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Comparison of Adaptations in the Gastrocnemius Muscle from an Exercise Program with and without Low-Intensity Blood Flow Restriction Banding in 18 Male Amateur Basketball Players Aged 16-45 Years

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Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
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Background: Basketball is a sport with a global impact and recognized major leagues, and is one of the most studied and analyzed sports for improvement at the level of the high-performance athlete. Increasing the jump height of basketball players is an essential factor for high athletic performance.

Material/Methods: This study aimed to identify the effect of low-intensity training with flow restriction versus the eccentric exercise protocol on amateur athletes. Eighteen amateur basketball players aged 16-45 years were divided into 2 groups: Group A consisted of 9 participants with low-intensity training with flow restriction (40% intensity) with 200 mmHg occlusion applying flow restriction bands in the popliteal area, while Group B consisted of 9 participants who performed an eccentric exercises protocol on the gastrocnemius. An anthropometric evaluation was applied, which consisted of perception of effort, range of movement (ROM), muscle strength intensity, and the power of the jump measured with a jump platform.

Results: Notable changes were observed in favor of Group A for the right dorsiflexion, with mean difference (MD)=-2.444 (*P*=0.018); left dorsiflexion with MD=-2.778 (*P*=0.027) and left foot perimeter variable with MD=-0.667 (*P*=0.026) at 95% confidence interval (CI); while the vertical jump was in favor of Group B, with MD=-2.899 (*P*=0.006).

Conclusions: Low-intensity training with flow restriction and eccentric exercise protocol were both effective in improving jumping performance. A significant improvement was shown in the jump height and ROM of the 2 study groups.

Clinical trial registration number ACTRN: ACTRN12623000229673
https://www.anzctr.org.au/ACTRN12623000229673.aspx

Keywords: **Muscle, Skeletal • Basketball • Blood Flow Restriction Therapy • Exercise**

Abbreviations: **MMII** – lower limbs; **1RM** – one-repetition maximum test; **ROM** – range of movement; **SD** – standard deviation; **BFR** – blood flow restriction bands; **CI** – confidence interval

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Introduction

Basketball was created by James Naismith in 1891 and became part of the Olympics in 1936 [1].

Basketball is a sport with a global impact and recognized major leagues, and is one of the most studied and analyzed sports for improvement at the level of the high-performance athlete [2].

Performance in basketball is characterized by having different changes of intensities and directions in the runs and fakes during training or in a game [3]. In addition, several game actions are carried out: throwing for 2 or 3 points, filtering towards the basket during attack, and defensively preventing the opposing team from scoring [4].

There is usually a stopper, which prevents the attacker from making a basket. All these actions are executed with the jump, leading us to think that the jump is an unbalancing action in the performance of the game [5]. For this reason, increasing jump height in basketball players is an essential factor for high athletic performance [6]. Several studies have tried to determine what type of training increases the power of the jump, concerning the set of lower limbs (MMII), by performing the jump a muscular synergy of the entire MMII is needed [3].

The vertical jump is a multi-joint and ballistic movement in which a maximum explosive force is used, depending on the speed, strength, and agility of the athlete [5].

Restriction of blood flow is an important method in jump training, which consists of positioning athletes in a sitting position on their heels, presenting swelling in the distal area of the lower limbs due to a maintained posture [7-9]. It is based on partial flow restriction with tourniquets in the muscular area and working with low-intensity load training. The parameters that must be taken into account are: a) the dimension of the occlusion sleeve, b) the pressure of the flow restriction, c) the location of the device, d) occlusion time, e) the type of training, f) and the intensity of training [10].

Regarding the physiological components of flow restriction, it is important to note that the physiological changes that occur with flow restriction combined with low-intensity training which consists in 30-40% of one-repetition maximum test (1RM) are the same as for high-intensity training with 75% of the 1RM [11].

Low-intensity blood flow restriction (BFR) training can achieve greater increase in muscle capacity compared to high-intensity training [12,13]. During high-intensity training, the mechanical tension serves as primary driver of muscle hypertrophy, but the mechanism underlying low-intensity BFR the muscle growth is not well understood [14,15].

Some of the mechanisms involved in the hypertrophic response from low-intensity BFR training include an accumulation of metabolites, cell swelling, increased motor unit recruitment, reactive hyperemia, and reduced protein breakdown [16-18].

The processes behind muscle growth might enhance hypertrophy during low-intensity BFR training when mechanical tension is lacking. Some studies have demonstrated that low-intensity BFR training is a safe and effective way to increase muscle size and strength in elderly people and in people with myositis [19,20].

There are many publications on various factors that are altered, such as metabolic stress and mechanical tension, which are responsible for muscle hypertrophy generating changes at the cellular level [21]. In addition, markers that cause muscle growth are associated with increased recruitment of fast-twitch fibers that help increase muscle strength [11,22]. However, not all the effects produced by flow restriction at the physiological level are known. Eccentric exercises on the gastrocnemius muscles also have an important role in training athlete to jump. These exercises generate muscle contraction at the physiological level of muscle elongation. During exercise, a slowing of movement can occur, involving both concentric and eccentric contraction phases, which activates type 2 muscle fibers, leading to increased strength [22-24].

The position of the patient is in a monopodal support with the knee in extension, supporting all the body weight on the forefoot with the ankle in plantar flexion. Another treatment has the same position of the patient with a change at the level of the knee, since a slight flexion must be performed in this way working at the level of the soleus muscle [23]. Based on scientific data and the importance of the 2 different jump training protocols, this study aimed to compare adaptations in the gastrocnemius muscle from exercise programs with and without low-intensity blood flow restriction banding in 18 male amateur basketball players aged 16-45 years.

Material and Methods

Ethics Statement, Study Design, and Participants

This study adhered to the Declaration of Helsinki and was approved by the Ethics Committee of the Catholic University of Murcia "San Antonio" with protocol No. CE012206. All participants were informed about the trial, and the screening began after consent forms were signed.

