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# The Effect of a Training Program with Venous Blood Flow Restriction on Muscular Strength and Skill Performance on the Rings Apparatus

Alaa Issa[1]

[1] Palestine Technical University – Kadoorie / Faculty of Physical Education and Sports Sciences / Department of Sports Training, alaa_issa1@outlook.com, https://orcid.org/0009-0000-1709-5964.

**ABSTRACT:** This study aimed to investigate the effect of an eight week blood flow restriction (BFR) training program on muscular strength and rings skill performance among university students, compared with a traditional training program of equal duration and frequency. Thirty male students enrolled in Gymnastics (1) at Palestine Technical University – Kadoorie were randomly assigned to an experimental group (n=15) or a control group (n=15). Both groups were equivalent at baseline. The experimental group performed BFR exercises three times per week using calibrated limb cuffs with progressive pressure (120→160 mmHg), while the control group followed the traditional program. Outcomes included vertical jump, pull ups, 10 s push ups, 10 s sit ups, and rings routine score. Both groups improved significantly ($p \leq 0.05$), but the experimental group achieved greater gains, particularly in pull ups (+41.20%), push ups (+21.62%), sit ups (+22.33%), vertical jump (+14.01%), and rings routine score (+94.44%). Posttest comparisons favored the experimental group across all measures. The study concludes that structured BFR training enhances strength and rings performance more effectively than traditional methods. It is recommended that BFR protocols be integrated into university gymnastics programs, with careful monitoring of cuff pressure and individual responses, and that future research explore broader populations to confirm generalizability

## 1. INTRODUCTION

The evolution of sports performance has never been accomplished without references to the scientific research which examines the new ways of improving the physical, technical, and functional capabilities [1]. Research on this topic has established that systematic training is central in equipping an athlete to compete on the highest level of competition since it offers an athlete a systematic method of enhancing efficiency and performance [2]. This relationship between research and performance highlights the importance to constantly investigate contemporary methods that can support the growing requirements of the various sports [3].

The physical preparation and technical performance are particularly important in gymnastics [4]. Athletes need to have great muscular strength of lower limbs, trunk and upper body to master the complicated routines, especially on the rings [5]. Lack of strength may cause gymnasts to have problems with body control, stability, and fluidity in performance of sequence [6]. The challenge necessitates the need of employing training techniques that have a direct relationship with enhancing physical needs that form the basis of skill performance [7].

Blood flow restriction training is one of the modern methods that have been accepted in the field of sports science [8]. This approach limits the venous return during an exercise, which produces a provisional state of low oxygen supply, which activates more muscle fibres recruitment and adaptation [9]. It is carried out by using special bands or cuffs put on the limbs and calibrated to certain amounts of pressure to safely achieve the desired physiological action [10]. The integration of these mechanical and physiological effects has led to the creation of blood flow restriction as a strategy to stimulate strength gain without the need to use maximal external loads [11].

The effectiveness of this training is evidenced by the applied research that shows that it can be used to improve muscular strength and endurance among different athletes [12]. Positive effects in power, hypertrophy, and sport-specific skill development have also been investigated with positive outcomes in case of blood flow restriction being systematically applied [13]. These results indicate that the technique could offer specific results in gymnastics, where a combination of strength and mastery of the technique are closely related [14]. It is based on this that the current research intends to investigate the influence of an organized blood flow restraint program of muscular strength and technical performance on the rings, which would provide practical information on enhancing the training of gymnastics in the university.

In gymnastics, muscular strength is among the most significant factors of performance as it offers a basis of technical stability and efficiency in terms of apparatus [15]. In case the strength is not enough, gymnasts are unable to maintain body mechanics, and this aspect makes them vary in execution and decrease in consistency during performance [16]. The skills on the rings, specifically, require the arms, trunk, and legs to produce extraordinary forces of production since they are in a sustained equilibrium postures and dynamic transitions which are reliant on strength that is fast and precise [17].

Although this apparent requirement is obvious, a great number of gymnastics training programs are still small-scale in their ability to provide apparatus-specific and scientifically-based strength preparation. The conventional approach tends to focus more on repetition of skills without much attention on the physical needs that support the effective implementation where the athlete is left weak in critical body parts [18]. Lack of specialized strength training in academic programs has been identified as a factor that led to problems among the students in the process of acquiring fundamental skills on the rings, since the lack of strength in the arms, core, and legs diminishes fluency and interferes with the quality of performance [19].

