The Influence of Unilateral Blood Flow Restriction Walk Training on Gait Parameters

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ABSTRACT

The purpose of this study was to investigate the influence of unilateral blood flow restriction walk training on gait spatiotemporal parameters. Forty-five healthy subjects (males, age: 21.91 ± 1.9 year, mass: 73.3 ± 3.71 kg, height; 1.72± 0.06 m) participated in this study. The Spatiotemporal gait parameters taken are: cadences, step length, step width, preferred walking speed (PWS), walk-run preferred transition speed (PTS), and walking speed reserve values (WSRv). The measures gathered using kinetisense360ai motion analysis system software. The study subjects distributed to three groups (condition A: with BFR and low intensity walking trails, condition B: without BFR and high intensity walking trails, and no condition: without BFR and low intensity walking trails) based on the study variables statistic homogeneity, each group attend two sessions every day for three weeks (total thirty-six sessions). The finding of this study showed that there was an increase of most of the gait parameter of the BFR-W training group (condition A) and the high intensity group (condition B), compared to the non-condition group with favor to condition A (p<0.05). Also, it showed that the combination of BFR-W training with low-intensity can induce similar gains of changes effecting gait parameters as the high intensity training.

KEYWORDS: blood flow restriction, gait parameters, low intensity training

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الملخص

هدفت هذه الدراسة إلى التحقق من تأثير حبس الدم لأحد اطراف الجزء السفلي للجسم خلال تدريبات المشي على المتغيرات المكانية والزمانية لها.خمسة واربعون شخصا اصحاء (رجال، عمر: ٢١.٩١ ± ١.٩ سنة، الكتلة: ٧٣.٣ ± ٣٠٧١ كغم،الطول: ١.٧٢ ± ٠.٠٦م) إشتركم في هذه الدراسة.تم أخذ المتغيرات :الإقاع، طول الخطوة، عرض الخطوة، سرعة المشي المفضلة، السرعة الإنتقالية من المشي إلى الجري ،و القيمة الإحتياطية لسرعة المشي. إستخدم نظام البرمجة للمجسات الكينماتكية ai٣٦٠ للتحليل الحركي.وزعت العينة على ثلاث مجموعات (المجموعة أ: حبس الدم مع شدة منخفضة للمشي، المجموعة ب:دون حبس الدم مع شدة عالية للمشي ، المجموعة ج: دون حبس الدم وشدة منخفضة للمشي). تم إجراء التكافؤ الاحصائي للمجموعات .قامت المجموعات بأداء جلستين للمشي يوميا لمدة ثلاثة أسابيع (٣٦ جلسة).أظهرت نتائج الدراسة تحسن بالأداء لمعظم متغيرات الدراسة للمجموعة (أ) والمجموعة (ب) مقارنة مع المجموعة (ج) ولصالح المجموعة (أ)($p<0.05$).كما أن النتائج قد أظهرت أن استخدام طريقة حبس الدم بتدريبات المشي ذو شدة منخفضة لها نتائج مشابهة في التحسن على متغيرات الدراسة كما فس تدريبات المشي ذو الشدة العالية.

الكلمات الرئيسية: حبس الدم، متغيرات المشي الكيناماتيكية، تدريبات منخفضة الشدة.

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Introduction

Blood Flow Restriction Training (BFRT) is a training modality that involves the partial restriction of blood flow at the proximal portion of the upper or lower limb (Shinohara et al., 1998; Loenneke et al., 2012). However, Blood Flow Restriction Walk (BFRw) training is a training pattern where participants walk instead of performing resistance exercises. Beekley et al.,2005; Abe et al., 2006, 2009 stated that three weeks of daily BFRW training increases muscle hypertrophy, strength, and endurance stability and balance. In addition, it can be an effective training modality across several musculoskeletal patient groups who have restrictions to use resistance training, such as elderly patients at risk of sarcopenia (Hughes et al., 2017). In the clinical environment, gait spatiotemporal parameters are considered to be a good indicator of human motion ability; to identify pathology and assess recovery for people with the asymmetric gait dysfunction of various origins such as cerebral palsy, stroke, hip or knee arthritis and surgery or leg length discrepancy (Telfer et al., 2017; Herssens et al., 2018). Thus, the influences of biomechanical variables such as joint kinematics, ground reaction forces, joint moments, power, and muscle activity are essential considerations in physiotherapy protocols and implementations (Tirosh et al., 2013; Murley et al., 2014; Lee HJ et al., 2017). Gait speed is emerging as the "sixth vital sign" in healthcare settings and is considered a useful measure to evaluate current and future health status (Fritz & Lusardi, 2009).

