>AOP mmHg</th>
<th>Duration of the protocol</th>
<th>Cuffs</th>
<th>Physical function test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abe et al.</td>
<td>Men (2) Women (9)</td>
<td>60–78 NR</td>
<td>BFR (11) Control (8)</td>
<td>~45% HRM</td>
<td>Walking 5x/week</td>
<td>6 weeks</td>
<td>160-200 arbitrary</td>
<td>20 min continuous pressure</td>
<td>Kaatsu Master</td>
<td></td>
</tr>
<tr>
<td>Ozaki et al.</td>
<td>Women (18)</td>
<td>66.0 (2.8)</td>
<td>BFR (10) Control (8)</td>
<td>62% HRR</td>
<td>Walking 4x/week</td>
<td>10 weeks</td>
<td>140-200 arbitrary</td>
<td>20 min continuous pressure</td>
<td>Kaatsu Master</td>
<td></td>
</tr>
<tr>
<td>Clarkson et al.</td>
<td>Men (6) Women (4)</td>
<td>69.5 (0.7)</td>
<td>BFR (10) Control (9)</td>
<td>~4 km/h</td>
<td>Walking 4x/week</td>
<td>6 weeks</td>
<td>60% AOP -134</td>
<td>10 min continuous pressure</td>
<td>Dual Port. single bladder cuff</td>
<td></td>
</tr>
<tr>
<td>Kargaran et al.</td>
<td>Women (24)</td>
<td>62.9 (3.1)</td>
<td>BFR (8) Non-BFRG (8) Control (8)</td>
<td>45% HRR</td>
<td>Walking + Cognitive tasks 3x/week</td>
<td>8 weeks</td>
<td>150–200 arbitrary estimate</td>
<td>20 min continuous pressure</td>
<td>Ghamat Pooyan, Tehran, Iran</td>
<td></td>
</tr>
</tbody>
</table>
This systematic review showed that AE (e.g., walking) combined with BFR resulted in increased functional performance according to the 30STS, TUG, and 6-minute walk test, which are widely used by both professionals and researchers to assess physical function in older adults. These findings are very interesting since AEBFR resulted in better performance in the majority of physical function tests. For instance, studies included in this review reported increases of ~15% in the TUG and 30STS tests, while no significant change was observed in the control group (~3%). Similar results to those of a previous study were observed between groups (AEBFR vs intervention without BFR), with increases of 10.7% and 20.5% vs 0.15 and 7.8% in the TUG and 30STS tests, respectively. These authors suggested that the improved physical function in the AEBFR group could be attributed to increased metabolic stress during a training session, with consequent improvement in strength and muscle mass.

Although BFR training involves low exercise intensities (i.e., 20-30% 1RM and/or walking), an important factor for individuals with musculo-skeletal pain and functional impairment (i.e., older adults), AEBFR could be an alternative to conventional resistance training as a means of improving physical function in older adults, corroborating recommendations and other training strategies.

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## TABLE 2. Methodological research quality according to the TESTEX scale.

<table>
<thead>
<tr>
<th>Reference</th>
<th>#1</th>
<th>#2</th>
<th>#3</th>
<th>#4</th>
<th>#5</th>
<th>#6</th>
<th>#7</th>
<th>#8</th>
<th>#9</th>
<th>#10</th>
<th>#11</th>
<th>#12</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abe et al.²²</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>10/15*</td>
</tr>
<tr>
<td>Ozaki et al.¹⁹</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>9/15*</td>
</tr>
<tr>
<td>Clarkson et al.²²</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>8/15*</td>
</tr>
<tr>
<td>Kargaran et al.²¹</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>12/15*</td>
</tr>
</tbody>
</table>

#1: Eligibility criteria specified; #2: Randomization specified; #3: Allocation concealment; #4: Similar groups at baseline; #5: Assessor blinding (for at least one key outcome); #6: Results evaluated in 85% of patients; #7: Intent-to-treat analysis; #8: Statistical comparisons between groups reported; #9: Point measures and measures of variability for all reported outcomes; #10: Activity monitoring in the control group; #11: Relative exercise intensity remained constant; #12: Exercise volume and energy expenditure. *Points were ONLY awarded if the criteria were clearly met.