Over the last several years, new types of training have been proposed to deal with these issues, and blood flow restriction (BFR) training seems to gain a specific popularity. BFR inhibits venous return during exercise causing a hypoxic muscle environment that enhances recruitment of more fibers and rapid strength adaptations even with low external loads [20]. The scientific community has proven that this technique could be used to promote muscular growth and functional performance to a greater extent in various populations of athletes [18]. Nevertheless, although its use in the sport has been shown to be effective in sports like swimming and weightlifting, there is little use of BFR in the learning of gymnastics [21].

This vacuum demonstrates that there is the need to conduct empirical research on the possibility of using BFR to overcome weaknesses that have consistently been witnessed among students of the gymnastics department especially with reference to the rings apparatus. Existing interventions lack sufficient incorporation of strength-specific interventions that are consistent with the needs of the apparatuses, and no systematic research has examined the impact of BFR on this issue. Thus, the given study attempts to address this gap by developing and testing a training plan, which would include exercises involving blood flow restrictions, and the focus of which would be the enhancement of not only the muscular strength but also the technical performance on the rings among university-level students.

The importance of this study lies in the fact that venous blood flow restriction training may play a vital role in developing the player's physical and skill performance. A student who lacks a certain aspect of muscular strength may face great difficulty in learning skills and achieving proper performance mechanisms, in addition to struggling with balancing movements and their outcomes when dealing with skills of high-performance difficulty. Moreover, the training program may significantly contribute to developing the muscular strength of students, while also increasing attention to muscular strength as one of the key factors that support achievement and reaching higher levels alongside other performance components.

### 1.1 Study Objectives

This study aims to achieve the following objectives:

1. To identify the effect of the proposed training program using venous blood flow restriction exercises on the muscular strength and skill level of the experimental group members.
2. To identify the effect of the traditional program on the muscular strength and skill level of the control group members.

3. To identify the differences between the experimental and control groups in muscular strength and skill level in the post-test measurement.

### 1.2 Study Hypotheses

The study will examine the following hypotheses:

1. There are statistically significant differences at the level (0.05) between the pre-test and post-test in favor of the post-test regarding the effect of the proposed blood flow restriction exercises on muscular strength and skill performance on the rings apparatus for the experimental group members.
2. There are statistically significant differences at the level (0.05) between the pre-test and post-test in favor of the post-test regarding the effect of the traditional exercises on muscular strength and skill performance on the rings apparatus for the control group members.
3. There are statistically significant differences at the level (0.05) between the experimental group and the control group in the post-test, in favor of the experimental group members.

### 1.3 Study Delimitations

#### 1.3.1 Human Domain

The study population consisted of students from the Faculty of Physical Education and Sports Sciences at Palestine Technical University – Kadoorie.

#### 1.3.2 Time Domain

The study, including its measurements and the proposed training program, was carried out during the academic year 2023/2024. The main experiment was applied for eight consecutive weeks, from 20/10/2024 to 20/12/2024.

#### 1.3.3 Place Domain

The study and the implementation of the training program were conducted with the research group in the gymnastics hall of the Faculty of Physical Education and Sports Sciences at Palestine Technical University – Kadoorie, where the necessary equipment for executing the program was available.

## 2. LITERATURE REVIEW

Systematic training methods based on scientific studies have always been the basis of the development of athletic performance. Research in the field of sports science has continuously emphasized that there is no way that performance can be dissociated with systemic preparation in the technical, psychological, tactical, and physical fields [1]. In this context, muscular strength has been highlighted as one of the core variables of success especially in sports involving accuracy, speed and control. Strength in gymnastics cannot be merely a supportive factor and instead, it is a precondition of technical mastery since complicity of various groups of muscles is essential in performing complex movements [22].

