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CASE-BASED INVESTIGATION OF BLOOD FLOW RESTRICTION TRAINING: LIMB OCCLUSION PRESSURE ON SELECTED MOTOR QUALITIES IN ACTIVE MALES

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ABSTRACT

Introduction: Every day, there is an advancement in sports and medicine, as well as in technology that enhances various aspects of the human body. One among them is Blood flow restriction (BFR) equipment, which is widely popular for its ability to improve muscular strength.
Background: Blood flow restriction (BFR) training is an efficient technique for improving physical performance with minimal mechanical stress. Today, it is in practice and plays a major role in rehabilitation worldwide.
Objective: To find the impact of BFR training on selected motor qualities in healthy males.
Methods: The effectiveness of blood flow restriction training was examined in an experimental case study involving two male intermediate-level athletes over 4 weeks. The performance parameters considered in the investigation were the effects of 30% and 40% limb occlusion pressure on the athletes' performance. The parameters considered were athletes' speed, lower body strength, muscular endurance, and cardiovascular efficiency.
Results: The 40% limb occlusion pressure was more effective in improving athletes' speed by 10.54%, lower-body strength by 9.78%, and muscular endurance by 56.5%. The 30% limb occlusion pressure was more effective in improving athletes' core strength by 94.6% and cardiovascular efficiency by 26.8%.
Conclusion: Blood flow restriction training is an effective technique for improving certain motor qualities. Different percentages of limb occlusion pressure were more effective in improving specific performance parameters.

KEYWORDS: Blood Flow Restriction Training (BFRT), Limb Occlusion Pressure (LOP), Training, Motor Qualities, Speed, Strength, and Endurance.

INTRODUCTION

Blood flow restriction training is an exercise technique that involves applying external pressure to a limb during physical activity. It received considerable attention for its ability to stimulate physiological adaptations while decreasing mechanical load [1]. Despite the most effective restrictive pressures for attacking such adaptations still being explored, little consensus exists on appropriate protocols along with a mathematical model of their physiological effects [2]. This also contributes to the heterogeneity of populations and anatomical regions covered in research, with a limited number of studies focused specifically on upper extremity applications, female cohorts, older adults, and athletic populations [3].In addition, acute neuromuscular, hemodynamic, metabolic, and perceptual responses are strongly influenced by differences in approaches to blood flow restriction across muscle groups and exercise types, ultimately affecting long-term adaptations in muscle strength, mass, and endurance [4]. Importantly, unanswered questions remain about the exact proportion of the estimated arterial occlusion pressure that produces the most acute muscle response when resistance training and BFR are coupled [5]. Restricting blood flow beyond 60% of limb occlusion pressure is essential for inducing substantial microvascular deoxygenation, the main mechanism underlying BFR-induced adaptations, as consistently reported across multiple investigations [6].
Although conclusive support for BFR's efficacy exists, additional research investigating proper methodology, usage, and safety protocols specific to each application is needed, given the wide variety of protocols used [7]. Since the introduction of BFR as a training intervention in 1983, exercise participants have used methods such as blood pressure cuffs or tourniquets to apply pressure to proximal muscle attachments, restricting blood flow into and out of the limb [8]. Although extensive evidence demonstrates its ability to elicit hypertrophy and strength with low-intensity stimuli, there has been limited discussion of

device characteristics, physiology based on individual differences, and safety concerns [9]. Therefore, there is a need to understand these principles to develop further research-based guidelines on pressure prescription [10] and to understand the mechanisms that underpin its effectiveness [11]. General recommendations advise practitioners to scale applied pressure based on limb size to decrease inconsistencies and increase safety during application [12]. Specifically, it was concluded that cuff size, material, and stabilizing interface pressure must be considered when measuring pressure to reduce bias and enable standardization across protocols [16]. Additionally, variations in study methodologies, such as inconsistent standardization of cuff pressure and arterial occlusion pressure, have hindered the translation of research into practice settings in both medicine and Exercise [13]. It was further noted that using non-standardized, randomized cuff pressures can be dangerous, as limb circumference can have a drastic effect on the occlusion applied [14].

By failing to adopt an individualized approach based on limb occlusion pressure, practitioners may unnecessarily expose users to excessive cardiovascular and hemodynamic strain. [15].

