Original Article (short paper)

Effect of walk training combined with blood flow restriction on resting heart rate variability and resting blood pressure in middle-aged men

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Abstract — **Aim:** To investigate the effects of low-intensity walk training with and without blood flow restriction (BRF) on resting heart rate variability (HRV) and blood pressure (BP) in middle-aged men. **Methods:** Twenty-one men were randomly assigned into the walk training group with (BRF-W; n = 11) and without (NOR-W; n = 10) BFR. The resting HRV and blood pressure were assessed pre- and post-6 weeks of the intervention [3 times/week, 5 sets of 3-min walking (6 $km.h^{-1}$) with 1-min of rest, totalizing 18 sessions of training]. The BFR-W group received the occlusive stimulus before of training sessions though of a standard sphygmomanometer and performed the training sessions with the vascular occlusion (80-100 mmHg) in both the legs. **Results:** Only BRF-W group improved HRV on time domain indices (SDNN and RMSSD; $p < 0.05$) after training but it was not found differences on frequency domain indices. In addition, systolic blood pressure (SBP) improved after training (PRE: 128.5 ± 5.9 vs POST: 119.1 ± 8.6 mmHg; Cohen's d = -1.30; $p < 0.01$) only in BFR-W group. There was not a significant difference on diastolic blood pressure (DBP) after training, however, effect size was moderate for BFR-W (Cohen's d = -0.56; $p > 0.05$). **Conclusion:** Our results showed that walking training with blood flow restriction can improve health cardiovascular parameters in middle-aged men.

Keywords: cardiac autonomic activity, blood pressure, vascular occlusion training, healthy aging.

Introduction

The aged-process promotes changes in the cardiovascular system, such as the rise of blood pressure (BP) due to negative changes in peripheral vascular resistance and large artery stiffening, increasing risk factors for the cardiovascular diseases[1].

Moreover, it has been shown that there are significant changes in the autonomic nervous system (i.e., increased sympathetic activity) in middle-aged men, which have a key pathophysiological role in the cardiovascular diseases[2]. Heart rate variability (HRV) is an interesting measure of cardiovascular autonomic function, and reduced HRV is a direct predictor of cardiovascular risks and all-cause mortality[2,3]. In addition, a decreased parasympathetic activity assessed by HRV has been associated with cardiovascular diseases[2,3].

Regular aerobic training is recommended to improve cardiovascular health, due to reduce BP[1] and improve HRV indices[4]. Physical exercise promotes adaptations in endothelial function and vascular remodeling, preventing hypertension[1]. Additionally, aerobic exercise can positively modify the sympathovagal control of HRV, mainly by increasing parasympathetic activity and reducing cardiovascular diseases risk[4].

Recently, a combination of low-intensity walk training with blood flow restriction (BFR) has been applied as a strategy to improve cardiovascular function, muscular strength and hypertrophy, since that combination showed similar improvements when compared with intense aerobic exercise[5,6]. However, to our knowledge, there is no evidence investigating the effects of walk training with BFR on HRV and it is not clear whether walk training with BFR could improve the resting BP in middle-aged men. Studies have shown that aerobic exercise training reduces resting BP and improve HRV, reducing the risk of mortality from cardiovascular diseases[1,4]. Therefore, it would be interesting to analyze normotensive middle-aged men to verify if the walk training with BFR would improve even more the cardiovascular system. The aging process leads to negative changes in peripheral vascular resistance and large artery stiffening, increasing risk factors for cardiovascular diseases[1]. Because of this, preventive actions on the cardiovascular system is very important for healthy aging. In addition, it was investigated whether a walking training with low-intensity, low weekly frequency (3 times/week) and a short-training session (~20 min) would improve the cardiovascular system using a lower volume of training than is recommended by ACSM[7]. Thus, the aim of this study was to investigate the effects of low-intensity walking training with and without blood flow restriction on resting BP and HRV in middle-aged adults.

Methods

Subjects

Twenty-one male volunteers (52.4 ± 3.7 years; 81.0 ± 11.6 kg; 169.5 ± 7.4 cm) took part in this study. Participants were recruited through printed advertisements and by word of mouth. The inclusion criteria were: (a) not been enrolled in a regular exercise program in the previous 6 months of the study, (b) do not have any previous experience in blood flow restriction training, (c) absence of any kind of cardiovascular or metabolic disease, (d) no joint or bone injury, (e) absence of use of any medication that could influence the cardiovascular response. All subjects had systolic blood pressure (SBP) between 119 – 138 mmHg and diastolic blood pressure between (DBP) 66 – 88 mmHg. Subjects were required to answer a questionnaire clarifying possible questions of health-related problems. All participants were aware of the procedures and risks of the experimental protocol and signed informed consent. The study was approved by the local Ethics Committee (number protocol approved 1.124.302/2015) and performed in accordance with the ethical standards. Participants were randomly assigned into two training groups: walk training group with (BFR-W; n = 11) and without (NOR-W; n = 10) blood flow restriction (BFR) (Table 1). The resting HRV and resting SBP and DBP were assessed pre- and post-6 weeks of intervention.

