International Journal of Computer Information Systems and Industrial Management Applications
ISSN 2150-7988 Volume 18 (2026) pp. 1-8

https://doi.org/10.70917/ijcisim-2026-3930
Article

Effects of Low-Load Blood Flow Restriction Resistance Training on Lower-Limb Strength in University Students

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Abstract: This study examined the effects of low-load resistance training combined with blood flow restriction on lower-limb strength in university Latin dance students. A total of 45 participants were randomly assigned to three groups: a blood flow restriction resistance training group (BFR-RT), a traditional resistance training group (TRT), and a dance training control group. The intervention lasted eight weeks. Lower-limb strength was assessed using two performance indicators, namely hip flexor peak torque and ankle rebound endurance, before and after the intervention. The results showed that both resistance training groups improved lower-limb strength after the training period. In particular, the BFR-RT group showed marked increases in hip flexor peak torque and ankle rebound endurance. The TRT group also demonstrated clear improvements, whereas only small changes were observed in the control group. Importantly, the magnitude of improvement in the BFR-RT group was comparable to that of the TRT group despite the substantially lower training load. These findings suggest that low-load resistance training combined with blood flow restriction can effectively improve lower-limb strength in university Latin dance students. This approach may therefore be considered a practical alternative to conventional resistance training when reducing mechanical stress on the musculoskeletal system is desirable.

Keywords: blood flow restriction; resistance training; lower-limb strength; dance students; exercise adaptation

1. Introduction

Lower-limb muscular strength represents a key component of physical performance and plays a central role in locomotion, postural stability, and overall athletic capacity. Adequate strength in the lower extremities contributes not only to improved performance in a wide range of sports but also to injury prevention and efficient movement patterns during complex physical tasks [1]. Resistance training has long been recognized as one of the most effective methods for improving muscular strength and neuromuscular performance in both athletic and recreational populations [2]. Traditional resistance training programs typically rely on relatively high mechanical loads in order to stimulate muscular adaptation and strength development.

In recent years, blood flow restriction resistance training (BFR-RT) has attracted considerable attention as an alternative training strategy capable of inducing muscular adaptations while using substantially lower external loads. This method involves applying controlled external pressure to the proximal portion of a limb during exercise, thereby partially restricting arterial inflow and venous return [3]. Under these conditions, metabolic stress within the working muscles increases, which may stimulate muscle activation and promote strength development even when the training load is relatively low. A growing body of research has demonstrated that low-load resistance training combined with blood flow restriction can produce improvements in muscular strength and hypertrophy comparable to those observed following traditional high-load resistance training [4-5]. Because this training method reduces mechanical stress while still eliciting significant physiological adaptations, BFR-RT has been increasingly applied in both athletic training and rehabilitation settings [6].

Despite the expanding evidence supporting the effectiveness of blood flow restriction resistance training, many previous investigations have primarily focused on muscle hypertrophy or general strength outcomes in clinical populations, elderly individuals, or athletes engaged in conventional resistance training programs. Comparatively fewer studies have examined the potential benefits of BFR-RT for improving lower-limb strength in university students participating in regular sport-specific training activities. In activities such as dance training, the lower limbs play a particularly important role in generating explosive movements, maintaining stability, and supporting repeated jumping tasks. Therefore, identifying training strategies that can effectively enhance lower-limb strength while minimizing excessive mechanical loading is of practical importance for this population. Accordingly, the aim of the present study was to investigate the effects of low-load blood flow restriction resistance training on lower-limb strength in university students.

2. Material & methods

2.1. Participants

A total of 45 university students who regularly participated in Latin dance training volunteered to take part in this study. All participants were physically active and free from musculoskeletal injuries or cardiovascular disorders that might interfere with the training intervention. Prior to participation, all individuals were informed about the experimental procedures and potential risks associated with the study, and written informed consent was obtained from each participant. Figure 1 shows flowchart of participant allocation to the three study groups.

Participants were randomly assigned to one of three groups: a blood flow restriction resistance training group (BFR-RT, n = 15), a traditional resistance training group (TRT, n = 15), and a dance training control group (CON, n = 15). The intervention lasted eight weeks. During the study period, all participants continued their regular Latin dance training activities.