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This was a double-blind, randomized controlled trial focused on the effectiveness or differences between the eccentric exercise protocol and low-intensity flow-restricted training. The CONSORT 2016 guideline for randomized clinical trials was used [25].

The individuals who participated in the trial were selected from Basket Club Molina from the Junior and Senior categories in Molina de Segura, Murcia, Spain. To be eligible, participants had to be basketball players aged 16-45 years, with a minimum 3 days of training per week for a total of at least 4.5 h of weekly training (4 and a half hours), and without injuries at the level of the calves. We excluded professional league basketball players who had a previous injury within the last 15 days, with presence of recurrent pain at the level of the Achilles tendon, and regular gym training (more than 3 times a week).

Twenty-two male amateur basketball players from Basket Club Molina were divided in 2 groups: Group A with low-intensity training (40% of 1RM) with flow restriction with 9 participants and Group B with eccentric exercise protocol with 9 participants.

The sample size was calculated in a finite population, number of players 24 in the junior and senior male category of 16-45 years of age with the finite population formula with a confidence level percentage of (Z^2 α=95%), the probability of (*P*=50%), the probability that it does not occur (q=50%) and finally with a maximum error estimate of (e=3%), resulting in a desired sample of subjects of n=21, which, due to exclusion criteria, was able to obtain a sample of n=18 players in this study.

$$n=\frac{N * Z^2 \alpha * p*q}{e2 * (N-1) + Z2\ \alpha * p* q}$$

Randomization and Blinding

The group selection process was manual, in which the participant had to take a piece of paper from an envelope containing Group A with low-intensity training with flow restriction) and Group B with eccentric exercise protocol. This envelope contained 18 papers divided into 9 from Group A and 9 from Group B. In this way, the selection of groups would be balanced and randomized. The participants did not know which group they belonged to. They underwent the exercise protocols without being aware of the types of exercises they were assigned.

The randomization process was performed by the coaches, who did not participate in this study.

This clinical trial was double-blind. Specifically, the participants were unaware of the participation group assignment and the outcome assessor was unaware of the intervention of each group.

For the distribution of groups, the division was carried out in a balanced random manner in 2 equal samples in 1: 1 frequency. The individuals had to select an envelope without knowing the content, which consisted in 2 different groups selection: Group A was low-intensity training with flow restriction on the gastrocnemius muscles and Group B was a protocol of eccentric exercises on the gastrocnemius muscles. The clinical trial had a 4-week duration with a frequency of 3 days a week and 1 h of training per day.

Study Intervention

The players were evaluated at the beginning of the first training session of week 1 and at the end of week 4 on the last day of training. The study lasted 4 weeks. The training protocol consisted in a training class where the instructions, advantages, and potential benefits were explained. There were no associated risks. Each training lasted 1.4 h and was developed in collaboration with the coach.

The training was planned as follows: Warm-up: 10-15 min of jogging at a medium intensity for 6 min and exercises with the ball (eg, passing, throwing) for 9 min. After the warm-up, the players continued the exercises planned for each study group.

Group A participated in low-intensity training with blood flow restriction applied to the gastrocnemius muscles. Bands were placed 2 finger-widths below the apex of the patella, with 200 mmHg occlusion. The exercise was performed at 40% of the 1 RM intensity, with an intervention time of 5 min. This included 3 sets of repetitions, with 15 s of rest between each repetition and 30 s between each set. The exercises were performed 3 times in a lunge position, with the athlete pushing with unipodal support and performing plantar flexion using a 3-10 kg elastic band.

Group B engaged in eccentric exercises, completing 4 sets of 15 repetitions, with 30 s of rest between sets. These exercises were repeated 3 times and included both Alfredson exercises and exercises with a 3-10 kg elastic band.

At the end of the training, a special stretching session was carried out with emphasis on the gastrocnemius muscles. These stretches were performed in a sustained manner for 30 s and culminated with ballistic stretching.

Figure 1 describes the 2 protocols.

Assessments

The evaluation was carried out at baseline and after 4 weeks of intervention. The sampling was done manually. The anthropometric assessments of this trial were: ROM [26,27] measured