### 2.1 Muscular Strength in Gymnastics

Among sports, gymnastics is unique due to its very high requirements regarding physical attributes, in particular, muscular power. According to Kokarev et al. [4], the demands of performing using the apparatus make gymnasts need thorough strength of lower limbs, trunk, and shoulder girdle. The rings apparatus, especially, requires long holds in an isometric position, swings, and explosive movements, which all require high levels of muscular strength and endurance. These areas are also weak which not only restricts acquisition of skills but also predisposes inconsistency and error. Wijaya et al. [6] has noted that in the event that there is no specific preparation of the strength, complex sequence may create challenges in keeping the body in order and stability. Liu [7] provided additional information that only through repetition of movements, the skill mastery does not become possible, because the underlying physical attributes that assist in the actual execution must also be developed by the athlete.

All the above findings prove the center of focus of both technical learning and performance stability in gymnastics is the power of muscle. They also, though, note a common problem: the training programs of conventional gymnastics, especially in the education, often neglecting the strength building in favor of the repetitions of the skills. This leaves a gap that students might have some partial technical knowledge but have a physical inability to make movements effective, particularly on equipment that demands the utmost control like rings.

### 2.2 Conventional Methods of Strength Training

The conventional methods of training the muscular strength in gymnastics have been mainly high-intensity resistance exercises, calisthenics and apparatus-related conditioning exercises. These techniques are useful and have been found to work well in enhancing production of forces. However, they can be very hard on the joints and connective tissues and this tendency may not be appropriate to all the populations especially beginners or people with less training background. Further, the requirements of university level teaching, in which time and resources are limited, imply that strength programs are by no means necessarily apparatus-specific. As Alhenawy [5] stressed, the problem is that gymnastics programs should strive to combine technical training with specialized physical training but in reality, it is not an easy task to maintain the balance.

The disadvantages of conventional methods have induced scientists and coaches to identify viable versions that offer similar or better adaptations with less mechanical tension. Such a search has prompted the increasing popularity of blood flow restriction (BFR) training that has been claimed to offer hypertrophic and strength benefits on lower external loads.

### 2.3 Development of Blood Flow Restriction Training

Blood flow restriction training is a Japanese training program that has become popular as an innovative form of training all over the world [23]. The compression of resistance exercise with partial vascular occlusion was presented by [24], and the results indicated a significant muscle functioning and strength improvement. This procedure can be used to reduce venous circulation and stabilize the arterial inflow into the muscle by placing calibrated bands or cuffs on the upper arms or thighs to establish a localized state of hypoxia. This physiological stress improves recruitment of slow- and fast-twitch fibers, causes hormonal responses, and increases protein synthesis. BFR training is basically enabling the athletes to receive the advantages of high-intensity training yet carry the light loads, which reduces the mechanical load [25].

It has also been revealed that BFR provokes a set of adaptations, such as the rise in lactate accumulation, growth hormone secretion, and muscle activation, that help to stimulate hypertrophy and strength gains [20]. Lorenz et al. [23] also stated that the technique can be scaled to training intensity, and pressures in the cuff ranged between 80 mmHg and 200 mmHg, which is why it can be used with diversified athletes.

### 2.4 Evidence from Applied Studies

The effectiveness of BFR training has been empirically confirmed by a number of studies in various sporting and population groups. Self [10] examined how BFR affects weightlifters, and the results showed that the participants experienced great improvements in terms of max strength of arms and thighs and better performance results. Manimmanakorn et al. [26] used the low-intensity training protocol with BFR in netball players and reported a greater increase in muscular strength and endurance than the high-intensity training protocol that has low load [26]. The study by Adams [27] pitted BFR against the traditional resistance training in college athletes and found out that BFR had a higher hypertrophic effect in the biceps brachii and thighs [27].

In a similar way, Fostiak et al. [28] were able to test the torque, electromyographic activity, and muscular endurance of athletes who are training in BFR at various intensities and found significant improvements, especially in low intensities [28]. Su et al. [13] applied this evidence to the swimming context and revealed that BFR training did not only increase the strength of bench press and squat tests, but also the maximum oxygen consumption and swimming performance in college athletes [13]. Taken together, these studies support the idea that BFR is an extremely powerful training protocol that can result in the development of both strength and performance adaptations in a variety of settings.