Table 1. Demographic characteristics.

	Groups	
	BRF-W (n = 11)	NOR-W (n = 10)
Age (years)	51.9 ± 3.7	53.5 ± 3.3
Height (cm)	170.8 ± 7.0	166.5 ± 5.4
Weight – PRE (kg)	83.6 ± 7.9	77.2 ± 15.1
Weight – POST (kg)	83.9 ± 6.7	78.5 ± 14.2
BMI – PRE (kg/m^2)	28.7 ± 3.0	27.7 ± 5.0
BMI – POST (kg/m^2)	28.8 ± 2.7	28.2 ± 4.6

Values of mean ± SD.
BRF-W (n = 11): walk training with blood flow restriction group;
NOR-W (n = 10): walk training without blood flow restriction group.
PRE (pre training), POST (post training), BMI: Body mass index.

Heart Rate Variability

Resting HRV was calculated from recorded beat-to-beat R-R intervals using a HR monitor, Polar RS800 (Polar, Kempele, Finland)[8]. The participants were requested to avoid beverages or food containing caffeine for at least 6 h, and do not perform physical effort for 24 h prior to the assessment.

Participants remained seated in a chair for 10 min for HR recording and supervised by an experienced researcher. R-R intervals were filtered using the software Polar Pro Trainer 5 (Polar, Kempele, Finland) and visually checked to exclude possible ectopic beats. The last 5 min of the 10-min recording was used to analyze resting HRV with the smooth prior method, using the software Kubios HRV (version 3.0).

Heart rate variability were analyzed in the time and frequency domains. The indices obtained in the time domain were the mean of normal R-R intervals (R-R mean), the standard deviation of normal R-R intervals (SDNN), and root means square of the successive differences between adjacent R-R intervals (RMSSD). The frequency domain indices were derived by a Fast Fourier Transform of the detrended tachogram of R-R intervals with the high frequency (HF: 0.15–0.40 Hz) and low frequency (LF: 0.04– 0.15 Hz) expressed in absolute and normalized units, and as the LF/HF ratio.

Blood Pressure Assessment

SBP and DBP were measured using an automated blood pressure cuff (Omron HEM-631 INT, Digital BP monitor, Omron Healthcare, The Netherlands). The resting SBP and DBP were measured in the left arm after participants remained seated for 10 minutes. At least two measurements with 5-min interval were performed and the SBP and DBP were considered the average of two measurements with a difference lower than 5 mmHg.

Training Protocol

BFR-W and NOR-W performed a 6-week, 3 times a week (18 training sessions), supervised exercise training. The walking program consisted of five sets of 3-min walking bouts with a 1-min rest between bouts[6]. Both groups (BFR-W and NOR-W) performed treadmill walking at an exercise intensity of 6 km · h^{-1} and 5% grade, which was maintained constant throughout the training period[6]. The exercise intensity corresponded to ~65% of peak heart rate in the NOR-W group and ~70% of peak heart rate in the BFR-W group.

In BRF-W group, a standard sphygmomanometer (width = 18 cm; length = 80 cm) was applied around the thighs of both lower limbs and immediately distal to the inguinal fold. As a warm-up for the BRF-W training, participants were seated on a chair with a standard sphygmomanometer and it was set for 30 s and then released for 10 s repeatedly from initial (50 mmHg) to the last (80 mmHg) pressure. On the first day, the training pressure was set to 80 mmHg and it was increased to 10 mmHg every two weeks until reach 100 mmHg (5th and 6th weeks). The pressure of standard sphygmomanometer was progressively increased in order to allow participants to adapt to the occlusion stimulus during the early phase of training[5]. The choice of training pressures was based on previous work that induced nearly 50-80% of the pressure that causes total occlusion of the tibial artery flow[9]. Restriction of leg muscle blood flow was maintained for the entire exercise session, including the 1 min rest periods. The belt pressure was released immediately after the fifth bout of walking. The total time of leg muscle blood flow restriction was about 22 min for each subject including the preparation process (~3 min) before the start of the training session.