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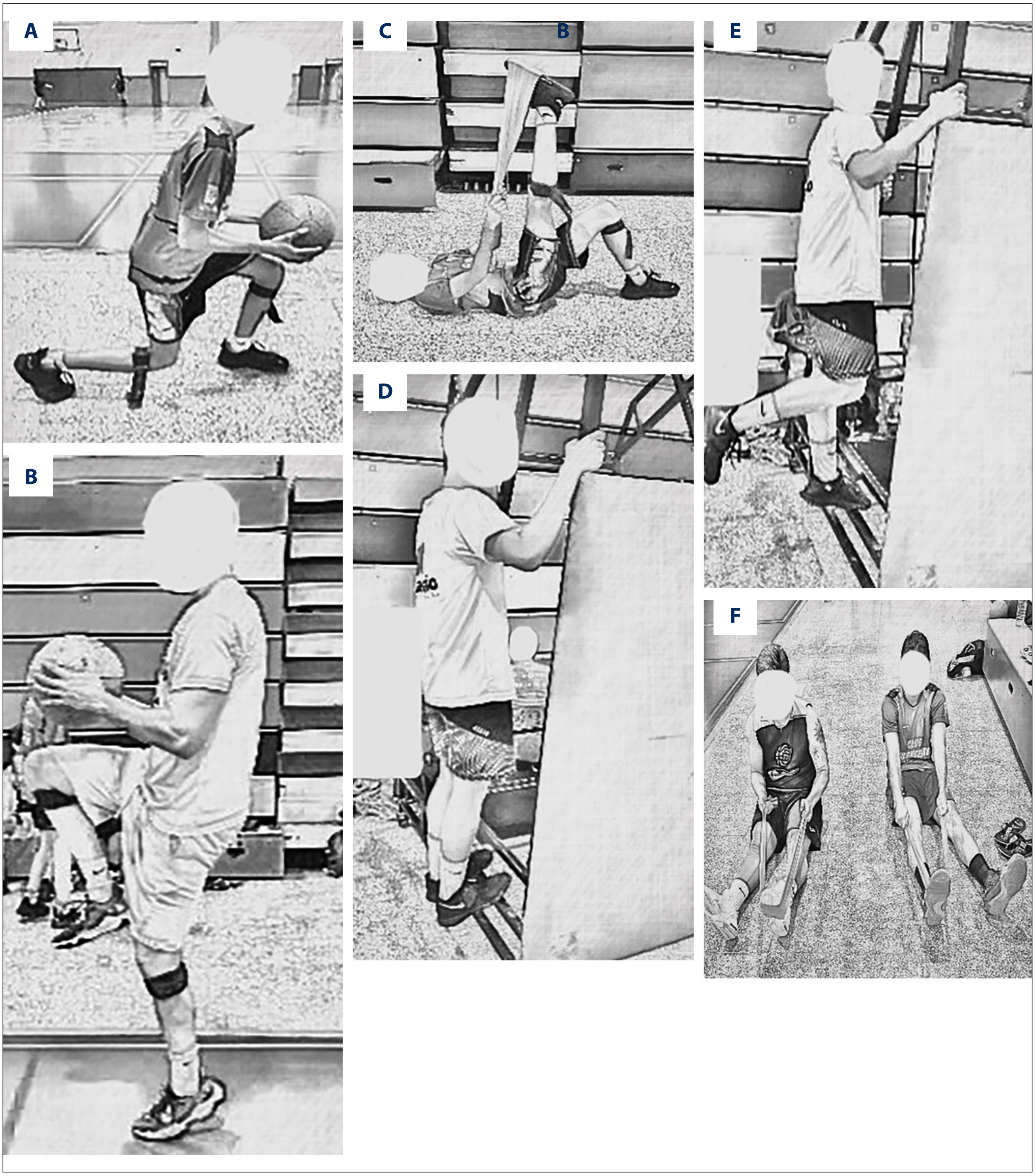

Figure 1. (**A**) Five-kg medicine ball lunge (Group A). (**B**) Push up with unipodal plantiflexion and 5-kg medicine ball (Group A). (**C**) Plantar flexion with elastic band, in prone position (Group A). (**D**) Bipodal Alfredson exercises (Group B). (**E**) Monopodal Alfredson exercises (Group B). (**F**) Plantar flexion exercises with elastic band, sitting down (Group B). Interventions of Group A with low-intensity training with flow restriction and Group B with eccentric exercises treatment protocol (*Photo Mania App iOS version*).

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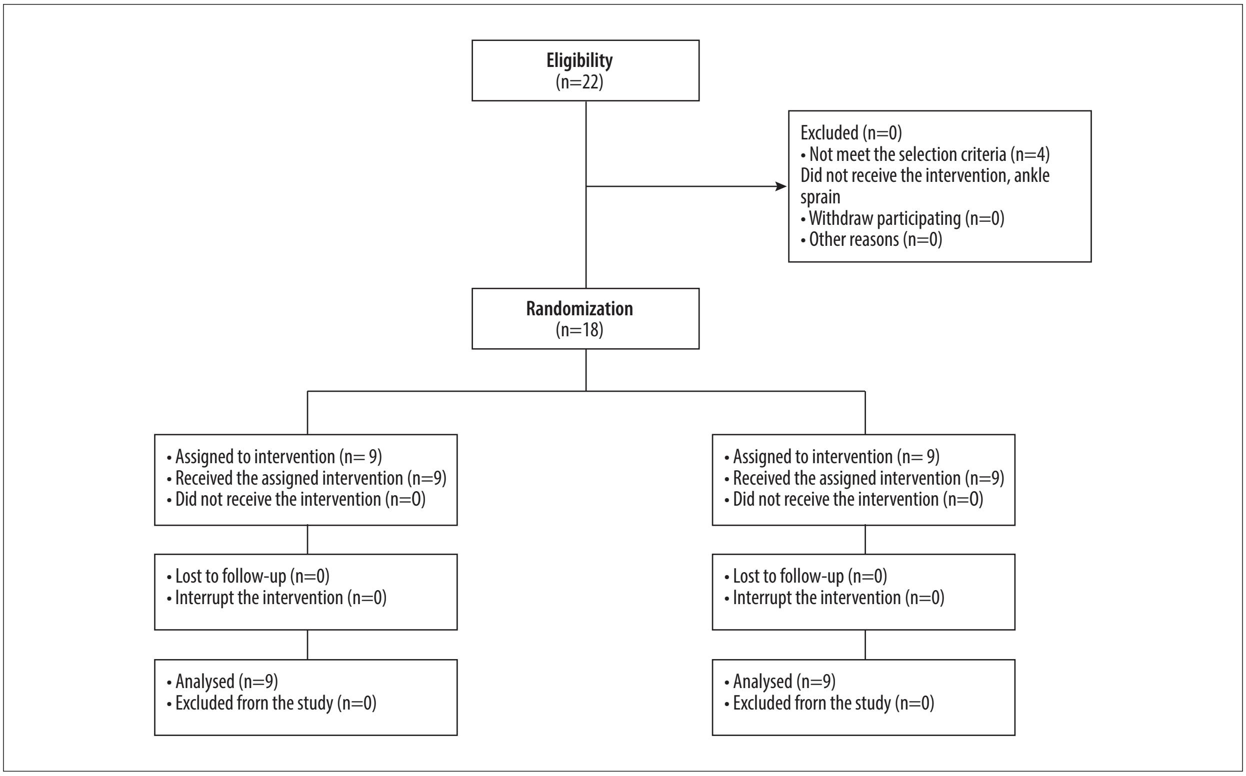

Figure 2. Flowchart of the study participants.

with athlete in prone position with 90° knee flexion to perform plantiflexion and dorsiflexion. Gastrocnemius girth [28] was measured with the athletes in seated position; the measurement was taken with a tape measure in the most prominent part of the muscle and the perimeter of both legs was assessed. Muscle strength was measured using the Daniels scale [29]. The strength of the gastrocnemius muscles was assessed with the athletes in prone position for evaluation of plantiflexion.

