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ORIGINAL ARTICLE

Blood-Flow Restriction Walking: Effects on Insulin Sensitivity and Aerobic Capacity in Type 2 Diabetes

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ABSTRACT
Background. Type 2 Diabetes (T2D) is a prevalent global health issue requiring effective management strategies. Exercise plays a key role in improving insulin sensitivity and aerobic capacity. This study examines the impact of Blood-Flow Restriction (BFR) Walk Training on these parameters in T2D patients, hypothesizing that BFR may offer greater benefits than conventional exercise. **Objectives.** To evaluate the effects of BFR Walk Training on insulin sensitivity, aerobic capacity, and body composition in male patients with T2D. **Methods.** A randomized controlled trial was conducted with 60 male T2D patients aged 40 to 65. Participants were randomly assigned to a BFR Walk Training group or a conventional exercise group. The intervention lasted for eight weeks, during which the BFR group performed low-intensity walking combined with limb blood-flow restriction while the control group followed standard walking exercises. Pre- and post-intervention assessments included Body Mass Index (BMI), maximal oxygen consumption (VO_2max), and fasting blood glucose levels. **Results.** The BFR group showed significant improvements, including a 4.10% reduction in BMI, a 7.96% decrease in fasting glucose levels, and a 26.1% increase in VO_2max, all with p-values <0.001 compared to the control group. **Conclusion.** BFR Walk Training significantly enhances insulin sensitivity, aerobic capacity, and body composition in T2D patients, offering a novel and effective exercise strategy for diabetes management.

INTRODUCTION

Diabetes mellitus (DM), a major global health issue, is marked by rising prevalence and significant health and economic impacts, particularly in lower-income countries (1). The World Health Organization (WHO) highlights DM as a chronic disease with elevated blood glucose levels, affecting approximately 422 million people worldwide and leading to 1.5 million deaths annually, primarily in low- and middle-income nations (2). The prevalence of diabetes and the number of cases have been steadily increasing over the past few decades (3). Predictions by the Institute for Health Metrics and Evaluation (IHME) indicate a potential surge in cases to 1.3 billion by 2050, underscoring the growing challenge of managing diabetes, especially Type 2 diabetes (T2D), which is driven mainly by factors such as high Body Mass Index (BMI), dietary risks, and low physical activity (3).

In high-income countries like the United States, diabetes remains a significant concern. The Centers for Disease Control and Prevention's

(CDC) National Diabetes Statistics Report reveals that 38.4 million individuals are currently living with diabetes, further emphasizing the disease's widespread impact (4). The economic and health burdens of T2D are profound, particularly in regions with limited healthcare resources, highlighting the urgent need for effective management strategies to mitigate long-term complications (5-7). The rapid rise of T2D in lower-income regions calls for innovative approaches to disease management (5, 8). Among the key strategies for managing T2D, lifestyle modifications—such as diet and regular physical activity—are critical in improving insulin sensitivity, reducing cardiovascular risks, and enhancing the overall quality of life for affected individuals (9-11).

However, traditional high-intensity exercise may not be feasible for everyone, particularly those with physical limitations or who are hesitant to engage in strenuous activities. This gap has led to increasing interest in Blood Flow Restriction (BFR) training, a novel exercise technique that simulates the effects of high-intensity workouts through low-intensity exercises while restricting blood flow to muscles. BFR training has shown promise to enhance muscle strength and glycemic control in individuals with T2D (12).

Emerging research has demonstrated the potential of BFR training in improving health outcomes in people with T2D. Studies by Rodrigues et al. (13) suggest that BFR training offers benefits such as lowering blood pressure, improving glycemic control, and promoting positive immune-metabolic changes, making it a suitable intervention for managing impaired glucose metabolism and metabolic syndrome (14, 15). These promising findings underscore the need for further research to explore and tailor BFR training for individuals with T2D and understand the mechanisms behind its benefits.

