Case Report

Investigating the Effects of Blood Flow Restriction Exercises on Strength and Cross Section Area of Hamstring Muscles and Tendons: A Case Report

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ABSTRACT

Introduction: Hamstring injuries are one of the most common tendon injuries, especially in sports that require running and jumping. A comprehensive training program can help athletes to prevent this injury. Among suggested exercises, the Nordic eccentric training can reduce the injury rate by up to 50%; however, it is a high-load exercise that cannot be prescribed in the first stages of rehabilitation. Here, we describe a football player who used low-load resistance exercise with blood flow restriction as an alternative method to strengthen their hamstring after nine months of anterior cruciate ligament reconstruction surgery.

Case Description: A 19-year-old non-professional footballer with a body mass index of 22.18 kg/cm^2 was invited to participate in this study. The variables examined included strength and cross-sectional area of the hamstring muscles (mean and maximum strength) and the cross-sectional area of the hamstring tendons at their origin. The treatment program included a seated hamstring curl with a load of 30% 1 RM with blood flow restriction for four weeks (thrice a week).

Results: The hamstring muscle strength improved by 6.54%, and the cross-sectional area of the muscles and tendons changed as follows: Semimembranosus (tendon=0.07%, muscle=2.57%), semitendinosus (tendon=0.00%, muscle=-4.04%), and biceps-femoris (tendon=5.5%, muscle=4.34%).

Conclusion: Low load resistance training with blood flow restriction in this athlete improved the strength and cross-sectional area of the hamstring muscles as well as the cross-sectional area of the tendons. The changes observed in tendon, and muscle cross-sectional areas were more prominent for biceps-femoris. This case showed that a training program with blood flow restriction may be a good alternative for people who cannot tolerate high-load exercises in the early stages of their rehabilitation. Doing more extensive studies with more cases and a control group in the future can help our knowledge in giving the best exercise prescription to our patients.

Keywords:

Blood flow restriction; Hamstring muscles; Hamstring tendons

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Introduction

Hamstring muscle injuries are one of the most common non-contact injuries. The prevalence of this injury has increased in the last decade, accounting for 12% to 17% of all sports injuries. Meanwhile, it is more common in sports that require fast running, ball shooting, and jumping. This injury alone accounts for 15% to 50% of all muscle injuries in soccer. The rehabilitation of this injury requires a long time, usually more than a month [1]; therefore, preventive methods are valuable. The results of Van Dyk's systematic study in 2019 showed that Nordic eccentric training as a high-load exercise could reduce the likelihood of developing hamstring strain in a wide range of athletes by up to 50% [2]. Since it is a high-load exercise, it may not be the first to be prescribed for preventing exercise-induced injuries. Hence, choosing an appropriate alternative exercise is needed.

Low-load exercises with 20% to 30% 1RM with blood flow restriction (BFR) have been introduced to increase muscle strength and cause hypertrophy. BFR consists of a cuff on the proximal region of the upper or lower limbs. The cuff is filled with air, reducing arterial blood flow and possibly stopping the return of venous blood [3-5].

In two different studies, Hughes and Manoel E Lixandrao in 2017 showed that low-load training with BFR can increase muscle hypertrophy as much as high-load training with no BFR, even though its effect on strength is lower [6, 7]. A systematic study by Grønfeldt in 2020 also showed that low-load training with BFR could increase strength and hypertrophy as much as high-load training with less tissue stress [8]. Another study also proved that muscle hypertrophy and increase in strength can occur in a shorter period using low-load training with BFR than high-load training [9]. In addition, the results of a study by Centner et al. in 2019 showed that long-term (14 weeks) of low-load training with BFR could increase the cross-sectional area of the Achilles tendon and gastrocnemius muscle as much as high-load training [10]. Hence, low-load training with BFR in the early stages can be a good alternative to high-load training. In this study, we describe a football player who attended a BFR training study and missed exclusion because of his anterior cruciate ligament reconstruction surgery nine months before the beginning of the study. However, his results showed the effectiveness of this method for this patient regarding muscle strength, cross-sectional area, and tendon cross-section.