### 2.5 Research Gap

Despite the focus placed on the importance of muscular strength in gymnastics, particularly in skills performed on apparatus, such as rings, which demand an isometric posture, explosive swings, and high stability [4, 6, 7], in standard training programs, excessive focus is still placed on learning skills rather than on the development of specific strength [5]. The traditional methods of resistance training and calisthenic training though effective in creating force may overstrain the joint and connective tissues and hence cannot be used in educational settings like universities. This is an imbalance, which implies that the gymnasts can gain biased technical knowledge and lack the physical ability to perform routines in an efficient manner, which results in inconsistency and a lack of fluidity in performance on the rings.

Blood flow restriction (BFR) training has since become one of the promising alternatives with its strengths and hypertrophic effects with less external loads [20, 25]. Its efficacy in enhancing performance outcomes and strength, as well as results obtained in different sports, has been confirmed in applied research in various fields: weightlifting [10], netball [26], and swimming [13]. However, even with this accumulating evidence, no study has studied the effects of BFR training on gymnastics, and in particular on the rings apparatus where the muscular strength cannot be separated with the mastery of technique. This gap explains why research is required to incorporate BFR in gymnastics training to establish its potential in improving physical capacity as well as practicing skills.

## 2. MATERIALS AND METHODS

### 3.1 Research Design and Procedures

The researcher employed the experimental method by using a two-group experimental design: one experimental group and one control group, with pre-test and post-test measurements for each group.

The study population consisted of students enrolled in the Gymnastics (1) course in the Faculty of Physical Education and Sports Sciences at Palestine Technical University – Kadoorie, as listed in the admission and registration records. The total population was (40) students.

The study sample was selected intentionally from students registered in the Gymnastics (1) course, consisting of (30) students from the Faculty of Physical Education and Sports Sciences at Palestine Technical University – Kadoorie. The sample was chosen based on the following considerations:

1. Easy availability of the participants at the scheduled training times.
2. Similar skill levels among the students in the sample.
3. The motor skills under study are part of the academic curriculum, and the students had not previously studied or practiced them.

The final sample of (30) students was randomly divided as follows:

- (15) students formed the control group, trained using the traditional program for practicing the motor skill on the vaulting table.
- (15) students formed the experimental group, trained using the proposed training program for practicing the motor skill on the vaulting table.

### 3.2 Sample Homogeneity and Group Equivalence

To ensure consistency, the researcher tested the homogeneity of the study sample in terms of primary variables (age, height, and weight), as well as in certain physical and skill performance variables.

**Table 1.** Description of the characteristics of the study sample and its homogeneity according to the variables of height, weight, and age (N = 30).

| Basic Variables | Unit of Measurement | Mean | Standard Deviation | Skewness |
|---|---|---|---|---|
| Height | m | 1.82 | 0.46 | 0.17 |
| Age | years | 21.80 | 1.18 | 0.016 |
| Weight | kg | 72.06 | 4.30 | 0.076 |

The results in Table (1) show that the means and standard deviations of the variables (height, age, and weight) for the students of the Faculty of Physical Education and Sports Sciences at Palestine Technical University (as a whole sample) were respectively (1.8263 ± 0.4642, 21.8000 ± 1.18613, and 72.0667 ± 4.30664). The skewness values were (0.173, 0.016, and 0.076) respectively, indicating a normal distribution for the study sample. Based on these results, participants were randomly assigned to the experimental and control groups. The experimental group (n = 15) trained with blood flow restriction exercises for eight weeks, while the control group (n = 15) trained with the traditional method for eight weeks. Prior to implementing the training programs, equivalence between the two groups in the pre-test of the physical and skill variables was confirmed using an independent t-test, as shown in Table (2).

**Table 2.** Equivalence between the experimental and control groups in the pre-test measurements of the physical and skill tests under study (N = 30).

| Variables | Unit | Experimental Group Mean | Experimental Group SD | Control Group Mean | Control Group SD | t-value | Sig. level |
|---|---|---|---|---|---|---|---|
| **Body Measurements** | | | | | | | |
| Height | m | 1.83 | 0.05 | 1.82 | 0.04 | 0.505 | 0.618 |
| Age | years | 22.00 | 1.25 | 21.60 | 1.12 | 0.921 | 0.365 |
| Weight | kg | 71.86 | 4.37 | 72.26 | 4.38 | -0.250 | 0.804 |
| **Physical Tests** | | | | | | | |
| Vertical Jump Test | cm | 46.66 | 1.49 | 46.80 | 1.47 | -0.246 | 0.808 |
| Pull-up Test | reps | 5.00 | 0.75 | 4.80 | 0.77 | 0.716 | 0.480 |
| Arm Push Test (10 sec) | reps | 6.66 | 0.89 | 6.46 | 1.12 | 0.538 | 0.595 |
| Sit-ups from Supine (10 s) | reps | 6.67 | 1.17 | 6.40 | 1.18 | 0.619 | 0.541 |
| **Skill Performance Test** | | | | | | | |
| Routine on Rings | score | 1.80 | 0.59 | 1.40 | 0.80 | 1.549 | 0.133 |