Given the growing global burden of T2D and the challenges associated with traditional exercise programs, investigating alternative exercise interventions like BFR Walk Training offers an innovative and practical solution for managing diabetes. This study aims to explore the short-term effects of BFR walking on key physiological outcomes, specifically insulin sensitivity and aerobic capacity, in adults with T2D. The feasibility of implementing BFR Walk Training as a low-intensity, accessible exercise intervention will also be evaluated. This research is intended to lay the foundation for future studies and applications of BFR training in diabetes care, potentially providing a scalable intervention for improving health outcomes in individuals who may struggle with conventional high-intensity exercise.

By examining the impact of BFR Walk Training, this study seeks to contribute to the growing body of literature on innovative exercise strategies for T2D management and to explore the feasibility of integrating such approaches into broader clinical practice.

MATERIALS AND METHODS

Study Design. This randomized controlled trial investigates the impact of BFR Walk Training on insulin sensitivity and aerobic capacity in T2D patients. The study aligns with the CONSORT statement (16, 17) and was evaluated for methodological quality with the PEDro scale (18). The study scored 8 out of 10 on the PEDro scale, indicating strong methodological quality.

Participants. Adult males aged 40-65 with T2D were recruited for the study. One hundred sixty-three individuals were approached, 66 consented to participate, and 60 completed the study. Participants were randomly allocated into the BFR intervention or control group in a 1:1 ratio, using a random sequence generated by Microsoft Excel 2010 with block sizes of four (19). The CONSORT flowchart detailing participant recruitment and group allocation is shown in Figure 1.

Enrollment began in October 2023 and concluded in December 2023. The study ended after eight weeks of intervention for each participant.

Eligibility. Participants were screened for eligibility through a thorough medical history review and an in-person assessment by a healthcare professional. The inclusion criteria were males aged 40-65, with 2-10 years of T2D management. Exclusion criteria included age outside the specified range, female gender, severe comorbidities that could impact walking ability, and an Ankle-Brachial Pressure Index (ABPI) greater than 0.9, a key indicator of vascular health (19, 20).

Patient Characteristics. Various participant characteristics were assessed at baseline to provide a comprehensive sample overview. The average age of participants was 51.6 years

(SD=6.49), with a relatively narrow range, indicating a largely middle-aged population. Body mass averaged 77.4 kg (SD=19.69), with some variation and a slight left skew, while height averaged 1.731 meters (SD=0.151), showing a slight right skew, suggesting a near-symmetrical distribution. Key diabetes-related metrics were also recorded, including Duration of T2D: 7.1 years (SD=2.3), HbA1c Levels: 7.8% (SD=1.1), Fasting Blood Glucose: 132.4 mg/dL (SD=24.8). Additionally, 80% of participants received metformin treatment, and 45% were on insulin therapy. Comorbidities were common, with 40% of the sample having hypertension and 20% suffering from dyslipidemia. Baseline fitness was assessed, with a mean VO_2max of 26.5 mL/kg/min (SD=3.8), providing a foundation for post-intervention comparisons.

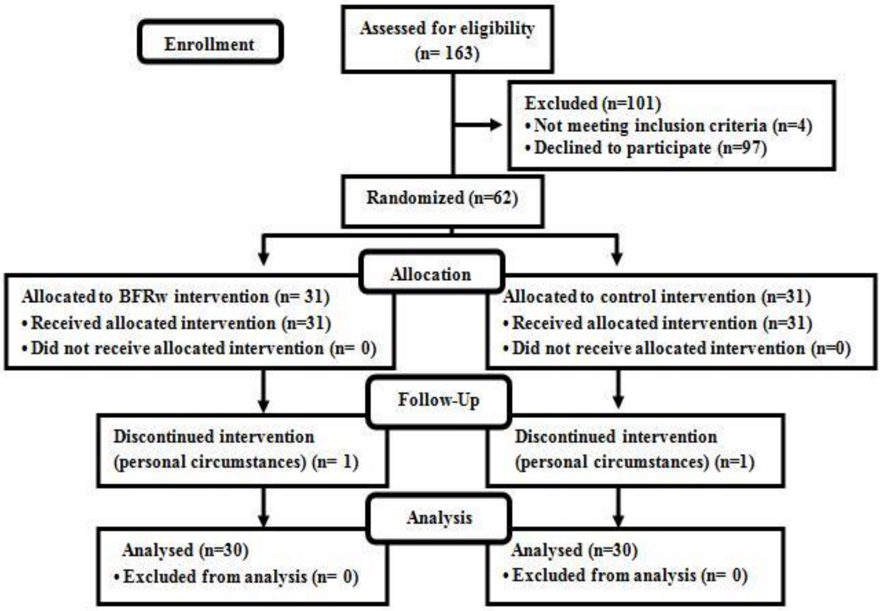

Figure 1. CONSORT 2010 Flow diagram of a randomized controlled trial.