Furthermore, it can be challenging to compare results across various training studies because standardized device features, such as bladder design and pressure stability, are lacking [16]. While several BFR pressure levels have been investigated, most studies have focused on moderate to high occlusion pressures, with less attention paid to comparing low-to-moderate pressure ranges, such as 30% and 40%. The paucity of research combining BFR with high-intensity functional training, such as plyometrics and sprint training, is another significant gap in the current literature. There is a knowledge gap regarding its implementation in more sport-specific, performance-oriented training conditions, as most research has been conducted in controlled resistance-training settings. The study aimed to identify differences in physical variables (speed, aerobic capacity, Muscular endurance, and lower-body strength) among intermediate athletes using blood flow restriction cuffs at 30% and 40% LOP.

METHODOLOGY

Subjects of this study

The study adopted an experimental design in which two male subjects with an intermediate level of fitness participated. Both participants met the criteria to take part in a structured training intervention, who were physically active, free from injury, and had training experience. The subjects were divided into two conditions to investigate the impact of different Blood Flow Restriction (BFR) levels on performance indicators. In every session of training, Subject A, with 169cms height, 61 kg weight, 22 years old, and used 30% LOP in (BFRT), whereas Subject B, with 169cms height, 63 kg weight, 22 years old, used 40% LOP in (BFRT). The minimum training conditions and testing were kept the same for both individuals to ensure the reliability of the result. The study lasted 1 month, with 3 sessions per Week. Alternate days were chosen for implementing BFR training, with a specific LOP of 30% for subject A and 40% for subject B.

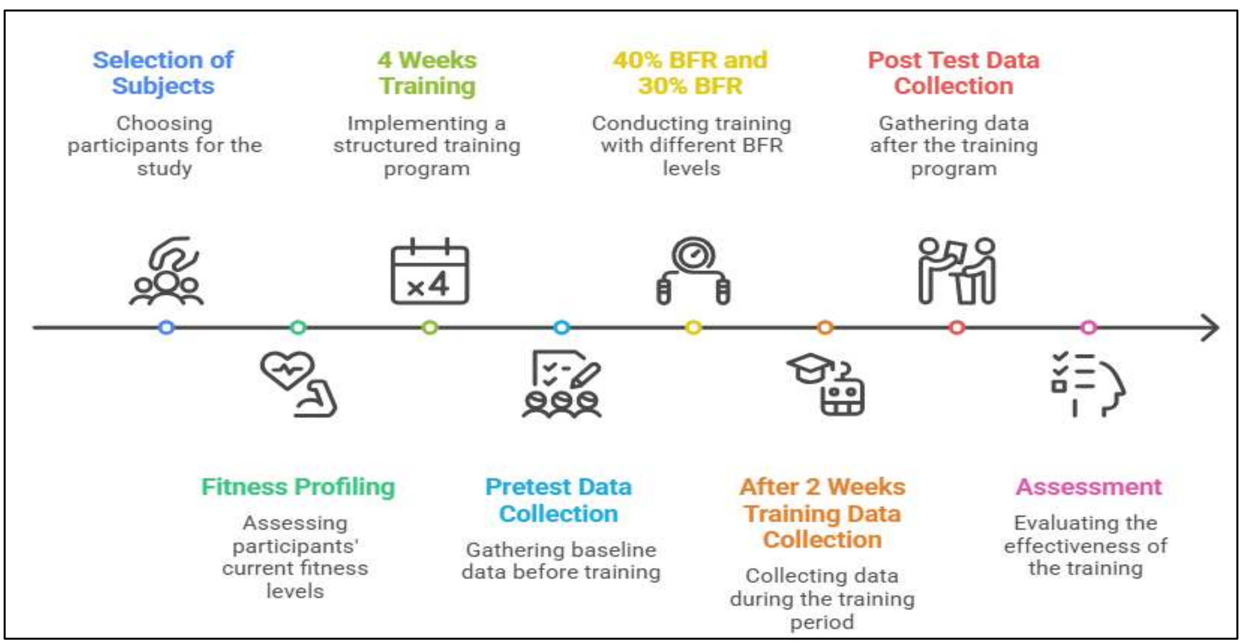

Figure 1. - An inclusive illustrative procedure of BFR Training implementation and assessment.