Case Description

The participant was a 19-year-old male (height=179 cm, weight=79 kg, and body mass index=22.18 kg/cm^2) non-professional football player who practiced regularly three days a week and attended a 12-session hamstring training study with BFR. The participant was informed about the benefits and risks of the study before the beginning of the research and provided the informed consent form. The patient could leave the treatment and study at any time he wanted.

As mentioned earlier, the subject had a history of anterior cruciate ligament reconstruction nine months before the study. The training program was as follows: The chosen exercise was hamstring curl since an electromyography study showed the maximum hamstring activity while doing curls compared to other exercises in the study [11]. The patient was first asked to sit on the bed to measure the strength of the hamstring muscles and find a basis for exercise load. The knee was fixed into 90-degree flexion, and the participant was asked to place his arms crosswise on his shoulders to prevent compensatory movements. In addition, two straps were fastened on the thighs to reduce compensatory movements in the lower limb. The strap connected to the dynamometer was located behind the calcaneus, preventing the ankle from moving backward and the knee from flexing. The person was then asked to try to flex the knee with maximum pressure for 5 s. Afterward, the participant rested for 10 to 30 s and then performed the other two trials. Of the three trials performed, the trial that recorded the most torque was considered the maximum force [12].

A 1 RM test was performed on the dominant leg (the leg used to shoot the ball) [13]. To determine the weight, a 1 RM test was performed, in which the person performed 1 to 3 hamstring curls with 40% to 80% 1 RM estimated by the therapist as a warm-up, then continuing in 5 trials with a maximum resting interval of 1 min. We determined the weight the person could tolerate during this movement [14].

After determining the weight, we used a weight of 15%-20% 1 RM, and in the next two weeks, a weight of 20%-30% 1 RM was used to prevent delayed-onset muscle soreness.

To use BFR, the person was first completely relaxed on a chair for 15 min. We calculated the minimum pressure that completely cut off the tibial pulse using a sphygmomanometer. The cuff was placed on the most proximal part of the lower limb to reduce the risk of superficial