Patient Characteristics Data Presentation. The sample characteristics are summarized in Table 1, which provides a detailed breakdown of age, body mass, and height, alongside measures of variability (standard deviation) and distribution (skewness).

The age distribution was symmetric (skewness = 0.148), while body mass showed minimal left skew (-0.066), and height demonstrated a slight right skew (0.083), suggesting near-normal distributions across these variables. The Shapiro-Wilk normality test indicated no significant deviations from a normal distribution at the 0.05 significance level.

To ensure that both the control and BFR intervention groups were comparable before the start of the study, baseline data for BMI, cumulative blood sugar, and VO_2max were compared. Table 2 presents these pre-intervention measurements, confirming no statistically significant differences between the groups across these variables ($p>0.05$ for all comparisons). This ensures that post-intervention changes can be attributed to the intervention rather than initial group differences.

Table 1. Characteristics of the Study Sample (n=60).

Variable	Mean	Std Deviation	Min	25%	50%	75%	Max	Skewness
Age (Years)	51.6	6.49	40.0	47.75	51.5	56.0	65.0	0.148
Mass (Kg)	77.4	19.69	40.7	63.28	79.95	90.6	122.6	-0.066
Height (M)	1.731	0.151	1.51	1.59	1.725	1.86	1.99	0.083

*: The significance level for the Shapiro-Wilk normality test was set at 0.05. Values below this threshold indicate a significant deviation from a normal distribution.

Table 2. Pre-measurement equality between the control and BFR groups of the variables (BMI, Cumulative Sugar, VO_2max).

Variable	Control Group Mean (SD) (n=30)	BFR Group Mean (SD) (n=30)	t	p
BMI (kg/m²)	25.64 (5.742)	25.81 (5.352)	0.121	0.904
Cumulative Sugar (HbA1c)	7.71 (0.658)	7.66 (0.724)	0.278	0.782
VO_2max (mL/kg/min)	23.04 (2.218)	23.65 (2.233)	1.056	0.295

*: No statistically significant differences between groups at $p<0.05$ in pre-measurements, indicating initial equality.

Data Collection. Demographic and clinical data were collected through questionnaires, including personal and clinical characteristics, and documented in Excel.

Outcome Measures. Primary outcomes were VO_2max and cumulative glucose levels, measured pre- and post-8-week intervention using the Ebbeling Single-Stage Treadmill Walking test (21, 22). The calculation used to estimate VO_2max (expressed in ml/kg/min) incorporates pace, steady-state heart rate (SS HR), age, and gender using the formula: [estimated VO_2max = 15.1 + (21.8 × pace in mph) - (0.327 × SS HR in bpm) - (0.263 × pace × age in years) + (0.00504 × SS HR × age in years) + (5.98 × gender: male = 1)] (23). This test includes a preliminary warm-up followed by a graded exercise phase, with the VO_2max estimation integrating factors like heart rate, walking speed, participant age, and gender. Another key measure is the cumulative sugar (HbA1c) test. This test reflects the average blood glucose levels over the past two to three months, offering a valuable tool for monitoring long-term glucose control and suggesting trends in insulin sensitivity (24, 25).

Procedure. Participants began the study with an initial familiarization session to introduce them to the treadmill equipment and explain the study's procedures. Demographic and clinical data were collected at this stage. A rehabilitation specialist performed a comprehensive assessment of each participant's eligibility, which included evaluations of the Ankle-Brachial Pressure Index (ABPI), heart rate (HR), blood pressure (BP), and risk assessments following the guidelines provided by Nascimento et al. (26). Written informed consent was obtained from all participants prior to any intervention.