The Jump Power DMJUMP 2.5 brand jumping platform was used, through a mobile application (DMLAB) that takes data on the athletes' jumping power [31,31]. The athlete stands on the platform in a standing position; the evaluator teaches the way to execute the jump, which is arms at the hips, knee flexion, and jump with both feet at the same time. The participant must make 3 jumps to choose the one with the higher value.

Baseline effort perception was measured in Group A, in which the researchers counted the maximum repetitions performed, the effort was assessed with the scale, and the work intensity of 40% was calculated with the rule of three [32].

Statistical Analysis

The values presented in the text, figures, and tables are means±standard deviation (SD). Variables were described and between-group difference tests were performed for means and proportions (the *t* test for continuous variables and chi-square for categorical variables).

Analysis of covariance (ANCOVA) was performed to compare the 2 groups, and the baseline data served as the covariate. A 2×2 (time×group) ANOVA was used to determine differences in the type of training protocol of each group. Where necessary, Bonferroni post hoc analysis was performed, adjusted for type I error.

Statistical significance was accepted for all cases at a confidence level of 95% ($P \leq 0.05$).

Statistical analysis was performed using IBM SPSS Statistics 25 (SPSS, Inc., Chicago, IL, USA). No missing data were presented in the analysis of the information. For the secondary analysis, a two-way ANOVA with graphical illustration was performed, using the GraphPad Prism 8.0.1 program.

Results

Based on the sample size calculation and the eligibility criteria, athletes who met the study conditions were included in this trial. Considering the small number of participants and the exclusion criteria, only 18 basketball players were randomized (**Figure 2**).

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Table 1. Baseline group characteristics.

	Group A (n=9)		Group B (n=9)	
Psychometric variables				
Height (m)	184.33 (5.650)		180.67 (10.060)	
Weight (kg)	82.22 (17.100)		79.67 (17.240)	
Clinical variables				
Age (years)	21.44 (4.900)		19.00 (3.960)	
	n	**%**	**n**	**%**
Sociodemographic variables				
Gender (Male)	9/18	100/X,X	9/18	100/X,X

N – number of participants; % percentage; m – meter; kg – kilogram.

The characteristics of the athletes in Group A were average age 21 years, weight 82.22 kg, and height 1.84 m, while the average of group B was age 19 years, weight 79.67 kg, and height 1.80 m. No significant difference was shown between the 2 study groups at the baseline (*P*>0.05) (**Table 1**).

Referring to the ROM, the following has been verified for the 2 study groups at the end of the training: the Group A had an improvement at the right dorsiflexion with a mean of 2.44 grades and Group B had an improvement of 1 grade with no significant difference between groups (*P*=0.113) compared with the baseline data. For left dorsiflexion, Group A had an improvement of 2.78 grades and for the same side Group B had an improvement with a mean of 1.56 grades with *P*=0.187. For right plantar flexion, Group A had an improvement of 0.78 grades and for the same side Group B had an improvement of 1.56 grades with *P*=1. For left plantar flexion, Group A had an improvement of 0.44 grades and the Group B had an improvement of 1.22 grades with *P*=0.85. Right leg circumference for Group A was 0.33 cm and for Group B it was 0.55 cm with *P*=0.681. Left leg circumference had an improvement of 0.66 cm for Group A and Group B had an improvement of 0.45 cm, with *P*=0.824.

The jump height had an improvement of 1.4 cm for Group A at the end of the treatment and an improvement of 2.89 cm for Group B (*P*=0.944). Therefore, based on the data analyzed, no significant difference was shown between groups (**Table 2**). The applied force was 5 Daniels in all cases.

Also, difference between groups was detected, applying the ANCOVA with baseline measurements as covariance (*P*>0.05). ANCOVA univariate test showed no significant difference in the baseline covariance between the 2 groups (**Table 2**).

The ANOVA repeated measures analysis showed a significant difference within groups in time (*P*<0.05) except for left plantiflexion ROM (p=0.164). Regarding the difference between group*time and between groups, there was no significance difference (*P*>0.05) (**Table 3**).

The Tukey post hoc test also did not detect any significant differences. Therefore, another secondary analysis two-way ANOVA with graphical illustration was performed, using GraphPad Prism software (**Figure 3**).

Applying the bidirectional ANOVA, a significant difference was verified between the 2 groups in favor of Group A on the right dorsiflexion variable with *P*=0.018 and a difference between means with 95% confidence interval (CI) -2.444 (-4.487 to -0.4021). Regarding left dorsiflexion, there was also a difference between groups in favor of Group A, with *P*=0.027 and a difference between means in 95% CI -2.778 (-5.249 to -0.3068); while in the right plantar flexion, there was no significant difference between groups (*P*>0.05). No significant difference between groups for the left plantar flexion variable, with *P*>0.05, and there was no significant difference between groups regarding the perimeter of the right foot (*P*>0.05). A significant difference was found between the 2 groups in favor of Group A on the left foot perimeter variable, with *P*=0.026 and a difference between means in 95% CI -0.667 (-1.258 to -0.075). There was a significant difference between the 2 groups regarding the height of the jump in favor of Group B, with *P*=0.006 and a difference between means in 95% CI -2.899 (-4.932 to -0.865) (**Figure 3**).