Statistical Analysis

Data are presented as arithmetic means ± standard deviation (SD). The Gaussian distribution was observed through the Shapiro-Wilk test. Data were analyzed using two-way ANOVA (group x time) with repeated measures. When significant differences were found, the LSD posthoc test was used to discriminate when significant differences occurred. In addition, it was used the Friedman test followed by the Wilcoxon to compare HRV variables. Physical characteristics were compared using independent *t*-test or Mann-Whitney test. Data were considered statistically significant when $p < 0.05$. Statistical analyses were carried out using Statistica 8 software. In addition, the smallest worthwhile change was calculated based on Cohen's d effect size principle. The magnitude of differences was expressed by Cohen's d effect size considering the following criteria: 0.0-0.19 (trivial), 0.20 - 0.49 (small), 0.50 - 0.79 (moderate) and > 0.80 (large)[10].

Results

There were no significant differences between groups for any parameters of the HRV assessed pre-training ($p > 0.05$). We did not find significant differences in R-R mean in both groups after training program ($p > 0.05$), while there were differences in SDNN and RMSSD for BRF-W group pre- and post-intervention ($p < 0.01$). In addition, it was not observed significant differences in the frequency domain indices in both groups after training program ($p > 0.05$) (Table 2).

SBP and DBP were not significantly different between groups in the pre-training assessments. However, it was found significant difference on SBP and the magnitude of change analyzed by effect size was increased after training, only for BRF-W group (BRF-W: Cohen's d = -1.30; $p < 0.01$ vs NOR-W: Cohen's d = -0.53; $p > 0.05$) (Figure 1A), but without difference between groups after training program ($p > 0.05$). Furthermore, there was not a significant difference on DBP after training in both groups, however, effect size was moderate for BFR-W and small for NOR-W after training (BRF-W: Cohen's d = -0.56; $p > 0.05$ vs NOR-W: Cohen's d = -0.34 $p > 0.05$) (Figure 1B).

In relation to RPE, there is significative difference only in first week of training between groups (BFR-W = 13.5 ± 1.2 vs NOR-W = 11.7 ± 1.6; $p < 0.05$), and both groups decrease the RPE in the time course during the weeks (BFR-W – 1st = 13.5 ± 1.2; 2nd = 12.4 ± 1.9; 3rd = 12.2 ± 1.4; 4th = 11.9 ± 1.2; 5th = 12.0 ± 1.2; 6th = 11.6 ± 1.1; NOR-W – 1st = 11.7 ± 1.6; 2nd = 11.6 ± 1.7; 3rd = 11.2 ± 1.3; 4th = 11.3 ± 1.2; 5th = 10.9 ± 0.9; 6th = 10.9 ± 1.0) ($p < 0.05$).

Table 2. Changes on resting HRV parameters after 6-week of walk training with or without blood flow restriction.

	BFR-W	**BFR -W**		**NOR-W**	**NOR-W**		**p- values**		
	PRE	**POST**	**Cohen's d**	**PRE**	**POST**	**Cohen's d**	**Group**	**Time**	**Interaction**
Time domain									
R-R mean (ms)	828 ± 148	871 ± 99	0.35	757 ± 126	783 ± 128	0.21	0.14	0.86	0.66
SDNN (ms)	24.2 ± 9.1	30.4 ± 6.2*	0.81	20.1 ± 8.4	24.2 ± 8.9	0.47	0.13	0.002	0.46
RMSSD (ms)	18.5 ± 9.3	22.7 ± 10.3*	0.43	13.3 ± 6.8	14.9 ± 7.4	0.23	0.08	0.01	0.26
Frequency domain (FFT)									
lnLF (ms^2)	6.0 ± 0.6	6.0 ± 0.5	0.05	5.5 ± 1.0	5.8 ± 0.8	0.27	0.23	0.24	0.42
lnHF (ms^2)	4.32 ± 1.2	4.74 ± 0.8	0.42	3.86 ± 1.0	4.15 ± 1.1	0.29	0.23	0.06	0.72
LF n.u.	79.7 ± 15.9	76.8 ± .13.7	- 0.19	83.0 ± 6.4	82.6 ± 8.1	- 0.06	0.31	0.26	0.41
HF n.u.	20.3 ± 15.9	23.2 ± 13.7	0.19	16.9 ± 6.4	17.4 ± 8.1	0.05	0.37	0.26	0.42
LF/HF ratio	5.1 ± 3.1	4.5 ± 2.7	- 0.23	6.0 ± 3.3	5.8 ± 2.7	- 0.04	0.33	0.54	0.67

Values of mean ± SD. BRF-W (n = 11): walk training with blood flow restriction group; NOR-W (n = 10): walk training without blood flow restriction group.
PRE (pre training) POST (post training), R-R mean = mean of normal R-R intervals; SDNN = standard deviation of normal R-R intervals; RMSSD = root mean square of the successive differences between adjacent R-R intervals; FFT = fast Fourier transform; LF = low frequency; HF = high frequency.
* Significant difference ($p < 0.05$).