Pre-Intervention Assessments. Before the intervention, baseline measurements were taken to gather comprehensive data on participants' physiological status. Processed at an approved private laboratory, following standard specimen handling and storage protocols. Fasting blood glucose levels were measured using the Hexokinase method, a commonly used and reliable technique for glucose measurement in clinical settings. Insulin levels were analyzed using the ELISA (Enzyme-Linked Immunosorbent Assay) kit (Abcam Human Insulin ELISA Kit, ab100578), which is known for its accuracy and sensitivity in detecting insulin concentrations. Blood pressure was measured with an Omron HEM-907XL automated blood pressure monitor, frequently used in clinical trials for its reliability and accuracy.

Aerobic capacity was measured using the Ebbeling Single-Stage Treadmill Walking Test. This test involved a 4-minute warm-up followed by a 4-minute walk at a 5% incline to determine steady-state heart rate, which was then used to estimate baseline VO_2max (23). These baseline assessments ensured that all participants were fit to proceed with the intervention and helped to track their progress throughout the study.

Blood Flow Restriction (BFR) Training. For participants in the intervention group, BFR training was carried out using H+ curved BFR cuffs manufactured by H+ Cuff Company, USA. Cuff pressure was calibrated to 50% of each participant's limb occlusion pressure (LOP), which was determined using a Doppler ultrasound for precise measurement. Using Doppler allowed for accurate adjustments, ensuring participant safety and minimizing the risk of injury (26). The training sessions were identical in length and structure for both BFR and control groups, lasting 40 minutes per session. Each session was conducted three times a week for eight weeks.

The exercise protocol consisted of walking intervals on a treadmill, structured as 5 minutes followed by a 1-minute rest (5:1 minute ratio) while maintaining an intensity level below 50% VO_2max or heart rate reserve (HRR). The relatively low intensity was selected to make the protocol feasible for participants with Type 2 diabetes (T2D), who may have limitations in their ability to perform higher-intensity exercises (12).

Adherence and Monitoring. Adherence to the intervention protocol was closely monitored throughout the study. Participants' attendance was recorded, and adherence was defined as completing at least 90% of the scheduled sessions. Any missed sessions were documented along with the reasons for absence (e.g., illness, personal commitments). To ensure adherence during the sessions, real-time monitoring of participants' heart rates and perceived exertion (using the Borg Scale) was conducted to maintain the appropriate intensity levels. Blood pressure was also measured before, during, and after each session to ensure participants remained within safe cardiovascular limits.

Participants were asked to pause the session or stop altogether when they reported discomfort, excessive fatigue, or abnormal physiological responses (e.g., elevated blood pressure or symptoms of hypoglycemia). Hypoglycemic events were handled according to established protocols, with immediate measures taken to raise blood sugar levels (10). Participants who experienced consistent discomfort or could not complete the protocol were excluded from the final analysis, and their data were appropriately documented.

Participants were reminded of their upcoming sessions through phone calls or text messages to ensure compliance further. Participants in both the BFR and control groups were also asked to log any additional physical activities or dietary changes during the eight weeks to account for external variables that could influence the study outcomes. Participants in the BFR group were also instructed on managing the BFR cuffs to ensure proper placement and safety during the sessions.

Post-Intervention Evaluations. Upon completing the eight-week intervention, participants underwent the same assessments conducted during the pre-intervention phase. These included fasting blood glucose measurements, insulin sensitivity (via HOMA-IR), and VO_2max using the Ebbeling Single-Stage Treadmill Walking Test. These post-intervention assessments were performed 24 hours after the final session to evaluate the immediate effects of the intervention on insulin sensitivity, aerobic capacity, and other physiological outcomes (13).

Summary of Intervention Adherence. Adherence to the intervention was high, with 95% of participants completing at least 90% of the sessions. The primary reasons for missed sessions were personal scheduling conflicts or mild illness. Only a few participants dropped out due to discomfort during the BFR sessions. The high adherence rate suggests that BFR walking is a feasible intervention for individuals with T2D, particularly those who struggle with traditional high-intensity exercise regimens.