As gait spatiotemporal parameters correlate with many functional mobility skills and activities of daily living thus, working toward improvements in specific gait parameters is a critical goal. Therefore, understanding the effect of BFRW training on gait parameters is essential during different velocities for research. A variety of methods and interventions has been demonstrated in research for improving the gait parameters due to conditioning of strength, aerobic training, and exercise routine with diverse therapeutic activities. Although a few of studies examined gait biomechanics, to our knowledge, no published research has taken the mechanical effects of BFRW training and its impact on spatiotemporal parameters such as walk to run preferred transition and preferred walking speed. This study aims to investigate the influence of unilateral BFRW training on gait spatiotemporal parameters and the walk to run transition speed and preferred walking speed. We hypothesized that the low intensity Blood Flow Restriction training is more effective than high intensity training. To our knowledge, this study is the first in our region to examine the influence of unilateral BFRW training on gait spatiotemporal parameters in healthy individuals.

Method

Participants were fully informed about the experimental protocol and the possible discomfort and risk involved in all sessions and testing procedures. Thus, the subject singes a written informed consent before participation.

Forty-five healthy Jordanian subjects: (males, age: 21.91 ± 1.9 years, mass: 73.3 ± 3.71 kg, height; 1.72± 0.06 m), free of musculoskeletal injury and previous joint surgeries, or any disease that might affect gait performance, physically active adults who exercised or engaged with physical activity average 40 minutes five days a week. Ethical approval conforming to the Declaration of Helsinki was obtained from the Human

Research Ethics Committees of the Hashemite University that has approved the study (IRB No. 13.)

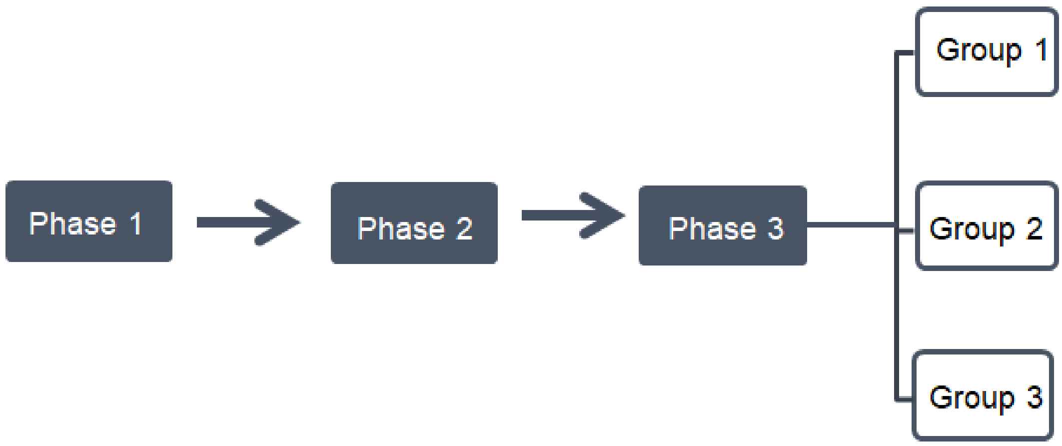
The spatiotemporal gait parameters taken in this study were: cadences, step length (SL), step width (SW), Stride length, preferred walking speed (PWS), walk-run preferred transition speed (PTS), walking speed reserve values (WSRv), and velocity. The measures were gathered using kinetisense360ai motion analysis system software.

