

Tanya Gujral¹, PhD Scholar, Department of Physiotherapy, School of Allied Health Sciences, Galgotias University, Greater Noida, India, <https://orcid.org/0000-0001-6288-5228>

Dr. Kamran Ali² (Corresponding author), Associate Professor, Department of Physiotherapy, School of Allied Health Sciences, Galgotias University, Greater Noida, India, <https://orcid.org/0000-0001-6492-3398>

Comparative analysis of Treadmill Walking with different occlusion pressure on aerobic capacity and muscle strength among Sedentary Collegiates-A Randomized Controlled Trial

Abstract

Background. Sedentary lifestyles among college students pose a significant public health challenge, contributing to diminished aerobic capacity and muscle strength. Blood Flow Restriction training (BFRT) has emerged as an effective method to enhance physiological adaptations with low mechanical stress.

Aim. This study evaluates the comparative effects of treadmill walking under varying occlusion pressures on aerobic capacity and knee extensors strength in sedentary collegiate.

Materials and Methods. Thirty sedentary college students (aged 18-25 years) were randomized into three groups: Group A (low-pressure BFRT at 40 % limb occlusion), Group B (high-pressure BFRT at 60 % limb occlusion), and Group C (control, no occlusion). Participants underwent supervised treadmill walking for 20 minutes, three times per week over four weeks. Outcomes measured pre- and post-intervention included VO_2 max (aerobic capacity) and quadriceps strength. Statistical analysis was performed using SPSS v25.0 with significance set at $p < 0.05$. A one-way ANOVA was employed to compare differences between groups at baseline and post-intervention. Paired t-tests were used for within-group comparisons.

Results. Significant improvements were observed in group A&B. Although Group B demonstrated the highest increase in VO_2 max (18 %) and muscle strength (22 %), followed by Group A (13 % and 16 %, respectively), while Group C showed minimal gains (6 % VO_2 max, 8 % strength) with no adverse events occurred in any group.

Conclusions. Treadmill walking with BFRT especially at higher occlusion pressures is an effective, safe, and time-efficient intervention to enhance aerobic capacity and knee extensors strength in sedentary young adults. These findings support the integration of individualized BFRT protocols in fitness and rehabilitation settings to counteract inactivity-related deconditioning.

Keywords: blood flow restriction training, exercise test, exercise physiology, muscle physiology, sedentary behavior.

Introduction. Blood flow restriction (BFR) training has emerged as a valuable method for improving muscular strength and aerobic capacity using low external loads [1]. This technique involves the application of external pressure to the proximal portions of the limbs to partially restrict arterial inflow and fully restrict venous outflow, thereby creating a hypoxic environment that stimulates muscle adaptations comparable to those achieved with high-load resistance training [2,3]. Because of its ability to induce significant physiological benefits with minimal mechanical stress, BFR has gained increasing attention in sports performance, rehabilitation, and clinical populations [4].

However, the selection of an appropriate occlusion pressure remains a critical variable influencing both

training efficacy and participant comfort. The pressure applied directly affects metabolic stress, neuromuscular recruitment, cardiovascular responses, and overall safety [5]. Prior studies recommend using 40-80 % Limb Occlusion Pressure (LOP) for safe and effective BFR application, yet direct comparisons between lower (40 %) and moderate (60 %) pressures over short training periods remain limited [6]. While higher pressures may enhance metabolic accumulation and training stimuli, they may also increase discomfort, reduce adherence, and potentially elevate the risk of adverse effects [7]. Conversely, lower pressures may be more tolerable but might not elicit the same adaptive response [8].

Existing literature has predominantly focused on long-term protocols or single-session physiological responses, leaving a gap in understanding how different pressure intensities influence functional outcomes over shorter interventions [9,10]. Moreover, there is limited

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evidence examining how variations in LOP affect aerobic parameters alongside muscular strength – an area that holds particular relevance for individuals engaged in rehabilitation or athletic conditioning programs.