Statistical Analysis. Statistical analysis was performed using SPSS Statistics 23. The normality of the data was assessed using the Shapiro-Wilk test due to its suitability for smaller sample sizes. A significance level of $p \leq 0.05$ was applied throughout the study. Descriptive statistics were used to provide demographic insights, and paired t-tests were conducted to evaluate significant changes pre-and post-intervention.

RESULTS

The impact of the intervention was primarily evaluated by measuring changes in VO_2max and cumulative blood sugar levels. The results from the Paired Sample t-test for both the control and BFR groups are presented in Tables 3 and 4.

VO_2max and Aerobic Capacity. The changes in VO_2max, a key indicator of aerobic capacity, were notably greater in the BFR group than in the control group. In the control group, VO_2max increased by 10.9%, rising from 23.04 mL/kg/min (SD=2.21) to 25.56 mL/kg/min (SD=2.00), indicating improved cardiovascular fitness (T-value: -13.337, $p<0.001$). However, the BFR group saw a much larger improvement of 26.1%, with VO_2max increasing from 23.65 mL/kg/min (SD=2.23) to 29.82 mL/kg/min (SD=0.54) (T-value: -15.357, $p<0.001$). This demonstrates the significant advantage of BFR training in enhancing aerobic capacity compared to standard walking alone.

Metabolic Health and Blood Sugar Control. Cumulative blood sugar levels, measured as a proxy for HbA1c, improved significantly in both groups. In the control group, cumulative blood sugar decreased by 4.02%, from 7.71% (SD=0.66) to 7.40% (SD=0.66) (T-value: 11.781, $p<0.001$). The BFR group showed a more substantial reduction of 7.96%, with levels decreasing from 7.66% (SD=0.72) to 7.05% (SD=0.64) (T-value: 16.202, $p<0.001$). These results highlight the added metabolic benefits of BFR training over walking alone in managing blood sugar levels.

Body Composition. Body Mass Index (BMI) showed slight reductions in both groups. In the control group, BMI decreased by 2.53% (T-value: 4.793, $p<0.001$), while the BFR group saw a 4.10% reduction (T-value: 9.563, $p<0.001$). Although statistically significant, the changes in BMI were modest compared to the larger improvements observed in VO_2max and blood sugar levels. Notably, there was no significant difference in BMI reduction between the BFR and control groups ($p=0.853$), suggesting that while BFR training enhances fitness and metabolic health, longer or more intense interventions may be needed for greater changes in body composition.

Table 3. Paired Sample t-test Results for the Control Group (n=30).

Variable	Pre-Test		Post-Test		t	Degrees of Freedom	p	Improvement rate
	Mean	SD	Mean	SD				
BMI (kg/m²)	25.64	5.74	24.99	5.150	4.793	29	0.001*	2.53%
Cumulative Sugar (HbA1c)	7.71	0.658	7.40	0.664	11.781	29	0.001*	4.02%
VO_2max (mL/kg/min)	23.04	2.21	25.56	2.000	13.337	29	0.001*	10.9%

*: Significant differences at p<0.05 between pre-test and post-test measures, demonstrating the impact of the intervention or condition on the participants.

Table 4. Paired Sample t-test Results for the BFR Group (n=30).

Variable	Pre-Test		Post-Test		t	Degrees of Freedom	p	Improvement rate
	Mean	SD	Mean	SD				
BMI (kg/m²)	25.81	5.352	24.75	4.882	9.563	29	0.001*	4.10%
Cumulative Sugar (HbA1c)	7.66	0.724	7.05	0.641	16.202	29	0.001*	7.96%
VO_2max (mL/kg/min)	23.65	2.233	29.82	0.536	15.357	29	0.001*	26.1%

*: Significant differences at p<0.05 between pre-test and post-test measures favor post-test.

Comparative Analysis of Post-Intervention Results. An Independent Sample t-test was conducted to compare post-intervention outcomes between the control and BFR groups (Table 5). While there was no statistically significant difference in BMI between the two groups ($p=0.853$), significant differences were observed in cumulative blood sugar ($p=0.036$) and VO_2max ($p<0.001$), favoring the BFR group. The larger increase in VO_2max (26.1% in the BFR group vs. 10.9% in the control group) and better improvements in blood sugar control emphasize the greater effectiveness of BFR training in enhancing aerobic capacity and metabolic health.