*Statistically significant differences at the level ($\alpha \leq 0.05$).

The results in Table (2) indicate that there were no statistically significant differences at the level ($\alpha \leq 0.05$) between the experimental and control groups in the pre-test measurements of the physical and skill tests under study. This confirms that both groups were equivalent before the start of the training programs.

### 3.3 Devices and Instruments Used

The researcher used a stadiometer to measure height (cm), a medical scale to measure weight (kg), a rings apparatus, foam mats, cones of different heights, a stopwatch, and blood flow restriction (BFR) devices to collect the data.

### 3.4 Blood Flow Restriction Application Procedure

The BFR bands were applied proximally on the arm, positioned between the biceps brachii and the anterior deltoid muscle, directly over the muscle tissue. The pressure required for each training session was individually determined according to the participant's arm circumference. An initial systolic pressure of 120 mmHg was set for the arm application. The same procedure was followed for the biceps femoris and leg muscles. Training intensity was increased by tightening the band by 10 mmHg every two weeks until it reached the maximum of 160 mmHg (Figure 1).


**Figure 1.** Method of Using Blood Flow Restriction (BFR) Bands During Training.

**3.5 Physical and Skill Tests**

The researcher used the following physical tests, chosen by consulting with five experts to select the appropriate tests:

**3.5.1 Vertical Jump Test**

The tester grasps a piece of chalk, stands facing the wall, reaches toward the floor as far as possible, and marks the wall with chalk or magnesium powder. The participant then stands side-on to the wall with both feet on the 30-centimeter line. The tester instructs the participant to swing the arms downward and then upward while bending the trunk forward and flexing the knees to 90 degrees. The participant pushes off with both feet, jumps vertically while extending the knees, and swings the arms rapidly forward and upward to mark the maximum height on the wall. The judge should preferably stand on a platform near the wall to observe and record each attempt accurately.

**3.5.2 Pull-Up Test**

This test measures the strength of the upper body muscle groups (back, arm, and shoulder muscles). Equipment needed are a horizontal bar or fixed pull-up bar. The participant grasps the bar with palms facing forward and hands just outside shoulder width. The participant hangs from the bar with the body fully extended and the feet off the ground. The participant pulls the body upward until the bar touches the participant's chin (chin are above the bar). The participant lowers the body back to the starting position in a controlled manner. The participant repeats the exercise as many times as possible. Proper form must be observed for each repetition. The score is the number of correct repetitions. This test measures the strength of the muscles of the upper body.

**3.5.3 Arm Push Test (10 seconds)**

This is a test of upper-body strength. The participant lies prone on an exercise mat, places palms on the floor slightly wider than shoulder width and in line with the chest, then places feet together or shoulder-width apart. The participant must maintain a straight line from head to heels. The participant then lowers the body by bending at the elbows until the chest nearly touches the mat, then pushes back to the starting position. The number of correct push-ups in 10 seconds is recorded.

**3.5.4 Sit-Ups from the Supine Position with Bent Knees (10 seconds)**

Test Objective: To assess the speed strength (explosive strength) of the abdominal muscles. Test Requirements: Starting from a supine position with hands intertwined behind the neck, the participant flexs the torso downward with the forehead touching the knees, repeating this movement as many times as possible in 10 seconds. A colleague assists the participant by holding the feet down during the test.

Scoring: The number of correct repetitions performed within 10 seconds is recorded.

### 3.6 Training Program

#### 3.6.1 Program Objective

The proposed blood flow restriction (BFR) training exercises were designed as a suggested program. The time allocated for the target skill in the traditional program was adapted and reformulated into a program consistent with the overall training plan.