To perform this study, the tools and software used are Treadmill, Intel-Realsense Depth camera D415, kinetisense360ai software (Maculay AJ., 2017, Doan Jon, 2014), Doppler ultrasound, and blood flow restriction cuff: H + cuff.

Experiment Protocol Design and Procedures:

The experiment was composed of three phases. At every session, the subject should practice several barefoot walk trials on a treadmill at self-selected walking speed to warm up and familiarization.

Figure 1. Procedure Phases design



Phase one

The goal of phase one is to find the preferred walking speed (PWS) of the subject.

Finding PWS Procedure

The subject was instructed to walk on a treadmill for 15 minutes, choosing a self-selected walking speed. A subject's capture begins three minutes after their apparent self-limited walking speed at steady state.

Phase two

The aim of phase two is to find the walk to run preferred transition speed (PTS) and walking speed reserve values (WSRv) of the subject.

Finding PTS Procedure

The subject performed a walking trial using a steady protocol (a steady increase of treadmill speed +0.25 m/s every 30s) to find PTS.

Finding WSRv Procedure:

The WSRv was founded by calculating the ratio between subject PWS and PTS speeds.

The Intel-Realsense Depth D415 camera used to capture the subject during the walking trails, while the kinetisense360ai software used to find PTS.

Phase three

In this phase, the subjects were divided statistically into three groups (condition-A, with non-dominated lower limb BFR; Condition-B, 80% intensity of PTS without BFR; and Non-condition, PWS without BFR)

Group (Condition-A)

Each subject in condition-A attends two treadmill walking sessions every day for three weeks (total thirty-six sessions). All sessions protocol restricts the subject to complete five intervals of treadmill walking (intensity 40% of PTS, intervals tempo 2:1 minutes) with non-dominated lower limb BFR.

Every session ends with an active recovery of 10 minutes for cooling down. Warming-up and active recovery treadmill walking performed without the BFR.

BFR Method and Protocol

The restriction cuff was placed around the non-dominant thigh proximally. After positioning the BFR cuff, the Doppler ultrasound was then implemented to determine the Limb Occlusion Pressure (LOP) by putting a small amount of ultrasound gel over the tibia venous. Next, holding the Doppler firmly to the skin, utilizing the gel as a conductor and listen to the sound of a pulse. Once hearing the pulse via the Doppler speaker, begin to increase the cuff pressure until the pulse no longer can be heard. At that point, the researcher recorded this number as it is the LOP. The amount of cuff pressure while performing the BFR walking is 80% of the LOP (in mmHg). During the experiment, participants practiced walking on the treadmill and feedback was given when required.

Group (Condition-B)

Each subject attends two sessions every day for three weeks (total thirty-six sessions) with 80% intensity of PTS, intervals tempo 2:1 minutes) without BFR. Every session ends with an active recovery of 10 minutes for cooling down.

Condition-B Session Protocol

The subject was restricted to do five treadmill walking intervals with intensity 80% of PTS without BFR, and intervals tempo 2:1 minutes.

Group (Non-condition)

Each subject (Non-condition) attends two sessions every day for three weeks (a total of thirty-six sessions) of treadmill walking. The session protocol restricts the subject to completed fifteen minutes of self-selected treadmill walking speed.

Data Collection

The data collected for all groups are the gait spatiotemporal parameters pre at session one, and post at session thirty-six.

Results

To examine the homogeneity of the participants' spatiotemporal gait parameters, the researcher divides the sample members statistically into three groups. Table (1) explores descriptive statistics for the study variables coefficient of variation (C.V), which expresses approximate results homogeneous among the individuals in each group spatiotemporal gait parameters. Concerning the skewness indicator, it was apparent that all the values were in the normal range.

