



Comparative Analysis of Treadmill Walking with Different Occlusion Pressure on Aerobic Capacity and Muscle Strength among Sedentary Collegiates: A Pilot Study

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Abstract

Background: Blood Flow Restriction Training (BFRT) has demonstrated potential as a low-load training method to improve muscular strength and aerobic capacity, particularly in sedentary individuals. However, little is known about the effects of varying occlusion pressures on aerobic activity and knee muscle strength. This study aimed to investigate the effects of treadmill walking and two different occlusion pressures 40% and 60% of Artery Occlusion Pressure (AOP), on aerobic capacity and quadriceps muscle strength in sedentary young adults.

Methods: This single-blind, randomized pilot study involved 40 sedentary college students, 18 of whom were women and 22 were men. The participants were randomly assigned to Group A (40% AOP) and Group B (60% AOP). Training was conducted three times a week for four weeks using a modified Balke protocol and H+ cuffs on the dominant leg. The Activforce 2 dynamometer and queen's college step test was used to evaluate quadriceps force and VO₂ max before and throughout the intervention, respectively.

Results: Both groups demonstrated significant improvements in aerobic capacity and knee extensor strength following the intervention ($p < 0.05$). Two-way repeated measures ANOVA showed a significant main effect of time and a significant group $\times$ time interaction ($p < 0.05$), indicating greater improvement in the 60% AOP group compared to the 40% AOP group. Percentage change analysis further supported these findings.

Conclusion: Moderate-pressure BFRT (60% AOP) combined with treadmill walking resulted in greater increases in muscle strength and aerobic capacity than lower pressure BFRT. The findings suggest that pressure-specific programming can be used to optimize the advantages of BFRT in sedentary populations.

Keywords: Aerobic capacity, Blood flow restriction, Limb occlusion, Muscle strength, Sedentary, Walking

Introduction

The World Health Organization (WHO) defines physical activity as any skeletal muscle movement that requires energy, including non-exercise activities (1). Despite technological benefits, incidental physical activity from daily tasks such as active transportation, labor, and household chores has declined and is often replaced by machines. Additionally, the increased use of mobile devices during leisure time is linked to more sedentary behavior (2). India's largest physical activity study reported that 54.4% (n=14,277) of individuals aged 20 and above were inactive (3). Globally, physical inactivity ranks as the fourth leading cause of death, followed by alcohol consumption, undernutrition, and unsafe sex, contributing to over 3.2 million deaths annually (4). Physical inactivity is a modifiable behavioral risk factor linked to increased morbidity and mortality, and contributes to chronic diseases such as asthma, Chronic Obstructive Pulmonary Disease (COPD), sarcopenia, and arthritis (5,6). The transition from school to university involves changes in household, workplace, and leisure environments, making individuals more vulnerable to risky behaviors such as alcohol use, gaming, reduced physical activity, and sedentary lifestyles (7). Lower Extremity Strength (LES) independently predicts mortality (8). Sedentary behavior may affect health by altering inflammation and increasing lipoprotein lipase activity, which increases triglyceride levels and lowers HDL cholesterol (9).

As people age, muscle mass loss is the primary cause of decreased strength in adults aged 25–80 yr and contributes significantly to the functional limitations associated with aging. This loss is more pronounced in extremely sedentary (hypokinetic) individuals. Among the muscles most affected by inactivity and disuse, the extensor and non-postural muscles exhibit the greatest atrophy (10). Factors such as poor diet, smoking, stress, inactivity, and modern lifestyle changes further alter physiological characteristics such as muscular strength and aerobic capacity, increasing susceptibility to functional decline.

The maximum oxygen consumption rate ($\text{VO}_{2\text{max}}$), commonly referred to as aerobic capacity, is an important ergonomic metric used to assess an individual's work capacity and physical capability (11).