BFR Device (Training equipment)

SAGA 2.0 BFR (Queensland, Australia, 10.0 cm cuff width) is a cutting-edge fitness device engineered for blood flow restriction training. These cuffs operate entirely without wires and inflate on their own, eliminating the need for any manual pumping or external power sources. The device integrates sensors that measure occlusion pressure, which is required to impede blood flow, and automatically fine-tunes this setting to ensure training safety and effectiveness. Through a mobile application,

the percentage of blood flow restriction can be precisely controlled, enabling the tailoring of the exercise routine as per the training needs.
The cuffs sync with a Smartphone app, which gives instant control over pressure settings, workout routines, and progress monitoring. These advanced-designed cuffs are different from traditional cuffs; they offer automatic inflation, application-based pressure control, and higher safety standards, whereas other cuffs rely on manual tightening and lack precision.

Figure 2. The BFR cuff used during the training session

List of Variables and Testing Procedures

Table 1:

Sl no	Variables	Test	Measurements
1	Speed	40 Yards	Sec
2	Muscular Strength-Lower Body	Standing Broad Jump	Mtr
3	Muscular Endurance	Squad Hold	Min
4	Cardiovascular Efficiency	Harvard step test	Level

3.3 Training Procedure

Table. 2: Four-Week Training Schedule 1st- 4th week training [7,18,17]

Session	Exercises	Reps/Sets	Rest between Sets	Duration in Minutes
General Warming Up	Jogging, Mobility exercises			10 Mins
Main Exercises - (BFRT IMPLEMENTATION)	LOWER BODY Double-leg box jump (45 cm) Jump Squats Depth Jumps SPEED 4O yard sprint	3 Sets (30-15-15) 3 Reps (Maximum effort)	In between reps- 15 seconds After 60Seconds In between reps- 120 seconds	30 Mins
Cooling Down	Stretching Exercise - (Butterfly stretch, V-hamstring stretch, Toe-touch, Forward bend, Cobra pose)			10 Mins
Total Duration **50 Mins**				

1-4weeks Training	Intensity	Load	Density	Focus
	30% limb occlusion pressure for subject A	30 -15 -15 repetitions as one set (Total 3 sets) Moreover, three 40-yard sprints, 3 reps.	Between 30 and 15 reps, 15 seconds' rest After each set 30-15-15 Reps) 60 Seconds rest Each Sprint has 20 seconds of rest.	Adaptation, Tolerance of reinforcement, Strength Development, Performance assessment
	40% limb occlusion pressure for subject B			

The training session began with a 10-12-minute warm-up without a BFR cuff. It consisted of light aerobic activity, such as jogging, and lower-body mobility exercises, mainly focusing on the hip, knee, and ankle joints. The main focus of this stage was to elevate the heart rate, optimize blood flow, and activate the muscles for fast movements.

The main training session combines two exercises: plyometrics and sprinting. The plyometrics component includes three exercises: Double-leg box jump (45 cms), Jump squats, and Depth jumps (45 cms), each performed for three sets of 30-15-15 repetitions. A 15-second rest interval was allotted between repetitions, such as after 30 reps: 15 seconds rest, 15 reps, and 60 seconds between sets to maintain performance quality. Explosive movement, proper technique, and controlled landing were emphasized more.

After completing the plyometric exercises, the subjects performed three 40-yard sprints at maximal intensity with 3 Reps. The rest duration between each repetition was 120 seconds for recovery and consistent performance. The session concluded with a 10-12-minute cool-down phase, featuring static stretching to promote recovery and reduce muscle soreness. During the main Exercise, BFR cuffs were placed on the proximal part of the lower limb while performing the framed exercises; during the rest time, BFR pressure was released. Subject A was trained with 30% occlusion pressure, while Subject B was trained with 40% occlusion pressure. The pressure remained constant, and subjects were monitored throughout the session. To evaluate performance changes over 4 weeks, a set of variables was measured at three time points: Pre-test (before training), Mid-test (after 2 weeks), and Post-test (After of 4th Week).To thoroughly evaluate the subjects' performance, a selection of tests was administered. Statistical Analysis: To understand the gathered data, we employed descriptive statistics. To assess the key performance indicators- specifically, how quickly participants could sprint 40 yards, how far they could jump in the standing broad jump, what level of aerobic fitness in the Harvard step test, how long they can perform the plank for core endurance, and squat hold for lower body strength.