Discussion

This study aimed to analyze the effect of low-intensity training with flow restriction versus the eccentric exercise protocol

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Table 2. Pre/post 1-month training measurements, mean differences, and analysis of variance.

Measures	Group A		Group B	
	Pre	Post	Pre	Post
Right dorsiflexion (°)	23.78 (±2.682)	26.22 (±1.856)	25.67(±2.062)	26.67 (±1.732)
Left dorsiflexion (°)	23.00 (±3,041)	25.78 (±1.202)	25.11 (±3.44)	26.67 (±2.236)
Right plantiflexion (°)	37.44 (±4.746)	38.22 (±4.738)	37.44 (±5.876)	39.00 (±4.123)
Left plantiflexion (°)	37.67 (±4.093)	38.11(±3.756)	38.11 (±5.833)	39.33 (±3.606)
Right leg perimeter (cm)	40.56 (±4.216)	40.89 (±4.372)	39.78 (±3.632)	40.33 (±3.606)
Left leg perimeter (cm)	39.78 (±4.265)	40.44 (±4.126)	39.33 (±4.062)	39.78 (±3.456)
Jump height (cm)	32.44 (±3.802)	33.84 (±5.060)	32.63 (±6.928)	35.52 (±7.339)

° – grade; cm – centimeter.

Variables	T1-T0		
	MD	IC 95%	Sig.
Right dorsiflexion (°)	-1.889	[-4.279 to 0.502]	0.113
Left dorsiflexion (°)	-2.111	[-5.358 to 1.136]	0.187
Right plantiflexion (°)	0.000	[-5.338 to -5.338]	1.000
Left plantiflexion (°)	0.444	[-5.509 to 4.620]	0.855
Right leg perimeter (cm)	0.778	[-3.155 to 4.710]	0.681
Left leg perimeter (cm)	0.444	[-3718 to 4.607]	0.824
Jump height (cm)	-0.188	[-5.773 to 5.395]	0.944

MD – mean difference; IC – Interval of Confidence, T1 – time 1 month; T0 – time baseline; Sig – significance.

Variables	Univariance ANCOVA for dependent variables		
	F	Sig.	Eta partial
Right dorsiflexion (°)	0.000	0.984	0.000
Left dorsiflexion (°)	0.236	0.634	0.016
Right plantiflexion (°)	0.930	0.350	0.058
Left plantiflexion (°)	1.352	0.263	0.083
Right leg perimeter (cm)	0.318	0.581	0.021
Left leg perimeter (cm)	0.847	0.372	0.053
Jump height (cm)	1.549	0.232	0.094

F – F test explained variance; Sig – significance.

on vertical jump power between 2 groups, in which important findings were identified as the improvement of ROM in favor of Group A training for the right/left dorsiflexion and the left leg circumference compared with the Group B protocol, which had an improvement for the right/left plantar flexion ROM, right leg circumference, and jump height.

Both groups had an improvement in the one month for the 2 different training protocols.

ROM analysis showed a significant difference in favor of Group A on right (*P*=0.018) and left (*P*=0.027) dorsiflexion, with a mean difference of 95%, due to the training protocol of Group A. Lunge exercises were performed using both legs

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Table 3. Difference within/between group analysis by time interactions, time, and group effect.

Variables	Differences within groups						Differences between groups		
	Time			Time*groups					
	F	Sig.	Eta partial	F	Sig.	Eta partial	F	Sig.	Eta partial
Right dorsiflexion (°)	8.697	0.009	0.352	1.529	0.234	0.087	2.085	0.168	0.115
Left dorsiflexion (°)	9.403	0.007	0.370	0.748	0.400	0.045	2.181	0.159	0.120
Right plantiflexion (°)	5.784	0.029	0.266	0.643	0.435	0.039	0.030	0.866	0.002
Left plantiflexion (°)	2.133	0.164	0.118	0.464	0.505	0.028	0.172	0.684	0.011
Right leg perimeter (cm)	5.565	0.031	0.258	0.348	0.564	0.021	0.128	0.725	0.008
Left leg perimeter (cm)	10.811	0.005	0.403	0.432	0.520	0.026	0.088	0.771	0.005
Jump height (cm)	13.682	0.002	0.461	1.657	0.216	0.094	0.116	0.737	0.007

° – grade; cm – centimeter; F – F test explained variance; sig – significance.

by enhancing the ROM since it starts from a position in which the athlete increases this dorsiflexion. The weight of the athlete, the 5-kg medicine ball, and environmental factors such as gravity are considered contributing factors [33,34]. These ROM measurements (dorsiflexion and plantiflexion) were taken at the beginning and at the end of the study. A 2016 study by Scott et al found minimal changes between groups, such as the control group and the group with an eccentric exercise protocol by using isometric exercises [22], and no significant findings were found in the plantiflexion ROM. Our study did not find significant differences in plantar flexion between groups (**Figure 3**).

It is important to highlight the mechanical changes at the tibiofibular-talar joint during the initial execution of the Alfredson exercise. This begins with the arthrokinematics of the ankle, particularly the posterior sliding of the talus during dorsiflexion. The loads and intensity used in the training played a significant role in the noteworthy findings of this study [35,36].

Regarding the measurement of the gastrocnemius perimeters, the statistics verified important changes between groups in favor of Group A of the perimeter of the left leg, with P=0.026 and difference between means in 95%; while in the right leg there were no differences between groups. Athletes always maintain a dominant leg for the execution of necessary responses that occur during the game, so it is important to know the dominant side of an athlete since a change in the difference in perimeters in the gastrocnemius is not worrisome if it remains within a range of 1-2 cm [5,26]. Therefore, most athletes carry out the initial impulse with the left leg to perform jumps, feints, and other game actions.