Discussion

In this study, we investigate the effects of low-intensity walk training with and without BFR on resting BP and HRV in middle-aged adults. To our knowledge, this is the first study to show the improvement on resting HRV and resting SBP after walking training with BFR in middle-aged adults, indicating an improvement in cardiovascular health and preventing cardiovascular diseases. The main findings of this study are (1) the improvement in time domain indices (SDNN and RMSSD) after training only in BFR-W group and (2) positive responses in BP (changes in SBP) were observed after training only in

BFR-W group. However, the effects of walking training with BFR did not change the indices of frequency domain and DBP.

After the exercise training program, only BFR-W group increased time domain indices (SDNN and RMSSD) of the HRV. Our study corroborates others that have also found an increase in these time domain indices after aerobic training with intensities higher than that used in the present study and without BFR[3,11]. On the other hand, we found no changes in R-R and frequency domain indices after training in both groups. These results were different from the previously cited studies since they showed an improvement in HF indices in response to aerobic training. However, Catai et al.[12] demonstrated that frequency domain indices did not change after aerobic training in middle-aged men, corroborating with the present study. One may reason to explain these different findings could be due to the different training protocol applied, because it has been observed with a higher exercise intensity (>70% peak HR) and/or volume training (>8 weeks, ≥3 sessions/week, >30 min) a consistent improvements of HF index[3,13,14,15]. In addition, due to the physiologic mechanism of HF index is associated with respiratory modulation, and only under controlled conditions while breathing at normal rates it can be used to estimate vagal tone[16]. Other possible reason for not change in the lnHF index after training was that we not controlled the respiratory rate of subjects.

Moreover, it was found a decrease in SBP only in BFR-W group after the training program. This result was similar to the study of Cornelissen et al.[17] that shown a decrease in SBP and not found differences in frequency domain indices after training with sedentary people. Accordingly, a previous study showed a decrease in SBP after aerobic training with higher intensities and without BFR[18]. In contrast, one study did not verify differences on SBP after the walking training combined with BFR but they examined a different population (i.e., athletes) as well as the period of training (i.e., 2 weeks)[6].

The results found in the present study indicate positive adaptations in the cardiovascular system after training in the BRF-W group. The mechanisms responsible for these adaptations in response to training with BFR are not well understood. It is believed that walking training with BFR potentiates the suppression of angiotensin II (known to inhibit cardiac vagal activity) mediate enhancement of cardiac vagal tone[19], as well as improvement in endothelial function and nitric oxide bioavailability[19], thus promoting increases cardiac vagal tone and reduces sympathetic cardiac influences[19]. Moreover, the training reduces sympathoexcitation by reducing activation of neurons within cardiovascular regions of the brain[20]. Additionally, we believe that walking training with BFR potentiates the increase in shear stress, which provides the physiological stimulus for the adaptations in endothelium and vasculature[21,22], leading to changes in cardiac remodeling[23] and decreasing SBP. Furthermore, it was verified that aerobic training remodels cardiorespiratory centers[24], with reduction of sympathetic and increasing parasympathetic (vagal) outflow, leading to an cardiac autonomic balance and improvement in heart rate variability[25]. Moreover, blood pressure reduction after aerobic training could be mediated by a neural mechanism, because vasomotor sympathetic nerve activity decreases after training[26]. This reduction in sympathetic nerve activity has been attributed to an increase in nitric oxide and a decrease in central angiotensin II[26]. Thus, these mechanisms can have contributed to adaptations after the BFR training.