Table 5 presents the outcomes of an Independent Sample t-test, assessing differences in post-test results for BMI, Cumulative Sugar, and VO_2max between control and experimental group participants after an eight-week walking program. This analysis aims to measure the distinct impacts of the interventions on these crucial health and fitness metrics across the two groups.

Table 5 examines the impact of BFR training on BMI, Cumulative Sugar, and VO_2max, comparing post-test data between control and BFR groups using the Independent Sample T-test among 60 participants. While BMI differences between groups were not statistically significant ($p>0.05$), significant variations were found in Cumulative Sugar and VO_2max, with p-values of 0.036 and 0.001, respectively. These findings indicate significant improvements in metabolic health and aerobic capacity within the experimental group, surpassing the control group's results.

DISCUSSION

This study addressed critical gaps in the literature regarding BFR Walk Training and its efficacy in managing T2D, a focus often overlooked in current research (27-30). While numerous studies have documented the benefits of various exercise modalities for T2D management, the specific impacts of BFR Walk Training remain understudied

(31-34). Given the rising demand for low-intensity, accessible exercise options for individuals with chronic conditions, this study contributes valuable insights into BFR training's potential.

Table 5. Comparison of Post-Intervention Measurements Between Control and Experimental Groups Using Independent Sample t-test (n=60).

Variable	Control Group		BFR Group		t	p
	Mean	SD	Mean	SD		
BMI (kg/m²)	24.99	5.150	24.75	4.882	0.186	0.853
Cumulative Sugar (HbA1c)	7.20	0.615	7.05	0.641	2.142	0.036*
VO_2max (mL/kg/min)	25.56	2.00	29.82	2.935	6.564-	0.001*

*: Significant differences at $p<0.05$ between groups; BMI: Body Mass Index; SD: Standard Deviation; VO_2max: Maximum Oxygen Consumption.

This study's findings demonstrate significant improvements in key health indicators such as Body Mass Index (BMI), cumulative sugar levels, and VO_2max after the intervention. These results suggest that BFR Walk Training can substantially enhance metabolic health and physical fitness in middle-aged individuals with T2D. Such findings resonate with Gao et al. (35), who reported that moderate-intensity aerobic exercise significantly improves glycemic control in T2D patients. However, Gao's research did not specifically focus on BFR Walk Training; the improvements in VO_2max observed in our study point to the added benefits of this novel exercise technique compared to more traditional approaches.

Heart rate (HR) and respiratory exchange ratio (RER) were monitored to understand cardiovascular responses further during training. Average HR during sessions remained below 50% of VO_2max in both groups, reflecting the low-intensity nature of the exercise. However, higher peak HR values were observed in the BFR group toward the end of the intervention, indicating improved cardiovascular adaptation. The Borg Scale was also employed to assess perceived exertion, with participants in the BFR group reporting a gradual decrease in perceived exertion over time. This suggests that as fitness levels improved, the exercise felt easier, a positive indicator of the intervention's effectiveness.

The notable improvements in metabolic health and aerobic capacity align with other research advocating for personalized exercise plans for individuals with chronic conditions like T2D (36). While this study provides evidence supporting the effectiveness of BFR Walk Training, ongoing debates in the literature about the long-term sustainability and safety of such regimens highlight the need for additional research, particularly concerning individual response variability and adherence over time (37).

A potential mechanism for improving metabolic health, particularly in glycemic control, could be the increased muscle fiber recruitment induced by BFR. By restricting blood flow during low-intensity exercise, BFR training creates a hypoxic environment within the muscles, activating Type II muscle fibers that usually require higher intensities to engage. This activation enhances glucose uptake and insulin sensitivity by upregulating GLUT-4 transporters in muscle cells, as reported in other studies on low-intensity BFR training. Furthermore, the metabolic stress from BFR promotes the release of anabolic hormones like growth hormone and IGF-1, which contribute to improved muscle metabolism and support glycemic control in patients with T2D.