## TABLE 3. Summary of the results from the aerobic exercise with BFR, non-BFR, and control groups.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Variable</th>
<th>BFRG pre-test mean (SD)</th>
<th>BFRG post-test mean (SD) or %</th>
<th>Variation ES, and/or % change</th>
<th>Non-BFRG pre-test mean (SD) or %</th>
<th>Non-BFRG post-test mean (SD) or %</th>
<th>Variation ES, and/or % change</th>
<th>CG pre-test mean (SD)</th>
<th>CG post-test mean (SD) or % change</th>
<th>ES and/or % change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abe et al.²²</td>
<td>TUG (s)</td>
<td>NR</td>
<td>NR</td>
<td>15.00*</td>
<td>9.00</td>
<td>4.20</td>
<td>12.00*</td>
<td>0</td>
<td>0</td>
<td>5.00</td>
</tr>
<tr>
<td></td>
<td>30STS (reps)</td>
<td>NR</td>
<td>NR</td>
<td>15.00*</td>
<td>9.00</td>
<td>4.20</td>
<td>12.00*</td>
<td>0</td>
<td>0</td>
<td>5.00</td>
</tr>
<tr>
<td>Ozaki et al.¹⁹</td>
<td>TUG (s)</td>
<td>5.00</td>
<td>4.50</td>
<td>3.30;</td>
<td>4.90</td>
<td>4.90</td>
<td>0.00</td>
<td>0</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>30STS (reps)</td>
<td>23.00</td>
<td>27.00</td>
<td>4.20</td>
<td>24.00</td>
<td>26.00</td>
<td>1.00</td>
<td>0</td>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td>Clarkson et al.²²</td>
<td>TUG (s)</td>
<td>6.60</td>
<td>6.80</td>
<td>0.70;</td>
<td>6.80</td>
<td>6.40</td>
<td>1.40</td>
<td>0</td>
<td>0</td>
<td>1.40</td>
</tr>
<tr>
<td></td>
<td>30STS (reps)</td>
<td>14.50</td>
<td>18.50</td>
<td>5.20</td>
<td>14.80</td>
<td>16.80</td>
<td>2.60</td>
<td>0</td>
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<td>2.60</td>
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<tr>
<td></td>
<td>6MWT (m)</td>
<td>504.00</td>
<td>54.009</td>
<td>4.20</td>
<td>527.00</td>
<td>538.00</td>
<td>0.90</td>
<td>0</td>
<td>0</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(9.00</td>
<td>(13.00)*</td>
<td>(9.00)</td>
<td>(13.00)</td>
<td>(12.00)</td>
<td>(2.00)</td>
<td>0</td>
<td>0</td>
<td>2.00</td>
</tr>
<tr>
<td>Kargaran et al.²¹</td>
<td>TUG (s)</td>
<td>6.40</td>
<td>5.40</td>
<td>1.40</td>
<td>7.20</td>
<td>6.90</td>
<td>0.30</td>
<td>0</td>
<td>0</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td>6MWT (m)</td>
<td>530.00</td>
<td>564.00</td>
<td>1.50</td>
<td>479.00</td>
<td>492.00</td>
<td>0.50</td>
<td>0</td>
<td>0</td>
<td>0.50</td>
</tr>
</tbody>
</table>

BFRG: blood flow restriction group; Non-BFRG: Exercise without blood flow restriction group; CG: control group; TUG: Timed Up and Go Test; 30STS: 30-s sit-to-stand test; 6MWT: 6-minute walk test; NR: not reported; ES: effect size; %: percentage of change. *Significant difference from pre-test p < 0.05; †Significant difference compared to CG (p < 0.05); ‡Significant difference compared to Non-BFRG (p < 0.05).
Intervention duration is another important factor to be considered. In general, the intervention period lasted between 6 and 12 weeks, with the total number of sessions ranging from 24 to 40. Although the studies were short-term, AEBFR effectively increased physical function in older adults.

Finally, the findings of this review suggested that restriction pressure did not influence functional outcomes, whether applied arbitrarily or according to the individual's arterial occlusion pressure. However, from the studies eligible for this review, it could not be determined whether applying BFR intermittently could lead to different results. Although the arterial occlusion pressure method remains a major concern from a safety point of view, higher pressures applied by pneumatic cuffs may not offer the same pressure as manually inflated devices. This issue deserves further research and consideration.

Thus, given its affordability and frequent prescription for older adults, AEBFR could become an important technique for increasing muscle adaptation and physical function.

Limitations and practical implications
Some limitations of this study must be acknowledged. First, the studies included were underpowered, and their moderate quality prevents extrapolation of the results. Second, the studies reported no measurement errors between tests prior to the intervention, which may have led to false-positive results. Third, all studies except Clarkson et al. used arbitrary pressure during the training period, so it is unknown whether different levels of pressure could have influenced the results. Fourth, it should be pointed out that a meta-analysis could not be performed due to the heterogeneity of the results. Fifth, the age of the participants varied greatly, which could have affected the results, given that the baseline physical condition of young people may better than that of older adults and, hence, fewer changes may appear in functional tests. Sixth, not all of the studies presented means and SD for the pre- and post-test and/or effect size results, only the percent of change from compiled data. It would be interesting to homogenize these data in future investigations. Finally, additional studies are needed to support the use of AEBFR in clinical settings and for practitioners, especially for the older population.

CONCLUSIONS
AEBFR resulted in improved physical function in older adults. Future research should explore several related topics, such as how to restrict blood flow (continuous vs intermittent), applying pressure (individual vs arbitrary), and to determine whether there is a dose-response relationship between increased muscle mass and strength as well as performance and physical function in older adults.

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