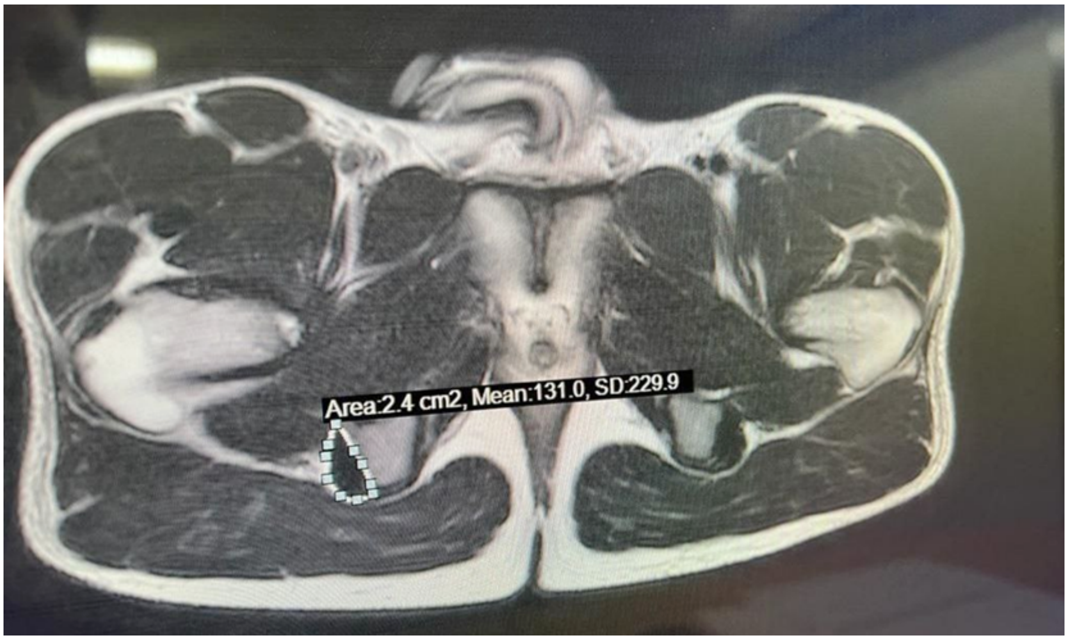

Figure 1. Cross section area of hamstring tendon (insertion to ischial tuberosity)

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nerve damage. Doppler ultrasound was also used to increase the accuracy in determining the pressure that interrupted the pulse and blood flow. So, the manual Doppler was held at an angle of 45 degrees (to prevent pressure and cut off the blood flow) in the direction of the flow on the posterior tibial artery in the lower limb. The minimum pressure that causes the Doppler device to stop and cut off the sound (acoustic noise) is called limb occlusion pressure, and 80% of it is used in the lower limb as the required pressure during exercise [13]. According to the protocol mentioned in previous articles (for strength training using BFR, the protocol of 30 repetitions in the first set and 15 repetitions in the following three sets was used (the rest interval between the sets is 30 s). Cuff pressure was not emptied between exercise sets, and the continuous technique was used [10]. During the training, the athlete was asked to determine the difficulty of the exercise based on the perceived exercise scale to determine the difficulty of the exercise. This number should be 6-8 (moderate to hard) [10] for athletes.

There was no complaint on the loading and tolerability of the intervention. Nevertheless, in the eighth session, the participant complained of pain at the origin of the hamstring tendon. Isometric muscle contraction and muscle tension tests were performed and positive to check for hamstring tendinopathy [15].

No intervention was taken to treat the suspicious tendinopathy, and there was no change in the training program, but the pain faded away after three sessions.

The variables evaluated in this study include the strength of the hamstring muscles, their cross-sectional area, the cross-sectional area of the tendons at their origin and insertion, and pain, which were evaluated before and after the intervention.

The method for measuring the strength has been described earlier, but to determine the thickness and cross-sectional area of the hamstring muscles and tendons, magnetic resonance imaging (axial T2 weighted, 1.5 Tesla, Philips sequence) was taken under the supervision of a resident radiologist.

The measurement site of the muscles was mid-thigh and the measurement site of the tendons was distal to the femur distal muscles. Meanwhile, the measurement site of the common tendons was inserted into the ischial tuberosity (Figure 1). To extract data from magnetic resonance imaging pictures, the ImageJ software (National Institutes of Health, Bethesda, Maryland, USA) was used to measure the cross-sectional area of each muscle [16].

Results

This study showed that after four weeks (12 sessions) of training with BFR, the maximum voluntary contrac-

Table 1. The outcomes before and after the intervention

Outcomes	Before	After	%Δ
Hamstring-muscle strength (mean) (kg)	27.5	29.3	6.54
Hamstring-muscle-MVC (kg)	17.7	18.9	6.77
Hamstring-tendon-origin-CSA (cm^2)	2.4	2.7	12.5
Semimembranosus-tendon-CSA (cm^2)	1.4	1.5	0.07
Semitendinosus-tendon-CSA (cm^2)	1.1	1.1	0.00
Biceps-femoris-tendon-CSA (cm^2)	1.8	1.9	5.5
Semimembranosus-muscle-CSA (cm^2)	19.4	19.9	2.57
Semitendinosus muscle -CSA (cm^2)	9.9	9.5	-4.04
Biceps-femoris- muscle -CSA (cm^2)	13.8	14.4	4.34

CSA: Cross-sectional area; MVC: Maximal voluntary contraction.