Further research is needed to assess this difference in perimeters between sides and see what changes were found on measurement of perimeters of the lower limbs. However, it is important to emphasize that studies have shown there is an increase in the perimeter at the lower limbs' muscle level with eccentric training for 1 month [13,22,37-39], so it would be of great interest to investigate the subject to find better explanations for this effect found in our study.

Finally, the vertical jump results favored Group B, with a P value of 0.006. This group worked under ischemia with loads at 40% of 1 RM, following a base protocol of 3 sets of 15 repetitions with an occlusion pressure of 200 mmHg, applied continuously for a maximum of 5 min.

This protocol was also applied in the Picón study [10]. It is important to evaluate the factors that could contribute to low-intensity training with flow restriction generating gains in jumping power.

Anatomically speaking, during medium- to high-intensity training (60-75% of 1 RM), there are physiological changes in the recruitment of muscle fibers. Specifically, there is an increase in the activation of fast-twitch muscle fibers. These fast-twitch fibers are predominantly responsible for generating muscle strength. This can be important aspect to consider about the application of bands (BFR) [39-41]. A 2020 study by Doma et al [34] involved a control group and an exercise group in which BFR was applied. They found a great change in the power of the jump compared to the control group; reaching a favorable result that influenced the training under ischemia, showing that this type of training can increase muscle strength with low intensities, which could be important. The

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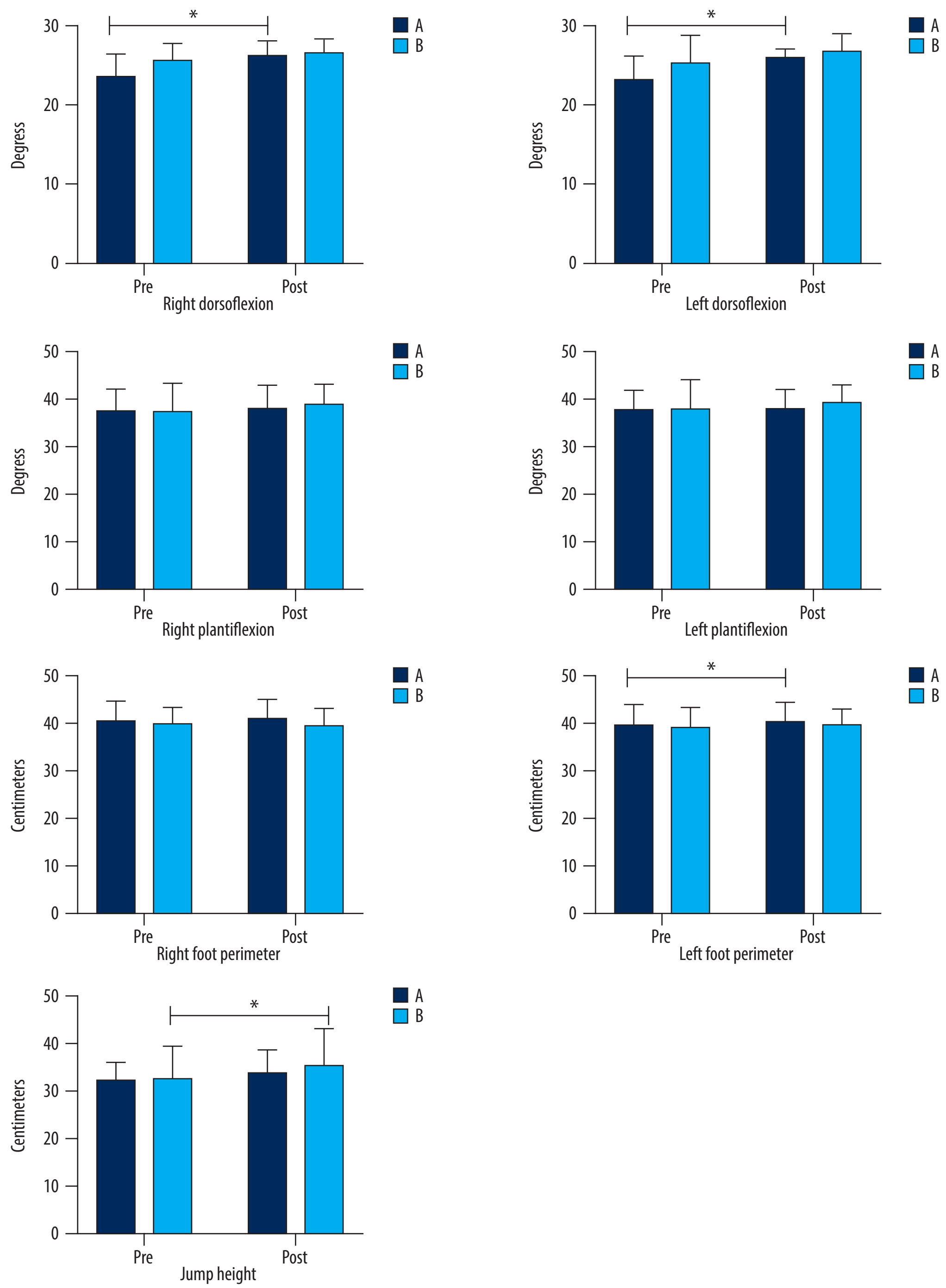

Figure 3. Mean and individual change comparison between group A, which followed low-intensity training with flow restriction and Group B with eccentric exercises treatment protocol pre and post 1-month training. Error bars represent standard deviation (*GraphPad Prism 8.0.1 version for Windows*).

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study by Gavanda et al used 7 cm wide cuffs secured below the patella during calf muscle training sessions, comprising 4 sets at 30% of the participants' 1-repetition maximum (1-RM) until failure. Their study findings indicated that utilizing blood flow restriction (BFR) during this regimen resulted in superior muscle mass and strength gains in the calf muscles compared to training without BFR. The results were similar to our study, where both groups were similar and had an improvement after 6 weeks of training. BFR protocols in both studies were more efficient in time.