The experimental protocol was approved by the Institutional Ethics Committee of Universiti Kebangsaan Malaysia (Approval No.: JEP-2025-1264) and was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki for research involving human participants [7].

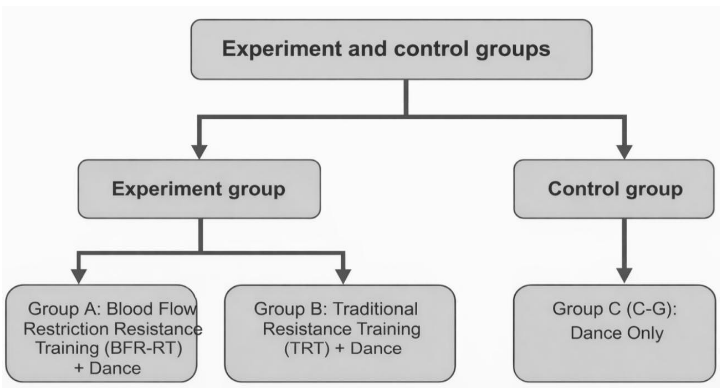

Figure 1. Flowchart of participant allocation to the three study groups.

2.2. Procedure and Training Protocol

The training intervention lasted eight weeks. Participants in the BFR-RT group performed low-load resistance exercises combined with blood flow restriction applied to the proximal region of the lower limbs using specialized cuffs. The external pressure was maintained within a safe range corresponding to approximately 40–60% of arterial occlusion pressure, which is commonly recommended for blood flow restriction training protocols [3]. The training load was set at approximately 30% of one-repetition maximum (1RM), allowing participants to perform resistance exercises under relatively low mechanical stress.

Participants in the TRT group performed the same resistance exercises without blood flow restriction but used higher training loads consistent with traditional strength training recommendations. The training intensity was set at approximately 70% of 1RM, which has been widely used in conventional resistance training programs designed to improve muscular strength [2].

The control group continued their regular Latin dance training and did not participate in additional resistance training sessions during the intervention period.

All training sessions were supervised by experienced instructors to ensure correct exercise technique and adherence to the training protocol. Training frequency and progression were standardized across the intervention period in order to maintain consistency among participants.

2.3. Measurements and Instruments

Lower-limb strength performance was assessed before and after the eight-week intervention. Two indicators were used to evaluate lower-limb muscular performance: hip flexor peak torque and ankle rebound endurance.

Hip flexor peak torque was measured using a standardized strength testing procedure and was expressed relative to body mass (Nm/kg). Ankle rebound endurance was assessed through a repeated rebound test in which participants performed continuous ankle jumps for one minute, and the total number of successful rebounds was recorded.

All measurements were conducted under standardized laboratory conditions to ensure testing reliability. Prior to testing, participants completed a standardized warm-up procedure consisting of light aerobic activity and dynamic stretching. Strength performance tests were administered by trained researchers following established testing protocols in order to minimize measurement error. When necessary, participants performed multiple trials, and the best performance was recorded for subsequent analysis.

2.4. Data Collection and Statistical Analysis

All data were collected before and after the intervention period. Descriptive statistics were calculated for all variables and are presented as mean ± standard deviation (Mean ± SD).

To examine the effects of the training intervention, repeated-measures analysis of variance (ANOVA) was conducted to evaluate changes over time and differences among groups. When significant effects were identified, post hoc comparisons were performed to determine specific group differences. Statistical significance was set at $p < 0.05$.All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) software.

3. Results

3.1. Baseline Characteristics of Participants

The baseline characteristics of the participants are presented in Table 1. A total of 45 university students specializing in Latin dance were randomly allocated to three groups: the blood flow restriction resistance training group (BFR-RT, n = 15), the traditional resistance training group (TRT, n = 15), and the dance training control group (CON, n = 15).

No meaningful differences were observed among the three groups with respect to demographic characteristics, including gender distribution, age, years of Latin dance training experience, and specialized course scores. In addition, the baseline values of the two primary outcome indicators—hip flexor peak torque and ankle rebound endurance—were similar across the three groups.