#### 3.6.2 Program Design

The program was developed by defining its general objective, considering individual differences among trainees, and aligning it with modern trends in advanced training methods. It was designed to be flexible, practical, and suitable for the research sample, with the necessary facilities and equipment available for implementation. Sufficient training time, appropriate exercise repetitions, and adequate rest intervals were also determined to ensure participants returned to their normal state.

#### 3.6.3 Considerations in Program Implementation

The researcher prepared the proposed program while considering the training principles and the objectives of the study, which are to develop muscle power and performance on the rings apparatus, and considered the suitability of the program for the research sample. The researcher applied the proposed training program to the research group in training units; the exercises of each unit were performed consecutively in stations, according to the functional level of each trainee. The researcher took into consideration the gradual increase of the load and the timing accuracy for each repetition, as well as the importance of continuity of the training program. The proposed program included specific physical exercises with progressive levels of difficulty while taking into account safety in using the tools and apparatus.

### 3.7 Experimental Procedures

The main study was conducted from 20 October to 20 December 2024. Pre-tests were administered to measure muscular strength in the targeted muscle groups and evaluate students' performance on the rings apparatus. The eight-week training program was then implemented, with three 90-minute sessions per week on Sundays, Tuesdays, and Thursdays, for a total of 24 sessions. Each session included preparatory, main, and concluding sections. The researcher followed the scientific principles and objectives of the program, used exercises selected by experts, applied appropriate training methods, and progressed from easy to difficult while considering directed spotting.

After completing the proposed training program, the researcher conducted the post-test measurements for muscular strength of the working muscle groups and the post-test evaluation of the students' performance on the rings apparatus to determine the program's effectiveness in improving technical performance.

3.8 Statistical Analysis

In accordance with the experimental design and study variables, the researcher used the arithmetic mean (M), standard deviation (SD), skewness coefficient, paired-samples t-test to determine differences within groups, and independent-samples t-test to determine differences between groups.

## 3. RESULTS AND DISCUSSION

### 4.1 Results and Discussion of the First Hypothesis

There are statistically significant differences at the significance level ($\alpha \leq 0.05$) between the pre-test and post-test in favor of the post-test in the effect of the proposed blood flow restriction (BFR) exercises on muscular strength and skill performance on the rings apparatus among the experimental group.

**Table 3.** Results of the paired t-test showing differences in the effect of BFR exercises on some physical variables and skill performance for the experimental group (N = 15).

| Variables | Pre-test (M ± SD) | Post-test (M ± SD) | t-value | Sig. level | % Improvement |
|---|---|---|---|---|---|
| **Physical Tests** | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Vertical Jump Test (cm) | 46.66 ± 1.49 | 53.20 ± 2.00 | -25.548 | *0.000 | 14.01 |
| Pull-up Test (reps) | 5.00 ± 0.75 | 7.06 ± 0.79 | -31.000 | *0.000 | 41.20 |
| Arm Push Test (10 sec, reps) | 6.66 ± 0.89 | 8.10 ± 0.78 | -12.128 | *0.000 | 21.62 |
| Sit-ups (10 sec, reps) | 6.67 ± 1.17 | 8.16 ± 1.20 | -10.869 | *0.000 | 22.33 |
| **Skill Performance Test** | | | | | |
| Routine on Rings (score) | 1.80 ± 0.59 | 3.50 ± 0.50 | -8.765 | *0.000 | 94.44 |

*Statistically significant differences at a ≤ 0.05. % = Percentage of change.*

The results in Table (3) indicate that there were statistically significant differences at the level ($\alpha \leq 0.05$) between the mean scores of the pre-test and post-test in favor of the post-test across all physical variables under study among students of the Faculty of Physical Education and Sports Sciences at Palestine Technical University – Kadoorie in the experimental group. These findings demonstrate the effective impact of BFR training on developing all physical and skill-related variables examined. The percentage of improvement was as follows: vertical jump (14.01%), pull-ups (41.2%), arm push (21.62%), sit-ups (22.33%), and rings routine performance (94.44%).