RESULT AND DISCUSSION

SPEED: (40 Yard Run)

Table 3 shows pre-test, post-test, and improvement % for the speed variable.

	Pre -Test	**Post-Test**	**Improvement %**
SUBJECT A - (30%)	5.31	5.14	3.20%
SUBJECT B - (40%)	5.41	4.84	10.54%

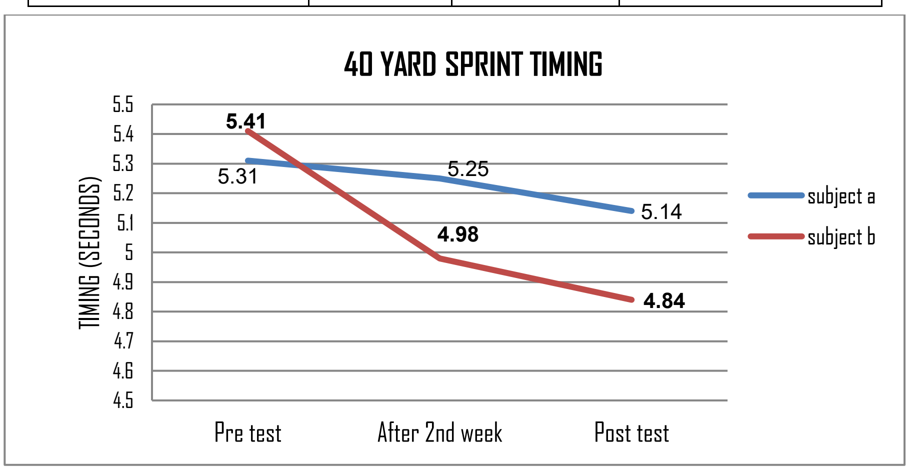

Figure 3: Diagram of Speed Variable of both Subjects Pre-Test, After Two Weeks, and Post-Test Data

The provided graph showcases how 40- yard sprint time evolved at three distinct intervals- the pre-test, after the second Week, and post-test for subjects undergoing training with different Blood flow restriction pressures. Over the four-week training period, both subjects consistently improved their sprint times, demonstrating a clear improvement in speed.

Subject A, who had 30% BFR, had better sprint times each Week: from 5.31 seconds at the start to 5.25 seconds after 2 weeks and 5.14 seconds in the post-test. This represents an overall improvement of approximately 3.20% over the training period, as shown in Table 3. Subject B, who had 40% BFR, did even better – the sprint time dropped from 5.41 seconds at the start to 4.98 seconds after two weeks and 4.84 seconds in post-test. This corresponds to an overall improvement of approximately 10.54% as shown in Table 3.

Subject B's significantly faster sprint times indicate that a higher blood flow restriction (BFR) pressure of 40% might be more beneficial for improving sprint performance than a lower pressure of 30%.

Muscular Strength- Lower body: (Standing Broad Jump)

Table 4 shows pre-test, post- test, and improvement %for the muscular strength variable

	Pre -Test	Post-Test	Improvement %
SUBJECT A - (30%)	2.18	2.24	2.75%
SUBJECT B - (40%)	2.25	2.47	9.78%