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tion and the average strength of the hamstring muscles were increased. The proximal hamstring tendons' cross-sectional area (CSA) rose more than other variables. The CSA of the semimembranosus and biceps femoris tendons also increased after the intervention, with a more significant increase in the biceps femoris muscle tendon. The CSA of the hamstring muscles rose only in the semimembranosus and biceps femoris, which was more significant in the biceps femoris. For the semitendinosus muscle, its CSA was reduced, and the CSA of its tendon remained unchanged. Regarding the participant's pain, it was reduced from 5 to 0 based on the pain numeric scale. More detail is provided in Table 1.

Discussion

This study described the effects of low-load training with BFR on the hamstring muscles and tendons' CSA and the strength of these muscles in an athlete. Hamstring muscles' strength and CSA, and the CSA of the semimembranosus and biceps femoris tendons at their origin, increased following the intervention. The results of this study are similar to the results of two studies conducted by Centner in 2019 and 2021 [10, 17], which compared the effects of low-load training using BFR with high-load training in Achilles and patellar tendons, respectively. The results of these two studies show that this method can increase the CSA of the tendons as well as the muscles' strength and cross-sectional area as much as high-load training. Therefore, this method can be a good alternative when it is not possible to use high-load exercises, such as when there is tissue damage. The results of a case study by Cuddeford and Skovlund in 2020 show that this method can be useful in patients with tendinopathy [18, 19]. Therefore, to compare the effects of this method with high-load exercises on the CSA of the hamstring tendons, it is better to do so with more cases and in the form of a clinical trial study.

Considering that this case was suspected of having hamstring tendinopathy in the eighth session, no change in treatment could reduce the patient's pain during the three sessions. Numerous studies have examined the effects of reducing pain using exercise therapy with BFR, such as the study by Skovlund in 2020, which showed that this method could reduce pain in single-leg squats in people with chronic patellar tendinopathyn [19]. However, the cause of the pain reduction in this method is still not completely clear, but the results of a study by Hughes in 2020 show that the levels of beta-endorphin and endocannabinoid following a minute of BFR training are higher than in high-load and low-load exercises. In addition, this study showed that a higher BFR pressure may reduce pain due to more significant discomfort and possibly activating the pain gate control pathway and greater secretion of analgesics [20]. Since, in our study, the hamstring tendons are located proximal to the cuff, we know that this method can also reduce pain in the proximal muscles of the cuff. The exact mechanism of these pain-reducing effects and biomechanical and morphological changes of the tendons, as well as the increase in strength and CSA of the muscles, are unclear; further research is required in this regard. Although there is little evidence in this regard, the physiological hypothesis for tendon thickening is that hypoxia, compared to normoxia, can improve the production of stem cells in tendon tissue. It has also been observed that hypoxia is a necessary condition for repairing the bone tendon junction, mainly due to hypoxia-inducible factors [21].

The reason behind small to no changes in the cross-sectional area of the semimembranosus muscle and tendon is also unclear yet; however, it can result from using hamstring curls, which will influence the biceps femoris the most [11].

Conclusion

This study was the first to show the effects of low-load resistance training with BFR on the hamstring tendon. In this case, low-load resistance training with BFR could increase the strength and CSA of the hamstring tendons and muscles. Therefore, it could be a good alternative for people who cannot tolerate high-load resistance training. Although this study demonstrates the benefits of this technique in increasing CSA of the hamstring tendons and muscles, more research should be conducted on patients with musculoskeletal injuries like hamstring tendinopathy to evaluate the effects of this technique.

Ethical Considerations

Compliance with ethical guidelines

This article was approved by the Institution's Ethics Committee of Iran University of Medical Science (Code: IR.IUMS.REC.1400.675). The participant was informed of all the benefits and risks of the study before the beginning of the study and approved an informed consent form. The patient could leave the treatment and study any time he wanted.

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Authors' contributions

All authors contributed equally to preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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