Table 1. Descriptive Statistics for the Study Sample Spatiotemporal Gait Parameters

Variables	Condition A				Condition B				No condition			
	Mean	SD	C.V	Skewness	mean	SD	C.V	skewness	Mean	SD	C.V	skewness
Step length (m)	0.691	0.018	2.60	-1.167	0.680	0.029	4.26	0.040	0.688	0.03	4.36	0.258
Step width (m)	0.130	0.001	0.77	-0.749	0.129	0.001	0.78	0.112	0.130	0.001	0.77	0.157
Stride length (m)	1.469	0.004	0.27	-0.113	1.470	0.003	0.20	0.109	1.471	0.004	0.27	-1.173
Cadence	111.39	1.765	1.58	-0.344	110.81	1.63	1.47	0.611	111.1	1.467	1.32	-0.165

PWS (m/s)	1.331	0.066	4.96	-0.124	1.329	0.048	3.61	-0.251	1.328	0.053	3.99	-0.037
PTS (m/s)	2.085	0.139	6.67	0.630	2.068	0.115	5.56	0.634	2.075	0.101	4.87	0.788
WSRv (m/s)	1.570	0.121	7.71	0.552	1.556	0.08	5.14	1.190	1.564	0.092	5.88	-0.252

To compare pre and post-tests for the three groups, Paired t-test was used. Tables (2), (3), and (4), respectively.

Table 2. T-Test Results Between the Pre and Post Tests for Condition (A) Group.

Variable	Pre Test		Post Test		T	Prob
	M	SD	M	SD		
Step length (m)	0.691	0.018	0.703	0.018	2.965	.010
Step width (m)	0.130	0.001	0.128	0.001	5.773	.000
Stride length (m)	1.469	0.004	1.506	0.024	5.917	.000
Cadence	111.390	1.765	112.680	1.510	8.213	.000
PWS (m/s)	1.331	0.066	1.378	0.069	10.468	.000
PTS (m/s)	2.085	0.139	2.346	0.139	8.579	.000
WSRv (m/s)	1.570	0.121	1.706	0.131	6.054	.000

The Condition (A) group probabilities values suggest that the pre and post-tests differ significantly, such that the differences were in favour of the post-test relying on the means values.

Table 3. T-Test Results between the Pre and Post-Test for (Condition B) Group

Variable	Pre Test		Post Test		T	Prob
	M	SD	M	SD		
Step length (m)	0.680	0.029	0.679	0.031	0.28	0.784
Step width (m)	0.129	0.001	0.129	0.001	0.695	0.499
Stride length (m)	1.470	0.003	1.500	0.026	4.785	0.000
Cadence	110.813	1.630	111.400	1.572	6.046	0.000
PWS (m/s)	1.329	0.048	1.364	0.041	6.394	0.000
PTS (m/s)	2.068	0.115	2.231	0.116	5.837	0.000
WSRv (m/s)	1.556	0.080	1.637	0.096	3.854	0.002

The (Condition B) group probability values listed that the SL and SW showed no statistical means differences. In contrast, the other tests: stride length, Cadence, PWS, PTS, and WSRv showed significant means differences, such that the differences were in favour of the post-test relying on the means values.

Table 4.T-Test Results Between the Pre and Posttest for (NO Condition) Group

Variable	Pre Test		Post Test		T	Prob
	M	SD	M	SD		
Step length (m)	0.688	0.030	0.686	0.028	1.000	.334
Step width (m)	0.130	0.001	0.130	0.001	1.000	.334
Stride length (m)	1.471	0.004	1.477	0.008	1.919	.076
Cadence	111.080	1.467	111.260	1.381	1.114	.284
PWS (m/s)	1.328	0.053	1.331	0.056	.619	.546
PTS (m/s)	2.075	0.101	2.069	0.089	.809	.432
WSRv (m/s)	1.564	0.092	1.557	0.091	.846	.412

The (NO Condition) group probabilities values suggest that the pre-test and post-test did not differ significantly.

To investigate the equivalence among the three groups in the pre and post-tests, One-way ANOVA was used. A comparison results for the pre and post-tests means differences among the three groups represented in tables (5), and (6) respectively.

Table 5. Means and Standard Deviations for the Study Variables among the Three Groups in the Pre-Test.