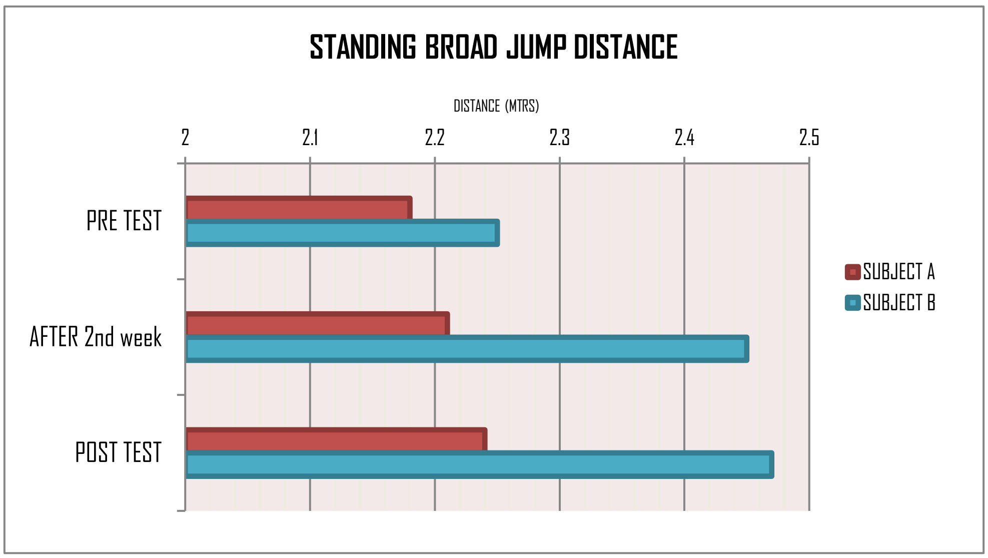

Figure 4: Diagram of Muscular Strength of Lower Body Muscles of Subject- A and Subject- B, Pre-Test, After Two Weeks, and Post-Test Data

Both participants showed an increase in their standing broad jump performance after completing the four-week training, as shown in Figure 4.

Subject A (30% BFR) showed a limited increase in standing broad jump and initially measured 2.18 meters in pre-test, 2.21 meters after the second Week, and 2.24 meters in post-test, reflecting an overall improvement of approximately 2.75% as shown in Table 4. On the other hand, Subject B (40% BFR) showed a substantial improvement; the jump distance increased from 2.25 meters at the start to 2.45 meters by the second Week and further increased to 2.47 meters in the pre-test, resulting in an overall improvement of approximately 9.78%, as shown in Table 4. Although both training conditions were effective in enhancing lower-body explosive power, the greater improvement observed in Subject B suggests that higher BFR pressure (40%) is more effective than lower pressure (30%) in improving power performance.

Muscular Endurance Lower Body: (Squat Hold)

Table 5 shows pre-test, post- test, and improvement %for the muscular Endurance variable (Lower body)

	Pre -Test	Post-Test	Improvement %
SUBJECT A - (30%)	02:05	02:51	36.8%
SUBJECT B - (40%)	01:55	03:00	56.5%

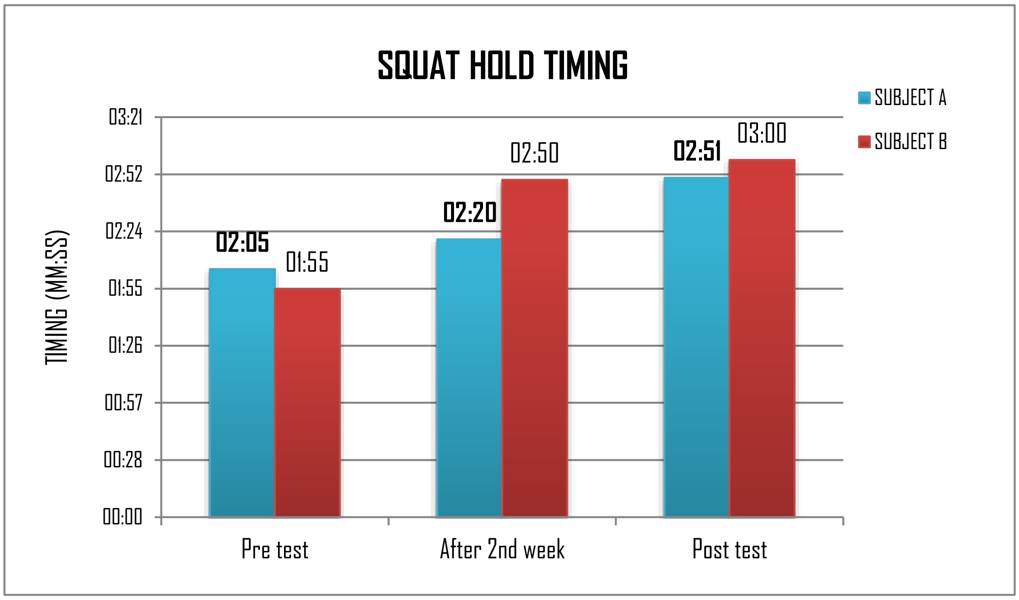

Figure 5: Diagram of Muscular Endurance of Lower Body Muscles of Subject- A and Subject- B, Pre-Test, After Two Weeks, and Post-Test Data