The researcher believes that the content of the proposed training program is one of the reasons for this progress, as the BFR training had a significant impact on improving the maximum strength of the muscles that execute the rings routine and on skill performance. Another contributing factor is the scientific organization of the training program and the moderation of the training loads to suit the sample. In addition, slow- and fast-twitch muscle fibers are stimulated during BFR exercises, which increases muscle tone, and BFR exercises enhance the secretion of growth hormone, which significantly contributed to improving the strength of muscles and in turn improving technical performance.

This also agrees with Davids et al. [11], who verified the benefits of BFR training, including greater capillary elasticity and efficiency, activation of slow- and fast-twitch muscle fibers, increased levels of growth hormone, and increased muscle strength.

The researcher also believes that BFR training induces blood flow in the muscles, which aids in muscle hypertrophy and functional strength, which directly affects skills performance on the rings. This agrees with Fostiak, et al. [28], who reported that low-intensity BFR training induces significant changes in torque, muscle activity, and endurance. It is also in agreement with Ishizaka, et al. [25], who described how muscle blood circulation induced by partial vascular occlusion leads to hypoxia in the related muscle, followed by an increase in the size of veins and muscle fibers, which ultimately improves muscular strength, hypertrophy, and skills performance.

Furthermore, these findings are in agreement with the studies of Su et al. [13], Deng et al. [14], and Ferguson et al. [20], who all confirmed that BFR training positively influenced muscular strength, power, and endurance, which in turn elevated skill performance.

The researcher further interprets the improvement in skill performance as a result of the systematic design of the proposed program, which included BFR training with regulated, wave-like variations in load intensity within each session. This approach enhanced the targeted physical variables, which subsequently improved skill performance. Continued exposure to training loads elicited positive adaptations in vital body functions, while the BFR program applied to the muscle groups involved in the routine was closely aligned with the movement pathway of the skills being studied.
This is supported by Alhenawy [5], who stated that training on the skill alone is not sufficient to improve performance; alongside skill development, physical variables related to the skill must also be improved. It also agrees with Liu [7], who emphasized that skill performance is strongly related to physical abilities, as mastering technical skills depends on the development of physical and motor requirements specific to those skills, and performance level is often measured by the acquisition of such physical qualities. Similarly, Wijaya et al. [6] stated that improvement in physical abilities and motor skill development occur simultaneously, and when individuals possess high physical capabilities, their level of technical performance also improves.

**4.2 Results and Discussion of the Second Hypothesis**

There are statistically significant differences at the significance level (α ≤ 0.05) between the pre-test and post-test in favor of the post-test in the effect of traditional exercises on muscular strength and skill performance on the rings apparatus among the control group.

Table4

*Results of the paired t-test showing differences in the effect of traditional exercises on some physical variables and skill performance for the control group (N = 15).*

| Variables | Pre-test (M ± SD) | Post-test (M ± SD) | t-value | Sig. level | % Improvement |
|---|---|---|---|---|---|
| **Physical Tests** | | | | | |
| Vertical Jump Test (cm) | 46.80 ± 1.47 | 48.26 ± 2.15 | -4.559 | *0.000 | 3.11 |
| Pull-up Test (reps) | 4.80 ± 0.77 | 5.36 ± 0.75 | -7.166 | *0.000 | 11.66 |
| Arm Push Test (10 sec, reps) | 6.46 ± 1.12 | 7.10 ± 1.12 | -4.750 | *0.000 | 9.90 |
| Sit-ups (10 sec, reps) | 6.40 ± 1.18 | 7.16 ± 1.29 | -6.487 | *0.000 | 11.87 |
| **Skill Performance Test** | | | | | |
| Routine on Rings (score) | 1.40 ± 0.08 | 2.03 ± 0.93 | -6.971 | *0.000 | 45.00 |

*Statistically significant differences at a ≤ 0.05. % = Percentage of change.*

The results in Table (4) show that there were statistically significant differences at the level (α ≤ 0.05) between the pre-test and post-test for the control group in all physical and skill performance tests. This indicates that the control group, which trained using the traditional program, achieved progress in all studied variables during the experimental period. The percentage of improvement was as follows: vertical jump (3.11%), pull-ups (11.66%), arm push (9.90%), sit-ups (11.87%), and rings routine performance (45.00%).