These findings indicate that the participants in the three groups had comparable physical and training backgrounds before the intervention, providing a reliable baseline for evaluating the effects of the different training programs implemented during the study period.

Table 1. Baseline characteristics and initial lower-limb strength indicators of participants (Mean ± SD).

Category	Variable	BFR-RT group (n=15)	Traditional group (n=15)	Control group (n=15)
Demographic characteristics	Gender (Female/Male, n)	10/5	9/6	11/4
	Age (years, x±SD)	19.8±1.1	20.1±1.2	19.9±1.0
	Years of Latin dance training (years, x±SD)	1.6±0.4	1.7±0.5	1.5±0.4
	S College Specialized Score (points, x±SD)	82.5±4.3	81.8±4.5	83.1±4.1
Baseline lower limb specific strength	Peak torque of hip flexors (Nm/kg, x±SD)	1.8±0.3	1.7±0.2	1.8±0.3
	Ankle joint bounce endurance (times per minute, x±SD)	26.5±3.8	25.7±3.2	26.1±3.5

3.2. Changes in Lower-Limb Strength During the Intervention

The changes in lower-limb strength during the 8-week intervention period are presented in Table 2.

For hip flexor peak torque, both the BFR-RT group and the TRT group demonstrated clear improvements from pre-test to post-test. In the BFR-RT group, the mean value increased from 1.80 ± 0.30 Nm/kg at baseline to 2.15 ± 0.32 Nm/kg after the intervention. Similarly, the TRT group showed an increase from 1.70 ± 0.20 Nm/kg to 2.00 ± 0.25 Nm/kg. In contrast, the control group showed only a slight change from 1.80 ± 0.30 Nm/kg to 1.85 ± 0.28 Nm/kg, which was not statistically significant.

A similar pattern was observed for ankle rebound endurance. Participants in the BFR-RT group improved from 26.5 ± 3.8 times/min at baseline to 32.5 ± 4.2 times/min after the intervention. The TRT group also demonstrated an improvement from 25.7 ± 3.2 times/min to 29.9 ± 3.6 times/min. However, the control group showed only a small increase from 26.1 ± 3.5 times/min to 27.1 ± 3.4 times/min.

Repeated-measures ANOVA indicated that both resistance training groups exhibited statistically significant improvements in the two outcome indicators ($p < 0.001$), whereas no significant changes were observed in the control group.

Table 2. Changes in lower-limb strength during the 8-week intervention (Mean ± SD).

Variable	Group (n=15)	Pre-test (T0)	Mid-test (T4)	Post-test (T8)	F	p
Hip flexor peak torque (Nm/kg)	BFR-RT	1.80 ± 0.30	2.01 ± 0.28	2.15 ± 0.32	28.65	<0.001
	TRT	1.70 ± 0.20	1.95 ± 0.23	2.00 ± 0.25	18.92	<0.001
	Control	1.80 ± 0.30	1.82 ± 0.29	1.85 ± 0.28	0.82	0.445
Ankle joint bounce endurance (times/min)	BFR-RT	26.5 ± 3.8	30.1 ± 3.5	32.5 ± 4.2	35.21	<0.001
	TRT	25.7 ± 3.2	28.8 ± 3.3	29.9 ± 3.6	22.57	<0.001
	Control	26.1 ± 3.5	26.5 ± 3.4	27.1 ± 3.4	1.05	0.358

3.3. Post-Intervention Inter-Group Comparison

The comparison of lower-limb strength among the three groups after the 8-week intervention is presented in Table 3.

For hip flexor peak torque, the BFR-RT group achieved the highest post-test value (2.15 ± 0.32 Nm/kg), followed by the TRT group (2.00 ± 0.25 Nm/kg) and the control group (1.85 ± 0.28 Nm/kg). One-way ANOVA revealed significant differences among the three groups ($F = 10.25$, $p < 0.001$).

A similar trend was observed for ankle rebound endurance. The BFR-RT group reached 32.5 ± 4.2 times/min, which was higher than both the TRT group (29.9 ± 3.6 times/min) and the control group (27.1 ± 3.4 times/min). Statistical analysis confirmed significant differences among the three groups ($F = 12.86$, $p < 0.001$).