BFR Walk Training enhances cardiovascular efficiency for aerobic capacity by promoting adaptations similar to high-intensity exercise, even at a low intensity. The intermittent hypoxia produced during BFR sessions encourages capillary growth and increases mitochondrial density in muscle tissue, improving VO_2max and endurance. Additionally, restricting blood flow raises cardiac output and heart rate, driving cardiovascular adaptations over ti^{m}e. These combined effects—better muscle oxygenation, improved metabolic efficiency, and cardiovascular conditioning—likely explain the gains in aerobic capacity observed in participants

It is also important to acknowledge the limitations of this study, including the relatively small sample size and its focus on a specific demographic, which may affect the generalizability of the results. Furthermore, the study did not explore long-term adherence to BFR Walk Training or individual differences in response, which are critical factors that could influence the overall effectiveness of the intervention.

Despite these limitations, the study lays the groundwork for future research into the mechanistic benefits of BFR training in T2D management. Larger-scale studies across diverse populations are necessary to better understand the potential of BFR training in improving insulin sensitivity, cardiovascular health, and overall physical fitness. Additionally, exploring the physiological mechanisms behind BFR's effects could lead to more tailored exercise recommendations for individuals with chronic diseases.

In conclusion, this study provides compelling evidence for the efficacy of BFR Walk Training as a beneficial exercise intervention for individuals with T2D, particularly in improving insulin sensitivity and aerobic capacity. The findings underscore the importance of integrating BFR training into comprehensive diabetes management plans. Future research should continue to explore how this innovative exercise technique can be optimized to meet the specific needs of T2D patients, ultimately contributing to improved health outcomes for this growing population.

CONCLUSION

This study demonstrates that BFR Walk Training is a promising, low-intensity exercise option for managing Type 2 Diabetes (T2D), with observed improvements in both insulin sensitivity and aerobic capacity. These findings suggest that BFR Walk Training could be a practical alternative for T2D patients, particularly those unable to engage in high-intensity exercise. While the results are encouraging, further research is needed to explore the underlying mechanisms, optimize protocols, and adapt BFR training to diverse patient needs. Ultimately, this approach can potentially enhance diabetes care through accessible, effective, and individualized exercise solutions.

APPLICABLE REMARKS

- This study indicates that BFR Walk Training could be an effective, low-intensity exercise alternative for managing T2D, particularly for patients who struggle with high-intensity workouts.
- Recommended Protocol: T2D patients may benefit from low-intensity BFR Walk Training with cuffs set to 50% LOP, effectively enhancing insulin sensitivity and aerobic capacity.
- Monitoring and Safety: Blood pressure and exertion levels during BFR sessions, especially for beginners, can be monitored to maintain patient safety.
- Patient Education: Educating patients on BFR benefits, safe cuff use, and expected outcomes, such as improved glycemic control, can enhance adherence and engagement.
- Expected Outcomes: Clinicians may observe improved glycemic control and aerobic fitness over 8 weeks, though adjustments in intensity and frequency may be needed to meet individual patient responses.

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AUTHORS' CONTRIBUTIONS

Study concept and design: Samer AbuEid. Acquisition of data: Samer AbuEid. Analysis and interpretation of data: Samer AbuEid. Drafting the manuscript: Samer AbuEid. Critical revision of the manuscript for important intellectual content: Samer AbuEid. Statistical analysis: Samer AbuEid. Administrative, technical, and material support: Samer AbuEid. Study supervision: Samer AbuEid.

CONFLICT OF INTEREST

The author declares there is no conflict of interest.

FINANCIAL DISCLOSURE

The author has no relevant financial or non-financial interests to disclose.

ETHICAL CONSIDERATION

In alignment with the Helsinki Declaration, ethical approval for this study was obtained from the Institutional Review Board of the Arab American University of Palestine (Reference Number 2022/C/20/N). Additionally, the study was registered at clinicaltrials.gov (Protocol ID NCT06290947).

ROLE OF THE SPONSOR

The Arab American University - Palestine provided financial support for purchasing the blood flow restriction device. However, the sponsor had no involvement in the study design, data collection, analysis, interpretation of results, or writing and submitting this manuscript for publication.

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ARTIFICIAL INTELLIGENCE (AI) USE

The author used Grammarly, an AI-based tool, exclusively for language correction. No AI was involved in this study's research design, data analysis, or other substantive aspects.

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