Therefore, this study aimed to evaluate the differential effects of 40 % and 60 % LOP BFR during a 4-week training intervention on muscle strength and aerobic fitness in young adults. An additional objective was to assess the balance between training effectiveness and tolerability across pressure conditions, thereby contributing valuable insights to optimize pressure selection for safe and efficient BFR training practice.

Materials and Methods

Participants

This study was conducted as a 4-week, aimed at comparing the effects of treadmill walking under different levels of occlusion pressure on aerobic capacity and knee extensor muscle strength among sedentary collegiate students. Ethical approval was obtained from the institutional review board, and all participants signed a written informed consent form before the commencement of the study. The study was conducted in accordance with ethical guidelines, and ethical approval was obtained from the School Ethics Committee (SEC/SAHS/PhD/24/17) before the commencement of the study. The study was registered with the Clinical Trials Registry of India (CTRI) under the registration number (CTRI/2024/11/076477). A priori power analysis (G*Power 3.1) indicated that 27 participants were needed to detect medium effect sizes ($f=0.25$), with $\alpha=0.05$ and power=0.80. To account for potential attrition and ensure adequate power, a total of 30 participants were enrolled in the study.

All participants were medically screened using the Physical Activity Readiness Questionnaire+ (PAR-Q+), and those who met the following inclusion criteria were included in the study. The inclusion criteria included students aged 18-25 years, a sedentary lifestyle (determined by the IPAQ), no participation in regular exercise training within the last 6 months, no cardiovascular, pulmonary, musculoskeletal, or neurological conditions, and willingness to participate and provide informed consent. The exclusion criteria were current smokers or individuals with a history of smoking in the past 6 months, use of medications affecting cardiovascular or muscular function, a history of lower extremity injury or surgery in the past 12 months, and any contraindications to blood flow restriction training (BFRT) screening questionnaire.

Randomization and Group Allocation

Participants were randomized into three groups ($n=10$ each): Low-pressure BFR (40 % LOP), High-pressure BFR (60 % LOP) and Control (no BFR). All groups underwent identical exercise protocols except for the level of occlusion pressure. The intervention lasted 4 weeks, resolving the inconsistency found in earlier drafts.

Assessment Tools and Outcome Measures

Pre- and post-intervention assessments were conducted to measure changes in aerobic capacity and quad-

riceps strength (Table 1). Data collection was carried out in the exercise therapy laboratory of the Department of Physiotherapy, Galgotias University, Greater Noida, Uttar Pradesh, India, between December 2024 and September 2025. Assessments were performed at baseline and at the end of the 4-week intervention by a blinded assessor to reduce bias (Table 2).

Table 1

Outcome measures

Tool/Measure	Outcome Assessed
VO ₂ max (Queen college step test)	Aerobic Capacity (ml/kg/min)
Active force2 Dynamometer (HHD)	Peak Quadriceps Strength (N)

Intervention Protocol

Occlusion pressure was determined using a H+ pneumatic cuff (FDA approved) placed at the proximal thigh on dominant leg and calibrated based on Doppler ultrasound (Edan SD3 Vascular Doppler with 8 MHz probe) estimation of limb occlusion pressure (LOP).




Both groups wore H+ cuffs on their dominant leg while walking on a treadmill using a modified version of the Balke-Ware technique. Walking was performed at a steady pace of 4.8 km/h, starting at a 0 % incline and increasing by a 2.5 % grade each stage, depending on the heart rate remaining within the acceptable range. Each session lasted 20 minutes and was conducted on three non-consecutive days per week, for a total of 12 sessions over four weeks. All participants were supervised by a certified blood flow restriction training provider under the direction of the International Health and Fitness Association, registered under registration numbers NOI/07/042 and IHFA2324608332, during each session to ensure safety and adherence. BFRT training was terminated if participants reported symptoms such as nausea, dizziness, increased heart rate, high perceived exertion on the Borg CR-10 RPE scale, or inability to continue. Participants were instructed to maintain their usual lifestyle throughout the study and to refrain from engaging in any additional exercise regimens. No dietary modifications were advised.