Variables	Condition	n	Mean	SD	F	Prob
Step length (m)	A	15	0.691	0.018	0.732	0.487
	B	15	0.680	0.029		
	NO condition	15	0.688	0.030		
Step width (m)	A	15	0.130	0.001	0.917	0.408
	B	15	0.129	0.001		
	NO condition	15	0.130	0.001		

Stride length (m)	A	15	1.469	0.004	1.474	0.241
	B	15	1.470	0.003		
	NO condition	15	1.471	0.004		
Cadence	A	15	111.390	1.765	0.473	0.627
	B	15	110.813	1.630		
	NO condition	15	111.080	1.467		
PWS (m/s)	A	15	1.331	0.066	0.008	0.992
	B	15	1.329	0.048		
	NO condition	15	1.328	0.053		
PTS (m/s)	A	15	2.085	0.139	0.081	0.922
	B	15	2.068	0.115		
	NO condition	15	2.075	0.101		
WSRv (m/s)	A	15	1.570	0.121	0.073	0.930
	B	15	1.556	0.080		
	NO condition	15	1.564	0.092		

The values of the probability indicated no significant means differences among the three groups, concluding that they are close in their pre means.

Table 6. Means and Standard Deviations for the Study Variables According to the Conditions of the Three Groups in the Post-test.

Variables	Condition	N	Mean	SD	F	Prob
Step length (m)	A	15	0.703	0.018	3.551	0.038
	B	15	0.679	0.031		
	NO condition	15	0.686	0.028		
Step width (m)	A	15	0.128	0.001	8.107	0.001
	B	15	0.129	0.001		
	NO condition	15	0.130	0.001		
Stride length (m)	A	15	1.506	0.024	7.041	0.001
	B	15	1.500	0.026		
	NO condition	15	1.477	0.008		
Cadence	A	15	112.680	1.510	4.139	0.023
	B	15	111.400	1.572		
	NO condition	15	111.260	1.381		
PWS (m/s)	A	15	1.378	0.069	2.774	0.074
	B	15	1.364	0.041		
	NO condition	15	1.331	0.056		

PTS (m/s)	A	15	2.346	0.139	21.415	0.000
	B	15	2.231	0.116		
	NO condition	15	2.069	0.089		
WSRv (m/s)	A	15	1.706	0.131	7.231	0.002
	B	15	1.637	0.096		
	NO condition	15	1.557	0.091		

The probability values reflect the means differences among the three groups. Only PWS had no significant means differences among the three conditions in their post-test means,

In order to specify which two groups differ significantly over the study variables, the Least Significant Difference LSD was performed. The results are presented in table (7) below.

Table 7. LSD Test to Specify the Significant Groups Mean Differences

Variables	Mean	Condition	B	No Condition
Step length (m)	0.703	A	0.013*	0.075
	0.679	B		0.445
	0.686	NO condition		
Step width (m)	0.128	A	0.007*	0.000*
	0.129	B		0.294
	0.130	NO condition		
Stride length (m)	1.506	A	0.447	0.000*
	1.500	B		0.004*
	1.477	NO condition		
Cadence	112.680	A	0.023*	0.012*
	111.400	B		0.798
	111.260	NO condition		
PTS (m/s)	2.346	A	0.010*	0.000*
	2.231	B		0.000*
	2.069	NO condition		
WSRv (m/s)	1.706	A	0.0.84	0.000*
	1.637	B		0.049*