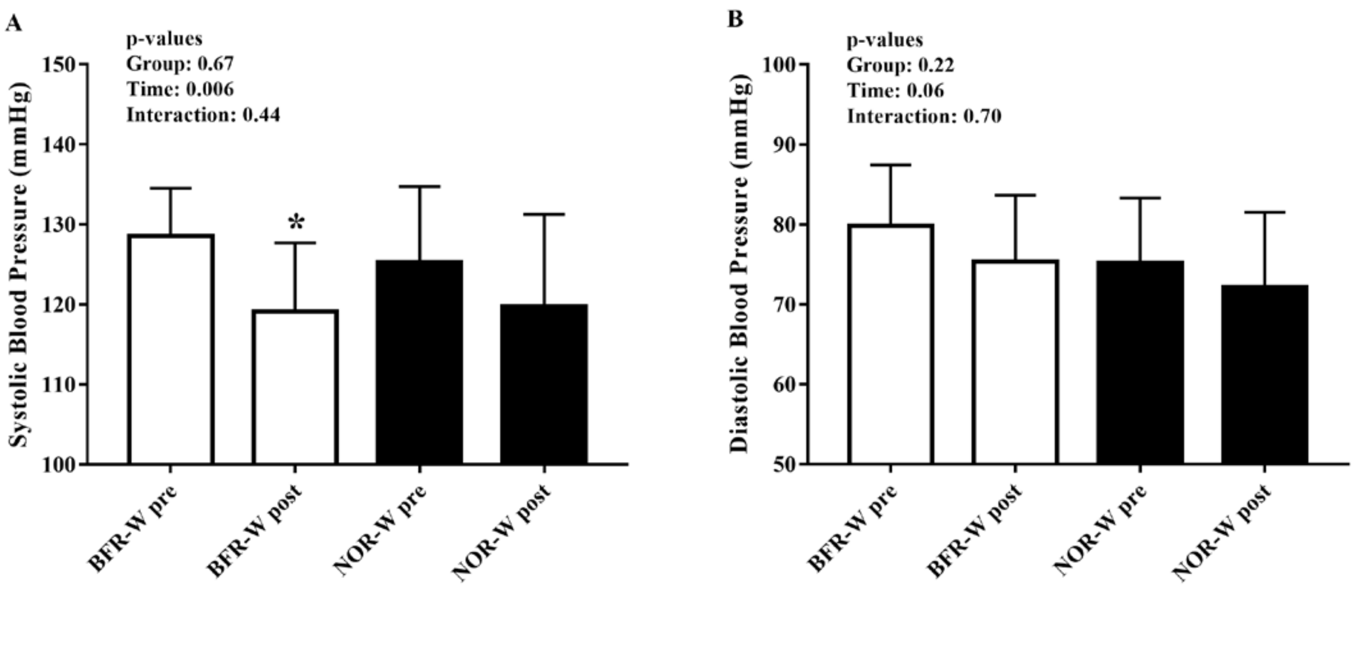

Figure 1. (A) Systolic blood pressure and (B) Diastolic blood pressure following 6-week of walk training with (BFR-W) and without blood flow restriction (NOR-W).

* Significant difference ($p < 0.05$).

The conventional walking training improves mainly cardiovascular fitness after a long period of training[27]. It has been showed that the walk training with blood flow restriction might be an interesting tool to improve muscular strength and hypertrophy, and cardiovascular fitness after a shorter period of training[5,6]. In this study, it was demonstrated that the walking training with BFR improved health cardiovascular parameters. Thus, the walk training with BFR seems to be an interesting alternative for people unable to perform high intensity exercise or elderly, because improve health cardiovascular and prevent the negative alterations related to aging even having used a low weekly frequency (3 times/week) and a short-training session (~20 min).

It is not clear whether walking training with BFR is completely safe when applied in special populations such as individuals diagnosed with heart failure, hypertension, or peripheral artery disease. It is believed that training with BFR intensified exercise pressure reflex (EPR), a reflex that contributes to cardiovascular modifications during exercise from the autonomic nervous system[28]. Thus, the increase of EPR could be negative for special populations (i.e. hypertensive subjects)[28,29]. However, some studies have indicated that exercise with BFR exercise seems to be safe in hypertensive subjects because they did not present any adverse events[30-32]. Furthermore, the acute effect during exercise with BFR slightly increases SBP[30], whereas the chronic effect decreases SBP in hypertensive subjects[31]. In relation to vascular diseases, there is not enough evidence to obtain consensus about the impact of training with BFR on vascular function. Evidence has demonstrated that training with BFR did not change coagulation factors and arterial compliance with inconsistency results in endothelial function[33]. Thus, future studies should be conducted to examining the effects of training with BFR on vascular function in risk populations and its potential therapeutic benefits.

The main limitations of the present study were not able to measure vascular parameters and other hemodynamics parameters, which would help us to better understand and explain the adaptations of walking training with BFR. Even though, this study helped to increase the understanding of blood flow restriction associated with walking training on cardiac adaptations.

Conclusion

The walking training combined with blood flow restriction can increase resting HRV indices and decrease resting SBP for 18 sessions (~20 min). These adaptations in the cardiovascular system could prevent and reduce cardiovascular diseases risks. Future researches are needed to examine the mechanisms responsible for improving HRV and SBP evoked by walking training combined with vascular restriction.

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