Overall, these results suggest that both resistance training approaches were effective in improving lower-limb strength, with the BFR-RT intervention demonstrating the greatest improvement among the three groups.

Table 3. Post-intervention comparison of lower-limb strength among the three groups (Mean ± SD).

Variable	BFR-RT group (n=15)	Traditional high-resistance group (n=15)	Only the dance training group (n=15)	F value	P value
Peak torque of the hip flexor muscles (Nm/kg)	2.15±0.32	2.00±0.25	1.85±0.28	10.25	<0.001
Ankle joint bounce endurance (times/min)	32.5±4.2	29.9±3.6	27.1±3.4	12.86	<0.001

3.4. Visualization of Training Effects

To provide a clearer illustration of the training effects, Figures 2 and 3 present the changes in the two strength indicators before and after the intervention across the three groups.

As shown in Figure 2, both the BFR-RT group and the TRT group exhibited noticeable improvements in hip flexor peak torque following the 8-week training period, whereas the control group showed only minimal changes.

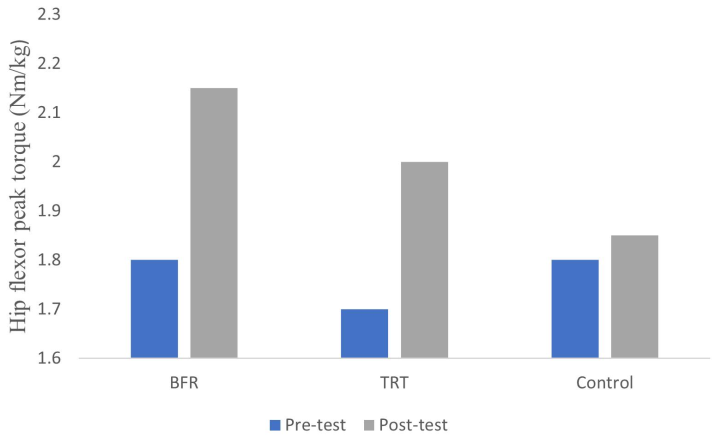

Figure 2. Changes in hip flexor peak torque before and after the 8-week intervention.

Similarly, Figure 3 illustrates the changes in ankle rebound endurance. The BFR-RT group demonstrated the largest improvement among the three groups, followed by the TRT group, while the control group showed relatively small changes during the intervention period.

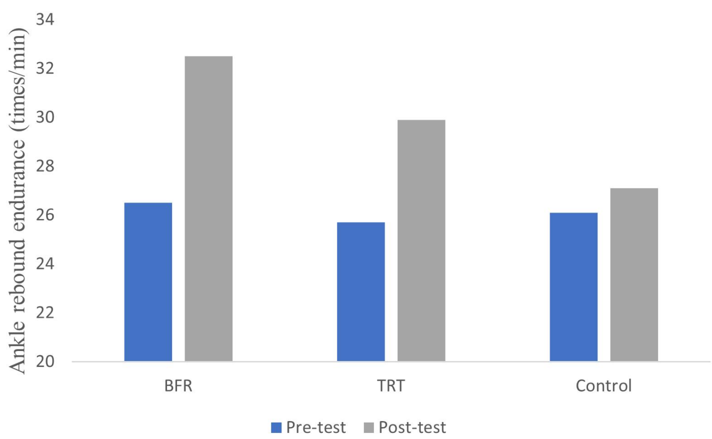

Figure 3. Changes in ankle rebound endurance before and after the 8-week intervention.

4. Discussion

4.1. Main Findings

The present study investigated the effects of low-load resistance training combined with blood flow restriction on lower-limb strength in university students who regularly participate in Latin dance training. The results demonstrated that both resistance training interventions produced significant improvements in hip flexor peak torque and ankle rebound endurance after the eight-week intervention when compared with the control group.

More specifically, participants in the BFR-RT group showed the largest improvements in both indicators, while the traditional resistance training group also demonstrated clear increases in lower-limb strength. In contrast, only minor changes were observed in the control group, which continued routine dance training without additional resistance exercises.