A structured exercise program is essential for improving cardiorespiratory fitness and muscle endurance while reducing cardiovascular and muscle loss risks later in life. However, unlike traditional ACSM protocols, it is less time-consuming and requires lower metabolic demands. KAATSU training, which involves limiting muscle blood flow during resistance and aerobic exercises, exemplifies such a program by producing significant gains in aerobic capacity, muscle size, and strength despite low-intensity training (20% of 1-RM) (12). According to the literature, 40–80% of arterial occlusion pressure is suitable (13,14) therefore, the goal of this study was to identify the optimal pressure required to produce meaningful outcomes rather than training with high arbitrary pressure or formula-based pressure.

Materials and Methods

Study design

This four-week study was conducted in Greater Noida, Uttar Pradesh, and authorized by the School Ethics Committee (Ref. No.: SEC/SAHS/PhD/24/17), was prospectively registered with the Clinical Trials Registry–India (CTRI/2024/11/076477). All the experimental methods detailed in this study were performed in compliance with the ethical guidelines of the Declaration of Helsinki.

Sample size and participants

Forty sedentary college participants (18 women and 22 men) were selected using convenient sampling. The typical pilot trial rule of thumb, which stipulates that at least 12 to 20 people per group are necessary to estimate feasibility and variability, or 20 participants per group, was applied to determine the sample size since this was a pilot study.

Screening criteria

The Physical Activity Readiness Questionnaire (PAR-Q+) was used to screen participants. The subjects who met the inclusion criteria were sedentary college students between the ages of 18 and 25 yr, categorized as “inactive” by the International Physical Activity Questionnaire (IPAQ), and free of known musculoskeletal, neurological, or cardiovascular conditions. Exclusion criteria include uncontrolled hypertension, any lower limb injury or surgery

within the last six months, any identified chronic condition that could interfere with the training, and contraindications to Blood Flow Restriction Training (BFRT) as defined by the BFRT screening questionnaire (15).

Intervention and group allocation

A single-blinded study was conducted among two groups randomly selected from among the participants: Group A (Low Occlusion Group) 40% Artery Occlusion Pressure (AOP) underwent walking training on a treadmill. Group B (Moderate Occlusion Group) underwent treadmill walking training with 60% AOP. Before training, the dominant leg AOP was measured in *mmHg* in the supine position, separately using the FDA-approved H+ Doppler instrument.

Training protocol

Using the modified Balke-Ware technique, both groups walked on a treadmill while wearing H+ cuffs on their dominant leg. Starting at a 0% incline, walking was performed at a steady pace of 4.8 *km/h*, increasing by 2.5% grade per stage based on the heart rate remaining within the desired heart rate range. For four weeks (12 sessions total), the sessions were held on three non-consecutive days per week and lasted for 20 *min* each. The participants who reported high perceived effort on the Borg RPE scale, headache, angina, or dizziness had their training immediately stopped (Table 1).