Over the course of post-tests, both subjects demonstrated a marked enhancement in their squat hold performance. Subject A (30% BFR) timing extended from 02:05 minutes in the initial test to 02:20 minutes by the second Week and further to 02:51 minutes in the post-test. This represents an overall improvement of approximately 36.8%, as shown in Table 5. Subject B (40% BFR) showed a significant improvement. The performance went from 01:55 minutes in the initial test to 02:50 minutes by the second Week and further to 03:00 minutes in the post-test, resulting in an overall improvement of approximately 56.5%, as shown in Table 5. Subject B demonstrated a greater improvement in lower-body muscular endurance, indicating that a higher blood-flow restriction pressure of 40% is more effective at enhancing isometric endurance performance than a lower pressure of 30%

Cardiovascular Efficiency: (Harvard Step Test)

Table 6 shows pre-test, post-test, and improvement % for the cardiovascular efficiency variable.

	Pre -Test	Post-Test	Improvement %
SUBJECT A - (30%)	74.35	94.31	26.8%
SUBJECT B - (40%)	75.58	80.21	6.13%

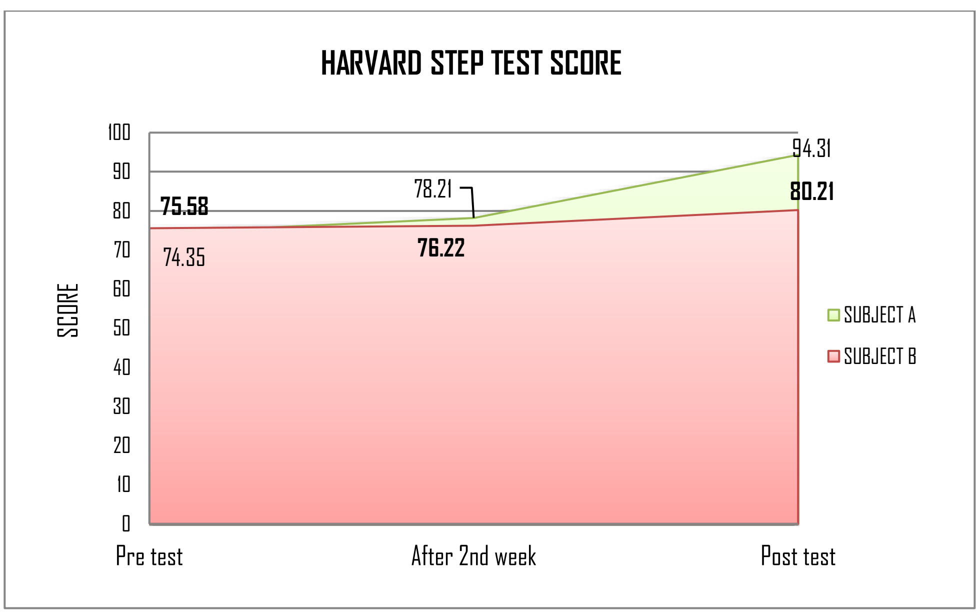

Figure 6: Diagram of Cardiovascular Efficiency of Subject- A and Subject- B, Pre-Test, After Two Weeks, and Post-Test Data

According to the testing plan, both subjects' Harvard Step Test scores improved over the four-week training session, indicating improved cardiovascular efficiency and recovery. Higher results on the Harvard Step Test indicate improved cardio-respiratory fitness because they result in a quicker recovery of heart rate after Exercise. Subject A (30% BFR) improved from 74.35 (pre-test), which is in the average category, to 78.21 (after the second Week) and then to 94.31 (post-test), which is in the good category of results, reflecting a substantial overall improvement of approximately 26.8% as shown in Table 6. Subject B (40% BFR) improved from 75.58 (pre-test), which is in the average category, to 76.22 (after the second Week) and then to 80.21 (post-test), which is still in the average category of results, for an overall improvement of approximately 6.13%, as shown in Table 6. While both subjects showed positive adaptations, Subject A demonstrated a significantly greater improvement and a higher final fitness classification. These results suggest that 30% BFR pressure may be more effective in improving cardiovascular recovery and endurance, as reflected by superior Harvard Step Test performance.