The effect of low-intensity training with flow restriction versus the eccentric exercise protocol on jump power was identified through the platform jump. For both protocols, the measured effect was positive because the jump power percentage increased with respect to the initial values, represented in **Table 3**.

Referring to the means of the ANOVA statistical analysis of multiple comparisons, the significance between the variables was determined, reaching the conclusion that there was a significant difference between groups in favor of Group A for right/left dorsiflexion and left foot circumference and in favor of Group B for the height of the jump, measured with the jump platform.

The increase in muscle mass obtained with low-intensity training with flow restriction over the gastrocnemius muscles was determined by measuring it with a tape measure. An increase in muscle mass of approximately 50% was observed (**Table 3**).

The effects of the optimal range of movement in the ankle dorsiflexion and plantarflexion were analyzed by comparing the goniometer instrument means for both study groups. These results were significant, observing increased mobility in the ankle (**Table 3**).

Study limitations were the evaluation of the calf perimeter, since there is no exact method to calculate the location of the tape measure, obtaining quantifiable objective results with a margin of error and the limited number of participants enrolled in the study**.** Studies with larger sample sizes are needed. With the objective of finding a greater specificity in the evaluation of the 1RM, it could be carried out in a gym and familiarize the athletes with multiple sessions of the 1RM test. Another study weakness is the lack of a standardized protocol consisting of 1 set of 30 repetitions followed by 3 sets of 15.

A recommendation to enhance the applicability of this study would be to incorporate equipment that accurately measures the occlusion pressure being applied during BFR training. By using such equipment, researchers can ensure a more precise and consistent application of ischemic pressure across participants, thereby improving the study's specificity and replicability. This approach would facilitate a deeper understanding of the relationship between occlusion pressure and training outcomes, making it easier to implement BFR training in a standardized manner across different settings and populations.

It is important to have a larger number of samples and to have a control group, which would allow us to better evaluate the changes at the level of the variables with the respective training and evaluate the control group without any type of added training, to see if there are significant changes. Finally, the application of the BFR bands use the same pressure in each evaluation.

Conclusions

Low-intensity training with flow restriction and the eccentric exercise protocol were both effective in improving jumping performance. A significant improvement was shown in the jump height and ROM of the 2 study groups.

Ethics Approval

This study was approved by the Ethics Committee of the Catholic University of Murcia "San Antonio" with protocol No. CE012206.

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Declaration of Figures' Authenticity

All figures submitted have been created by the authors, who confirm that the images are original with no duplication and have not been previously published in whole or in part.

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References:

1. Takotra P. Past & present scenario of basketball in relation to olympics. Int J Res Ped Techno in Educ and Mov Sci. 2022;11(2):24-30
2. Hoffmann F, Batchelor RP. Manning MJ. Basketball in America: From the playgrounds to Jordan's game and beyond. Routledge. 2016. Available from: https://www.routledge.com/Basketball-in-America-From-the-Playgrounds-to-Jordans-Game-and-Beyond/Hoffmann-Batchelor-Manning/p/book/9780789016133
3. Seron BB, Oliveira de Carvalho EM, Greguol M. Analysis of physiological and kinematic demands of wheelchair basketball games – a review. J Strength Cond Res. 2019;33(5):1453-62
4. Facchinetti T, Metulini R, Zuccolotto P. Filtering active moments in basketball games using data from players tracking systems. Ann Oper Res. 2023;325(1):521-38
5. Rodríguez-Rosell D, Mora-Custodio R, Franco-Márquez F, et al. Traditional vs. sport-specific vertical jump tests: Reliability, validity, and relationship with the legs strength and sprint performance in adult and teen soccer and basketball players. J Strength Cond Res. 2017;31(1):196-206
6. Canavan PK, Vescovi JD. Evaluation of power prediction equations: Peak vertical jumping power in women. Med Sci Sports Exerc. 2004;36(9):1589-93
7. García-Pinillos F, Cámara-Pérez JC, Soto-Hermoso VM, et al. A high intensity interval training (HIIT)-based running plan improves athletic performance by improving muscle power. J Strength Cond Res. 2017;31(1):146-53
8. Sánchez-Sánchez J, Torres Martin L, Ramirez-Campillo R, et al. The effects of jump training on measures of physical performance, lower extremities injury incidence and burden in highly trained male soccer players. Res Sports Med. 2024;32(1):107-21
9. Pope ZK, Willardson JM, Schoenfeld BJ. Exercise and blood flow restriction. J Strength Cond Res. 2013;27(10):2914-26
10. Picón-Martínez M, Chulvi-Medrano I, Cortell-Tormo JM, et al. Acute effects of resistance training with blood flow restriction on Achilles' tendon thickness. J Hum Kinet. 2021;78:101-9
11. Jessee MB, Buckner SL, Mouser JG, et al. Muscle adaptations to high-load training and very low-load training with and without blood flow restriction. Front Physiol. 2018;9:1448
12. Dankel SJ, Jessee MB, Abe T, Loenneke JP. The effects of blood flow restriction on upper-body musculature located distal and proximal to applied pressure. Sports Med. 2016;46(1):23-33
13. Gavanda S, Isenmann E, Schlöder Y, et al. Low-intensity blood flow restriction calf muscle training leads to similar functional and structural adaptations than conventional low-load strength training: A randomized controlled trial. PLoS One. 2020;15(6):e0235377
14. Marcotte GR, West DW, Baar K. The molecular basis for load-induced skeletal muscle hypertrophy. Calcif Tissue Int. 2015;96(3):196-210
15. Martin-Hernandez J, Marin PJ, Menendez H, et al. Muscular adaptations after two different volumes of blood flow-restricted training. Scand J Med Sci Sports. 2013;23(2):114-20
16. Nielsen JL, Aagaard P, Bech RD, et al. Proliferation of myogenic stem cells in human skeletal muscle in response to low-load resistance training with blood flow restriction. J Physiol. 2012;590:4351-61
17. Loenneke JP, Fahs CA, Wilson JM, et al. Blood flow restriction: The metabolite/volume threshold theory. Med Hypotheses. 2011;77(5):748-52
18. Patterson SD, Ferguson RA. Increase in calf post-occlusive blood flow and strength following short-term resistance exercise training with blood flow restriction in young women. Eur J Appl Physiol. 2010;108(5):1025-33
19. Vechin FC, Libardi CA, Conceicao MS, et al. Comparisons between low-intensity resistance training with blood flow restriction and high-intensity resistance training on quadriceps muscle mass and strength in elderly. J Strength Cond Res. 2015;29(4):1071-76
20. Hylden C, Burns T, Stinner D, et al. Blood flow restriction rehabilitation for extremity weakness: A case series. J Spec Oper Med. 2015;15(1):50-56
21. Rahimian P, Toka L. A data-driven approach to assist offensive and defensive players in optimal decision making. Int J Sports Sci Coach. 2024;19(1):245-56
22. Scott BR, Loenneke JP, Slattery KM, et al. Exercise with blood flow restriction: An updated evidence-based approach for enhanced muscular development. Sports Med. 2015;45:313-25
23. Lim HY, Wong SH. Effects of isometric, eccentric, or heavy slow resistance exercises on pain and function in individuals with patellar tendinopathy: A systematic review. Physiother Res Int. 2018;23:1721
24. Cebrián-Ponce Á, Irurtia A, Carrasco-Marginet M, et al. Electrical impedance myography in health and physical exercise: A systematic review and future perspectives. Front Physiol. 2021;12:740877
25. Ryan D, O'Donoghue G, Rio E, et al. The effect of combined Action Observation Therapy with eccentric exercises in the treatment of mid-portion Achilles-tendinopathy: A feasibility pilot randomised controlled trial. BMC Sports Sci Med Rehabil. 2022;14(1):1-17
26. Gajdosik RL, Bohannon RW. Clinical measurement of range of motion. Review of goniometry emphasizing reliability and validity. Phys Ther. 1987;67(12):1867-72
27. Ore V, Nasic S, Riad J. Lower extremity range of motion and alignment: A reliability and concurrent validity study of goniometric and three-dimensional motion analysis measurement. Heliyon. 2020;6(8):04713
28. Andrews AW, Thomas MW, Bohannon RW. Normative values for isometric muscle force measurements obtained with hand-held dynamometers. Phys Ther. 1996;76(3):248-59
29. Hislop, H. Daniels and Worthingham's muscle testing: Techniques of manual examination and performance testing, 9e. Elsevier India. 2013. Available from: https://shop.elsevier.com/books/daniels-and-worthinghams-muscle-testing/brown/978-0-323-56914-9
30. Loturco I, Gil S, Laurino CF, et al. Differences in muscle mechanical properties between elite power and endurance athletes: A comparative study. J Strength Cond Res. 2015;29(6):1723-28
31. Carlos-Vivas J, Martin-Martinez JP, Hernandez-Mocholi MA, et al. Validation of the iPhone app using the force platform to estimate vertical jump height. J Sports Med Phys Fitness. 2018;58(3):227-32
32. Aleais DAS, Sullivan K, Ferreira P, et al. Acute dose-response of duration during the isometric forearm plank exercise on muscle thickness, echo-intensity, peak force, and perception of effort in recreationally-trained participants. Int J Exerc Sci. 2022;15(6):676-85
33. Sprick JD, Rickards CA. Cyclical blood flow restriction resistance exercise: A potential parallel to remote ischemic preconditioning?. Am J Physiol Regul Integr Comp Physiol. 2017;313(5):R507-R17
34. Doma K, Leicht AS, Boullosa D, et al. Lunge exercises with blood-flow restriction induces post-activation potentiation and improves vertical jump performance. Eur J Appl Physiol. 2020;120(3):687-95
35. Stevens M, Tan CW. Effectiveness of the Alfredson protocol compared with a lower repetition-volume protocol for midportion Achilles tendinopathy: A randomized controlled trial. J Orthop Sports Phys Ther. 2014;44(2):59-67
36. Habets B, Van Cingel REH. Eccentric exercise training in chronic mid-portion Achilles tendinopathy: A systematic review on different protocols. Scand J Med Sci Sports. 2015;25(1):3-15
37. Chulvi-Medrano I, Cortell-Tormo JM, Hernández-Sánchez S, et al. Blood flow restriction training in clinical rehabilitation: Occlusion pressure methods relative to the limb occlusion pressure. J Sport Rehabil. 2023;32(4):361-68
38. Feger MA, Donovan L, Herb CC, et al. Effect of impairment-based rehabilitation on lower leg muscle volumes and strength in patients with chronic ankle instability: A preliminary study. J Sport Rehabil. 2019; 28(5):450-58
39. Thiebaud RS, Abe T, Loenneke JP, et al. Acute muscular responses to practical low-load blood flow restriction exercise versus traditional low-load blood flow restriction and high-/low-load exercise. J Sport Rehabil. 2019;29(7):984-92
40. Killinger B, Lauver JD, Donovan L, et al. The effects of blood flow restriction on muscle activation and hypoxia in individuals with chronic ankle instability. J Sport Rehabil. 2019;29(5):633-39
41. Burkhardt M, Burkholder E, Goetschius J. Effects of blood flow restriction on muscle activation during dynamic balance exercises in individuals with chronic ankle instability. J Sport Rehabil. 2021;30(6):870-75

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