Measures of outcome

All the assessments were conducted at the baseline

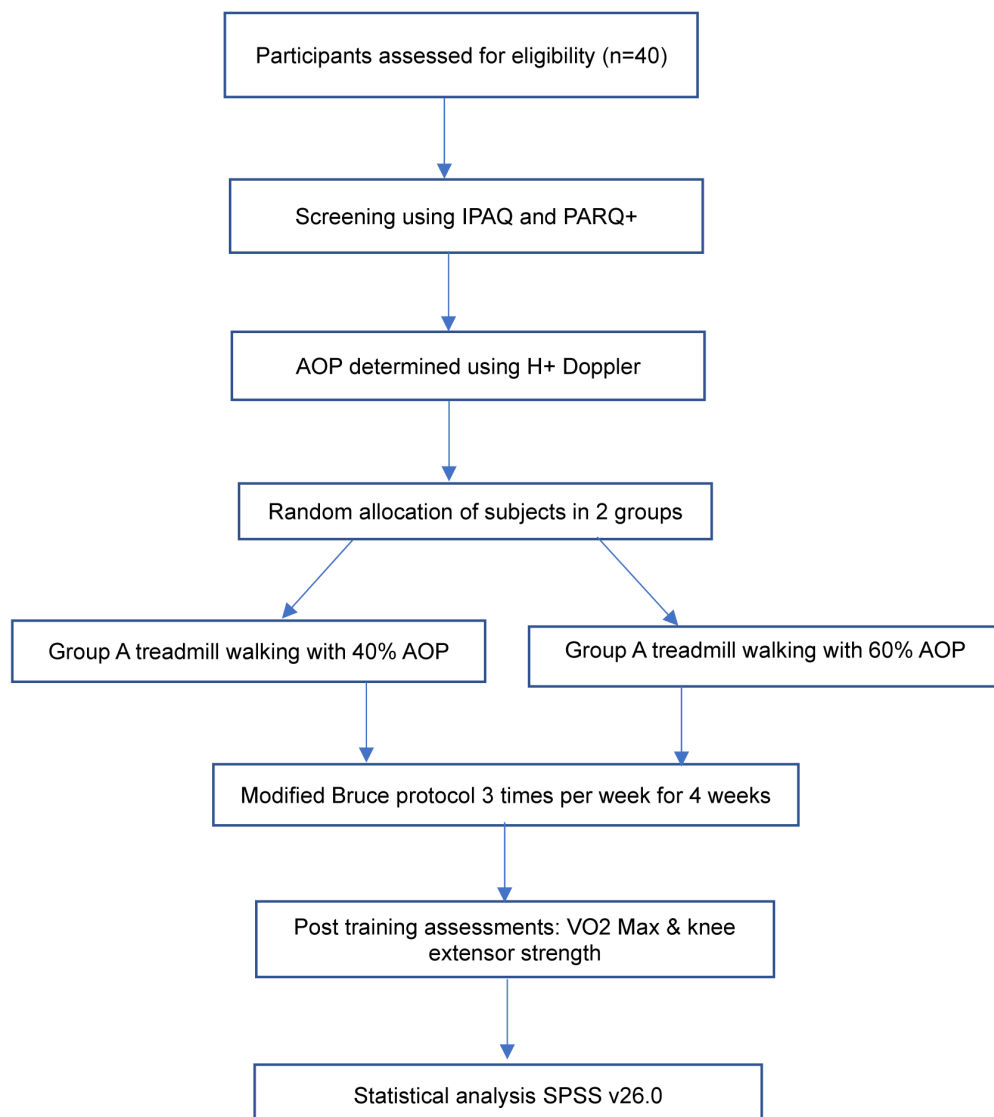


Table 1. The flowchart of the study participants.

(pre-intervention) and following the last session (week 4). The Queen's College Step Test was used to measure aerobic capacity, and VO_2 max was estimated using the post-test heart rate. The strength of the knee extensor muscles was measured using an Activforce 2 dynamometer (Kg). The portable Activforce 2 dynamometer (ICC values ranging from 0.64 to 0.78) was fixed by a nonelastic band at the distal anterior portion of the tibia, with a height determined at 2 cm above the malleolus. Participants were instructed to perform a maximum contraction to extend the knee, keeping muscular contraction for at least 6 seconds, alongside the expiratory phase the 3 trials were averaged while the participants were seated during the procedure. The amount of blood flow restriction pressure (40 vs. 60% AOP) used while walking on a treadmill was considered an independent variable. Variations in aerobic capacity (VO_2 max) and peak force (N) of the quadriceps were the dependent variables (Figure 1).



Figure 1. Treadmill walking with occlusion pressure on H+ cuff.

Statistical analysis

All the data were analyzed using IBM SPSS Statistics Version 26.0. The significance level was set at $p < 0.05$. Descriptive statistics (mean $\pm$ standard deviation) were used to summarize the participant demographics and outcome measures. The normality of the data distribution was assessed using the Shapiro-Wilk test. Statistical analyses were performed by a two-way analysis of variance (ANOVA) with repeated measures. Post hoc testing was performed using a paired t test when appropriate. All baseline differences and percent changes between both the groups were evaluated with one-way ANOVA. Statistical significance was set at $p < 0.05$. Participants who dropped out were excluded from the final analysis, and per-protocol analysis was performed on those who completed the intervention.