Statistical Analysis. Descriptive statistics were used to summarize demographic and baseline data (Table 3). Normality assumptions were confirmed using the Shapiro-Wilk test. A one-way ANOVA was employed to compare differences between groups at baseline and post-intervention. Paired t-tests were used for within-group comparisons. Statistical significance was set at $p<0.05$. Holm correction was applied for multiple comparisons.

Results. After 4 weeks of intervention involving treadmill walking with varying occlusion pressures, significant improvements were observed in both aerobic capacity and muscle strength among sedentary collegiate participants.

Table 2

Enrolment, intervention, and assessment schedule for the SPIRIT 2025 statement

	Enrolment	Allocation	Post allocation				
TIMEPOINT**	-1 week	baseline	week ₁	week ₂	week ₃	week ₄	Post assessment
ENROLMENT:							
Eligibility screen	X						
Informed consent	X						
Allocation		X					
INTERVENTIONS:							
Group A							
Group B							
Group C							
ASSESSMENTS:							
Aerobic capacity		X					X
Quadricep muscle strength		X					X

Baseline Characteristics**Aerobic Capacity (VO₂ Max)**

At baseline, all participants across groups exhibited low aerobic capacity, consistent with sedentary behavior (Table 4). Following the intervention, the high-pressure BFRT group demonstrated the most substantial improvement in VO₂ max, with an average increase of 18 %, followed by the low-pressure BFRT group (13 %). The control group showed a modest gain of 6 %. These improvements were attributed to enhanced cardiovascular strain and oxygen utilization induced by occlusion pressure during aerobic activity. Participants in the high-pressure BFRT group reported higher perceived exertion during early sessions, which diminished over time as cardiovascular conditioning improved [4].

Quadricep Muscle Strength

Quadriceps muscle strength, assessed using an Active Force2 dynamometer, showed significant improvements in both occlusion groups (Table 5). The high-pressure BFRT group recorded a 22 % average increase in quadriceps strength, while the low-pressure group improved by 16 %. The control group achieved only an 8 % gain. The augmented strength in the BFRT groups is consistent with other studies, which suggested that localized hypoxia promotes recruitment of fast-twitch fibers, metabolic stress, and muscular adaptation, despite the low external workload of walking, providing a rationale for the observed improvement [11].

Discussion. This study demonstrated that both 40 % and 60 % LOP BFR training significantly improved muscle strength and aerobic capacity in young adults over a 4-week intervention. Although the 60 % LOP group showed the greatest overall gains, the 40 % LOP group exhibited better comfort and adherence, highlighting an important balance between training efficacy and tolerability. These findings suggest that while higher pressures may be preferable when maximizing strength is the goal, moderate pressures such as 40 % LOP may offer a more practical and sustainable option for general populations and rehabilitation settings.

As expected, the 60 % LOP group showed greater overall effectiveness, particularly for strength, which aligns with evidence suggesting that higher occlusion pressures produce stronger physiological adaptations [12,13]. However, the 40 % LOP group demonstrated higher comfort, lower perceived exertion, and better adherence, consistent with previous reports that lower pressures are generally more tolerable [14,15].

This balance between efficacy and tolerability is critical. Although higher pressures yield stronger adaptations, they also increase the likelihood of discomfort, which may limit long-term compliance [16,17]. For practical application, moderate occlusion levels (40 % LOP) may offer a favorable risk – benefit ratio for general populations. Further research with larger and more diverse

Table 4

Effect of BFRT on aerobic capacity

Group	Baseline Mean ±SD	Post Mean ±SD	Mean Change (%)	95 % CI of Change	p-value (within group)
Control (n=10)	30.2±3.8	32.0±3.6	+6 %	0.8 to 3.1	0.041*
Low-Pressure BFRT (n=10)	29.8±4.1	33.7±3.9	+13 %	2.7 to 5.5	0.008*
High-Pressure BFRT (n=10)	30.5±3.7	36.0±3.8	+18 %	4.2 to 7.0	0.001*

Note: One-way ANOVA post-intervention: F(2,27)=6.21, p=0.005; High-pressure BFRT > Control (p=0.003), Low-pressure BFRT > Control (p=0.021).