The researcher believes that the positive development is due to the content of the official training plan received by the control group, as well as the continuity of this training. During practice, the gymnast moves the body in as many patterns as possible, at different levels of strength or endurance. In fact, gymnastic exercises increase core and muscle strength, which increases overall strength and flexibility, especially for the limbs and trunk. Flexible joints are a key feature in gymnastics, and regular practice of gymnastics will naturally increase joint flexibility because of the smooth and fluid movements that increase balancing factors. In addition, gymnasts train in complex skills that require harmonious and coordinated movement between the eyes, hands, and body. Training on different devices such as the pommel horse, floor, rings, and parallel bars will increase the gymnast's balance and quick reaction rate, which will have positive effects on the performance of gymnastics exercises.

This goes in accordance with the study of Farana et al. [16], who noted that gymnastics is a sport that requires the use of all muscles of the body and leads to the overall development of physical and skill abilities. The training process of a gymnast leads to increased concentration and control of tension, which helps in improving motor responses and skills.

### 4.3 Results and Discussion of the Third Hypothesis

*There are statistically significant differences at the significance level (a ≤ 0.05) between the post-test means of the experimental and control groups in muscular strength and skill performance on the rings apparatus, in favor of the experimental group.*

**Table 5.** Results of the independent t-test showing differences between the post-test means of some physical and skill performance variables for the experimental and control groups.

| Variables | Unit | Experimental Group (n = 15) M ± SD | Control Group (n = 15) M ± SD | t-value | Sig. level |
|---|---|---|---|---|---|
| **Physical Tests** | | | | | |
| Vertical Jump Test (cm) | cm | 53.20 ± 2.00 | 48.26 ± 2.15 | 6.490 | *0.000 |
| Pull-up Test (reps) | reps | 7.06 ± 0.79 | 5.36 ± 0.75 | 6.002 | *0.000 |
| Arm Push Test (10 sec, reps) | reps | 8.10 ± 0.78 | 7.10 ± 1.12 | 2.831 | *0.008 |
| Sit-ups (10 sec, reps) | reps | 8.16 ± 1.20 | 7.16 ± 1.29 | 2.193 | *0.037 |
| **Skill Performance Test** | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Handstand Forward Roll-on Rings | score | 3.50 ± 0.50 | 2.03 ± 0.93 | 5.358 | *0.000 |

*Statistically significant differences at a ≤ 0.05.*

It is evident from Table (5) that there are significant differences between the experimental group and the control group in the post-test in all the physical tests as well as in the skill performance test of the studied rings routine. This result indicates the superiority of the experimental group over the control group in the physical and skill performance variables with a significance level of ($\alpha \leq 0.05$).

The researcher believes that this is due to the superiority of the experimental group's training program, which was proposed using blood flow restriction (BFR) exercises with controlled repetitions, sets, and rest times, as well as the continuity of the experimental group training three times a week for eight weeks, because this allowed the experimental group gain greater physiological and performance adaptations than the traditional training group.

Similarly, Lorenz et al. [23] stated that BFR training boosts muscular strength, muscle cross-sectional area, muscular endurance, glycogen storage in skeletal muscle, and general physical fitness. Perera et al. [12] confirmed the significant effect of BFR-based training programs in boosting muscular strength and improving various physiological variables.

The results are also in line with the opinion of Davids et al. [11], who mentioned that BFR training is a novel training method that improves fitness in a holistic and balanced way, especially muscular strength in all its forms, which contributes to enhancing skill performance. In agreement with the findings of Deng et al. [14], Su et al. [13], and Ferguson et al. [20], the researchers concluded that BFR training is an effective training method for individual and team sports because of its holistic fitness training emphasis.

## 4. CONCLUSION AND RECOMMENDATIONS

Based on the study results, methodology, and sample characteristics, the proposed blood flow restriction (BFR) training program had a positive and effective impact on the physical abilities associated with the rings routine and improved participants' skill performance. In contrast, the traditional training program applied to the control group produced only slight improvements in the physical abilities related to performance on the rings apparatus.

Within the scope of the study design and procedures, the researcher recommends adopting the proposed blood flow restriction (BFR) training program among gymnastics instructors and coaches to enhance physical abilities and improve technical performance on the rings apparatus. Similar studies should also examine the effects of BFR training on skills performed across other gymnastics apparatuses.

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## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

## DATA AVAILABILITY STATEMENT

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

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