Results

Forty sedentary young adults (18 females and 22 males) participated in the study and were randomly assigned to group A ($n=20$, low occlusion-40% AOP) and group B ($n=20$, high occlusion-60% AOP). Baseline data were obtained, and the mean $\pm$ standard deviation ($M \pm SD$) was used for continuous data. The subjects in groups A and B had mean Body Mass Index (BMIs) of 21.11 ± 0.9 and $22.9 \pm 1.2 \text{ kg/m}^2$, and mean ages of 21.29 ± 1.40 and 21.88 ± 1.18 yr, respectively. Age, BMI, baseline VO_2 max, and muscle strength did not significantly differ between the groups ($p > 0.05$), suggesting homogeneity. Both groups demonstrated a significant improvement in aerobic capacity (VO_2 max) and knee extensor strength following the intervention ($p < 0.05$), as shown by paired comparisons (Table 2).

Two-way repeated measures ANOVA revealed a significant main effect of time for both VO_2 max and strength ($p < 0.05$), indicating overall improvement across participants. There was no significant main effect of group ($p > 0.05$). However, a significant group $\times$ time interaction was observed for both variables ($p < 0.05$), suggesting that the magnitude of improvement differed between groups (Table 3). Further analysis of percentage change demonstrated greater improvement in the 60% AOP group compared to the 40% AOP group for both VO_2 max and muscle strength ($p < 0.05$) (Table 4).

Table 2. Comparison of pre- and post-intervention aerobic capacity (VO₂ max) and knee extensor strength within groups using paired t-test

Variable	Group	Pre (Mean ± SD)	Post (Mean ± SD)	p-value
VO ₂ max (ml/kg/min)	40% AOP	31.66±1.3	33.2±1.4	0.04*
	60% AOP	31.8±1.4	33.9±1.4	0.01*
Strength (kg)	40% AOP	17.5±1.4	18.9±1.6	0.03*
	60% AOP	18.5±1.2	20.7±1.2	0.01*

Table 3. Two-way repeated measures ANOVA showing the effects of group, time, and group×time interaction on aerobic capacity and muscle strength

Variable	Time (p)	Group (p)	Group×Time (p)
VO ₂ max	0.01*	0.18	0.04*
Strength	0.01*	0.22	0.03*

Table 4. Comparison of percentage change in aerobic capacity and muscle strength between groups using one-way ANOVA

Variable	40% AOP	60% AOP	p-value
VO ₂ max	+4.7%	+8.1%	0.04*
Strength	+8.8%	+14.9%	0.03*

Discussion

To the best of authors' knowledge, this is the first study to compare the effects of two different occlusion pressure training methods with treadmill walking on the sedentary collegiate population's muscular strength and aerobic capacity.

The findings demonstrated that in a sedentary college population, both occlusion pressures were equally effective in improving aerobic capacity and knee extensor muscle strength; however, Group B, which had 60% AOP, produced noticeably more physiological changes than group A (40% AOP). The findings indicate that moderate occlusion pressure may provide a more effective training stimulus during treadmill walking, suggesting that the effectiveness of blood BFRT is contingent upon the applied pressure.

One study similar to the current study suggested anabolic pathway activation, metabolic stress, and hypoxia-induced type II fiber recruitment are

among the physiological processes of BFRT that are responsible for current reported increase in quadriceps force and estimated VO₂ max (16). In addition, greater venous return limitation, which increases intramuscular metabolic demand and neuromuscular adaptation, accounts for the more obvious advantages of the 60% AOP group (17). Previous studies using similar techniques have consistently demonstrated that BFRT plus walking or cycling improves aerobic capacity and muscular strength (18,19). Abe *et al* (12-2010) found that BFR and four weeks of low-intensity walking enhanced older individuals' thigh muscle cross-sectional area and VO₂ max. The present study contributed to this body of work by demonstrating that the pressure gradient is crucial in regulating the degree of these adaptations, even in a younger, sedentary group (20).