Table 5
Effect of BFRT on quadricep strength

Group	Baseline Mean ±SD	Post Mean ±SD	Mean Change (%)	95 % CI of Change	p-value (within group)
Control (n=10)	410±45	443 ± 47	+8 %	18.0 to 48.3	0.036*
Low-Pressure BFRT (n=10)	415±49	482 ± 50	+16 %	46.5 to 78.2	0.004*
High-Pressure BFRT (n=10)	412±52	503 ± 55	+22 %	64.2 to 97.1	0.001*

Note: One-way ANOVA post-intervention: F(2,27)=7.12, p=0.003; High-pressure BFRT>Control (p=0.002), Low-pressure BFRT>Control (p=0.017).

samples is recommended to optimize BFR prescription across various contexts.

Future studies should explore the long-term effects of different BFR pressure intensities across diverse populations, including older adults, clinical groups, and athletes with varying training backgrounds. Investigations comparing combined BFR protocols, such as interval training or neuromuscular training, may provide deeper insights into optimizing performance and rehabilitation outcomes. Additionally, examining psychological responses, adherence patterns, and safety markers over extended periods would help refine evidence-based guidelines for BFR prescription.

Conclusions. Both 40 % and 60 % LOP BFR training effectively improve strength and aerobic fitness over 4 weeks. Lower pressure may be preferable for long-term adherence, whereas higher pressure produces superior short-term strength gains.

Conflict of Interest. The authors declare that there are no conflicts of interest related to the conduct, analysis, or publication of this study.

Use of Artificial Intelligence. No AI tool was involved in study design, data collection, statistical analysis, interpretation of results, or generation of scientific

Primary Data and Materials. The primary datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request. All study materials, protocols, and supplementary documents can also be provided as needed.

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Declarations Ethics. This study was conducted in accordance with the ethical guidelines, ethical approval was obtained from the School Ethics Committee SEC/SAHS/PhD/24/17 before the commencement of the study. Written informed consent was obtained from the all participants. The study was registered with the Clinical Trials Registry of India (CTRI) under the registration number (CTRI/2024/11/07647).

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Порівняльний аналіз ходьби на біговій доріжці під різним тиском оклюзії щодо аеробної витривалості та м'язової сили у сидячих студентів: рандомізоване контрольоване дослідження

Tanya Gujral¹, Dr. Kamran Ali² (Corresponding author)

Galgotias University, Greater Noida, India

Резюме

Мета. Дослідження оцінювало порівняльний ефект тренувань з обмеженням кровотоку (BFR) за низького (40 % LOP) та високого (60 % LOP) тиску на м'язову силу та аеробну здатність у здорових молодих дорослих протягом 6-тижневого інтервенційного періоду.

Матеріали та методи. У дослідженні взяли участь 30 осіб (n=30), які були випадковим чином розподілені на групу BFR за низького тиску, групу BFR за високого тиску та контрольну групу. Тривалість інтервенції становила 4 тижнів. М'язову силу оцінювали за допомогою тесту на максимальне одноразове навантаження (1RM) на жим ногами, а аеробну підготовленість – за VO₂max за модифікованим протоколом Брюса з визначеними критеріями завершення тесту. Попередній розрахунок потужності (a priori) показав, що мінімум 27 учасників забезпечують 80 % потужності для виявлення середніх ефектів. Статистичний аналіз включав ANOVA з повторними вимірюваннями з корекцією Холма для множинних порівнянь. Результати наведено як середнє ±SD з 95 % інтервалом.

Результати. Обидві групи BFR продемонстрували значне покращення 1RM жиму ногами та VO₂max порівняно з контрольною групою (p<0,05). Група з 60 % LOP показала більший приріст сили, тоді як група з 40 % LOP відзначалася кращою переносимістю та дотриманням програми. Контроль через 4 тижні після завершення інтервенції показав часткове збереження покращень.

Висновки. Обидва рівні тиску були ефективними, проте 40 % LOP може бути більш придатним для довготривалого дотримання програми через менший дискомфорт та кращу переносимість.

Ключові слова: обмеження кровотоку, тиск оклюзії, аеробна здатність, 1RM жим ногами, модифікований протокол Брюса, рандомізоване дослідження

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