An important finding of this study is that the strength improvements observed in the BFR-RT group were comparable to those achieved in the traditional resistance training group despite the substantially lower training load. This result supports previous findings suggesting that blood flow restriction training can effectively stimulate strength adaptations even when relatively low mechanical loads are used [4-5]. Therefore, low-load resistance training combined with blood flow restriction may represent an effective strategy for improving lower-limb strength while reducing mechanical stress on the musculoskeletal system.

4.2. Possible Mechanisms

Several physiological mechanisms may explain the strength improvements observed following blood flow restriction resistance training. One of the most widely discussed mechanisms is the increase in metabolic stress during exercise when blood flow is partially restricted. Under these conditions, the accumulation of metabolites such as lactate within the working muscles may stimulate the recruitment of higher-threshold motor units, even when relatively low external loads are applied [8].

Enhanced motor unit recruitment may lead to greater neuromuscular activation during exercise, which contributes to improvements in muscular strength over time. In addition, the hypoxic environment created during blood flow restriction exercise may promote the activation of fast-twitch muscle fibers, which play a key role in strength production and explosive movements [9].

Another possible explanation involves the endocrine responses associated with blood flow restriction training. Previous studies have reported elevated concentrations of anabolic hormones, such as growth hormone, following BFR exercise, which may contribute to muscle adaptation and strength development [10]. Taken together, these physiological factors may explain why low-load resistance training combined with blood flow restriction can produce strength gains comparable to those observed with traditional high-load resistance training.

4.3. Comparison with Previous Studies

The findings of the present study are generally consistent with previous research examining the effectiveness of blood flow restriction resistance training. A growing number of studies have reported that low-load resistance exercise combined with blood flow restriction can produce substantial improvements in muscular strength.

For example, several systematic reviews and meta-analyses have demonstrated that BFR training performed with light loads can induce strength gains comparable to those achieved with conventional high-load resistance training [4] [11]. These effects are believed to be associated with the unique physiological environment created by blood flow restriction exercise, including increased metabolic stress, enhanced motor unit recruitment, and greater neuromuscular activation [3].

The results of the present study extend these findings by demonstrating similar strength adaptations in university students who regularly participate in dance training. Compared with many previous studies conducted with general fitness populations or clinical participants, the present study focused on physically active students involved in a sport-specific training environment. Therefore, these findings provide additional evidence supporting the application of blood flow restriction resistance training in physically active populations engaged in specialized physical activities.

4.4. Practical Implications

From a practical perspective, the findings of this study suggest that blood flow restriction resistance training may represent an effective alternative training strategy for improving lower-limb strength when the use of heavy training loads is not desirable.

In many training situations, particularly in sports such as dance, excessive mechanical loading may increase the risk of joint stress and overuse injuries. Under such circumstances, low-load resistance training combined with blood flow restriction may provide a useful strategy for improving muscular strength while reducing mechanical stress on the musculoskeletal system [3].

Furthermore, BFR training may allow athletes and physically active individuals to maintain or enhance muscular strength during periods when high-intensity training cannot be performed, such as during rehabilitation or recovery phases [6] Consequently, blood flow restriction resistance training may represent a practical and flexible training approach for improving lower-limb strength in physically active populations.

5. Conclusions

The present study investigated the effects of an eight-week low-load resistance training program combined with blood flow restriction on lower-limb strength in university students who regularly participate in Latin dance training. The results indicated that both blood flow restriction resistance training and traditional resistance training significantly improved hip flexor peak torque and ankle rebound endurance compared with routine dance training alone.

Notably, the improvements observed in the blood flow restriction resistance training group were comparable to those achieved through traditional resistance training despite the substantially lower external load used during exercise.

These findings suggest that low-load resistance training combined with blood flow restriction can effectively enhance lower-limb strength while reducing mechanical stress on the musculoskeletal system. Therefore, this training approach may represent a practical and efficient strategy for improving muscular strength in physically active populations.

Conflicts of interest
The authors declare that there are no conflicts of interest regarding the publication of this paper.

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