Significant improvement in VO₂ max was observed in both groups, but group B (60% AOP) yielded the most significant gain compared to Group A (40% AOP). The higher VO₂ max advantages observed in the 60% AOP group may also be explained by the increased activation of the hypoxia-inducible factor-1 alpha (HIF-1α) pathway, which stimulates angiogenesis and mitochondrial biogenesis (21). Furthermore, reduced blood flow at greater occlusion pressures appears to cause more robust lactate accumulation and hormonal responses, both of which improve endurance (22). These findings align with (23) and (24) support the hypothesis that moderate occlusion pressures may allow for more substantial cardiovascular conditioning due to higher shear stress and vascular remodeling resulting in VO₂ max improvement.

Given that the treatment period is just one month, early neuromuscular adaptations and additional metabolic stress from BFR training during treadmill walking can account for the gain in muscle strength

in both treatment groups. Furthermore, even after engaging in low-intensity exercise, metabolic accumulation from a limited blood supply results in elevated lactate concentration and hypoxia, which stimulates growth hormone release and activates muscle protein synthesis signaling pathways (such as mTOR and MAPK) (25). The quadriceps peak force changes (Group A: $+8.6 \pm 3.5$ N; Group B: $+12.4 \pm 2.7$ N; $p < 0.001$) suggest that these processes may significantly increase both muscular strength and aerobic capacity over the brief 4-week intervention period.

Group B (60% AOP) outperformed Group A (40% AOP) due to increased occlusion-induced global metabolic and mechanical stress, which probably led to increased activation of fast-twitch muscle fibers and intramuscular signaling for adaptation (26). Together, these neurological and metabolic variables contributed to the strength gains observed throughout the brief one-month intervention period.

It was also generally known that BFR walking exercise can improve the size and strength of the muscles in the lower limbs (27). Similarly, quadriceps strength increased much more in the 60% group, suggesting a significant therapeutic advantage. These findings are consistent with recent studies that propose moderate occlusion pressures for maximal strength and hypertrophic responses (28). By forcing fatigue to begin early, BFRT at moderate pressure promotes the recruitment of higher-threshold motor units, even during low-load tasks. By mimicking high-intensity training adaptations, this neuromuscular recruitment offers a simple yet effective approach for groups incapable of enduring traditional resistance treatments (29).

Furthermore, the safety profile in the current study was reassuring. Although a small number of respondents reported temporary discomfort and increased perceived exertion, no substantial negative effects were observed. This proved that moderate-pressure BFRT is possible and safe during aerobic exercise, particularly when procedures are tailored using tools

like the H+ Doppler for accurate AOP measurement. However, this study has some limitations. The sample size limits generalizability, even though it is adequate for a pilot study. Furthermore, the participant anticipation effects cannot be completely ruled out, even though the single-blinded strategy reduces observer bias. Future research should employ larger cohorts and incorporate imaging or molecular markers to elucidate the mechanistic pathways.

This study provided promising evidence for the integration of moderate-pressure BFRT into rehabilitation or fitness regimens targeting sedentary populations. Given the low mechanical load, this approach is particularly relevant for individuals with joint limitations and deconditioning. The ability to elicit significant aerobic and muscular benefits through brief, low-impact protocols can transform preventive and therapeutic exercise prescriptions in clinical and community settings.

Conclusion

In conclusion, both 40% and 60% AOP significantly improved aerobic capacity and muscle strength in inactive young adults. However, greater improvements were observed at 60% AOP indicating that maximal physiological adaptation benefitted from moderate occlusion pressure. These findings underline the importance of customized occlusion pressure selection and lend credence to the wider application of BFRT as a low-load, time-efficient training method.

Acknowledgement

The School Ethics Committee granted ethical permission for this study (Ref No: SEC/SAHS/PhD/24/17) on 15/04/2025. This study was also registered with the Clinical Trials Registry – India (CTRI/2024/11/076477) on 15/05/2025.

Conflict of Interest

Authors declare no conflict of interest.

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