DISCUSSION

The current study demonstrates that 30% and 40% limp occlusion pressures improved all assessed motor skill variables, with the degree of enhancement varying across measures.

Speed (40-Yard Sprint)- The present findings demonstrate that both BFR conditions (30% and 40% LOP) improved sprint performance; however, the magnitude of improvement was greater under the 40% condition. The improved performance observed at 40% BFR might be explained by increased metabolic stress and neuromuscular activity, which allow greater recruitment of fast-twitch muscle fibers [4,6]. This is in line with previous studies, which suggested that adequate occlusion pressure is important for maximizing performance adaptation [5].

Explosive Power (Standing Broad Jump): Both subjects improved their performance. The subject in the 40% BFR condition improved more compared to the 30% BFR condition. The improvement in the 40% BFR condition could be attributed to the increased metabolic accumulation and muscle hypoxia, as the increased occlusion pressure is likely to enhance anabolic signaling and muscle contractility [2,6]. The addition of plyometric exercises has increased the effect of BFR. The results agree with previous studies indicating that increased BFR pressure likely enhances power output [10].

Lower Body Muscular Endurance (Squat Hold)- Improvement in the performance of the squat hold Exercise in both conditions indicates an improvement in muscular endurance in the lower body region. The subject in 40% BFR condition demonstrated slightly better results. This may be attributed to the high metabolic stress and low oxygen availability in the muscle, which can improve muscular endurance by developing fatigue resistance [7]. The hypoxic environment in the muscle during BFR training has been reported to improve muscle endurance by more efficiently utilizing muscle energy, thereby delaying the onset of fatigue [8].

Cardiovascular Efficiency (Harvard Step Test) - In contrast, however, aerobic capacity, as assessed by the Harvard step test, showed greater improvements in the 30% BFR condition than in the 40% condition. This implies that lower levels of restriction may be more effective in improving cardiovascular endurance. This may be explained by the fact that lower levels of restriction enable a more efficient flow of blood and oxygen during repeated bouts of Exercise, thus supporting aerobic metabolism and delaying fatigue. Higher levels of restriction, although effective at causing metabolic stress, may reduce oxygen availability, limiting exercise duration and quality.

This is supported by previous findings suggesting that moderate levels of BFR can enhance aerobic performance without placing undue cardiovascular stress on the body [8]. In this respect, the findings of this study emphasize that lower levels of BFR may be more beneficial for individuals seeking to enhance their aerobic performance. Overall, this study reveals that BFR training is effective across multiple motor skills, but optimal limb occlusion pressure (LOP) may vary depending on the targeted variable. According to the results, lower pressure may be better for cardiovascular performance and endurance, while higher pressure may enhance strength, speed, and explosive power. Hence, this result shows that the hypothesized relationship is true and that there is a significant improvement in the selected variables.

CONCLUSION

In this investigation, a 4-week/12-session BFR training experiment with 40% occlusion pressure on a sample produced significant enhancements in the following variables: speed, muscular endurance (as evidenced by the squat hold test), and lower-body muscular strength (assessed via the standing broad jump). These findings evidence that moderate BFR occlusion pressure can effectively elevate athletic performance, as listed above. Conversely, in 4 weeks/12 sessions of BFR training with 30% limb occlusion pressure, the experiment showed a positive effect on cardiovascular efficiency variables. These results provide evidence that BFR training with low or moderate occlusion pressure and multiple modalities, delivered over a short intervention period, can stimulate dynamic and static muscular performance.

Future Research Road Map

Future studies can examine different age-group samples, use different BFR occlusion pressures, and choose different environments for implementing the BFR adoption evaluation.

Other Information

Funding: No external funding was involved in the study.

Conflict: There is no conflict of interest in this research.

Consent: consent was obtained from subjects who were involved in this study.

Ethical: Ethical clearance was obtained from the Ethical Board of Central University of Tamil Nadu.

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