	1.557	NO condition		

* Denotes for significant means difference at 0.05 level

Discussion and Implications

BFR are applied during both voluntary resistance exercise and aerobic exercise. Recent research has examined the combination of BFRs with non-traditional exercise methods, such as whole-body vibration techniques and neuromuscular electrical stimulation. In this study we used the BFR technique to the PWS for the three groups underwent the experiment. The results of this study revealed differences between the three groups, low-intensity BFRw (group A), high-intensity walk training without BFR (group B), and the no-condition group in step length, stride length, and cadence such that the difference was in favor of both condition A and condition B compared to the no-condition group. The researchers attributed these differences to the effect of the high-intensity training program in group B and the mechanisms behind BFR training and its effect on muscle growth in group A. Also, the differences were detected between condition A and both conditions B and No condition for the step width variable, and this difference was in favor of conditions A as it reported less step width (mean 0.128 m) compared to condition B (mean 0.129 m) and the no condition (mean 0.130 m) with a probability of the mean difference of 0.007 and 0.00 respectively. From a biomechanical point of view, decreasing step width and increasing step length limits the lateral distance of the center of mass, which can be considered a sign of more control and stability of gait pattern (Chamberlin et al., 2005). Therefore, participants in condition A might felt that they have greater control and stability, indicating that BFRw training promotes the perception of stability and hence a more stable gait pattern is adopted. On the other hand, the results revealed significant differences in most of the gait spatiotemporal parameters between group A and group B, the difference was in favor of condition A as it is reported a longer step length (mean of 0.703 m) compared with the group B (mean 0.679 m) with a probability of the mean difference of 0.013, and longer stride length mean 1.506 m and 1.5 m respectively. It is also reported greater cadence (mean 112.680) with a probability of the mean difference of 0.023 compared to the group B (mean 111.40). Due to the mechanisms behind BFR training and its effect on muscle growth, this result is with the agreement of recent research, which showed that the combination of blood flow-restricted BFR training with low-intensity exercise can induce similar gains in muscular strength and hypertrophic adaptations as the high-intensity training load (Paul S, and Darryn S. 2019; Faras T. et al. 2019). Furthermore, the difference was in favor of condition A as it reported a higher PTS (mean 2.346 m/s) compared to the condition B (mean 2.231 m/s) with the mean difference 2.069 m/s with a probability of the mean difference 0.00 and 0.00 respectively. These measures are synonymous with increased step length and cadence.

Several studies have confirmed that preferred walking speed is a reliable, valid, sensitive and specific measure, and is associated with functional ability and confidence in balance, also been linked to clinically meaningful changes in quality of life and walking behavior. (Schmid, et al, Hughes et al., 2017).

Moreover, Fritz S, Lusardi M., 2009 considered PWS an essential 'vital sign" in the medical field because it is easy to measure, clinically interpretable, modifiable, and beneficial to older adults. In this study, there is no significance for PWS, even though there is a deferent in means with favor to condition A, this result can be interesting for further research; the study protocol applied for three weeks may not be sufficient to adopt a new pattern. In addition, due to the increased PTS for conditions A and B with favor to condition A, thus the WSRv differences between the three groups in favor of condition A as it reported greater means (1.706 m/s) and condition B (1.637 m/s) compared to no condition (mean 1.477 m/s) with a probability of mean difference 0.00 and 0.004 respectively. This result supports our hypothesis that low-intensity BFRw training is more effective than high-intensity walk training .In practical terms, and despite the fact that our protocol applied for three weeks may not be sufficient, given the results we obtained , we can conclude that it seems reasonable to apply low-intensity BFRw training session to enhance the perception of stability and balance as well as might induced a preserved muscle size in older adults. This imply a new hypothesis to be tested of low-intensity BFRw training can increase hypertrophy with slow twitch muscle fiber recruitment. Schoenfeld, et al (2015) indicated that both high load and low load training to failure can elicit significant increases in muscle hypertrophy among well-trained young men. However, using the BFRw may enhance the benefits with more safe procedure. In addition, gait alters its patterns using various kinematics combinations and compensate for the preferred speed much better than control speed.

The results explore the importance of studying the effect of BFRw training on the PWS variable and its consideration as a nearly ideal measure in predicting future health status and functional decline.

Conclusion

The present study encourages BFRw instead of high-intensity walk training as most of the study variables' gait parameters increased after the BFR-intervention compared to the high-intensity training. The study findings confirm that the low-load BFRw training is more effective and safter than high-intensity walk training; therefore, BFRw training is a potential clinical rehabilitation tool. More research is needed to determine whether interventions of BFRw training can improve PWS. Thus, studying the effect of BFRw training in a longer period is highly recommended.

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