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The Effects of 8-Weeks Selected Exercises on Muscle Torque and Proprioception of Knee in Athletes with Injured Meniscus: A Clinical Trial Study

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Original Article

Abstract

Introduction: Applying rehabilitative exercise instructions before surgery is fundamental to minimize surgery complications and rehabilitation period as well. The aim of this research was to study the effects of 8 weeks of selected exercises on knee muscle torque and proprioception among the athletes with injured meniscus.

Materials and Methods: This was an applied research with quasi-experimental method. Subjects were 24 athletes with injured meniscus who were selected through convenience judgmental sampling. Based on the orthopedic surgeon's decision and their availability, subjects were divided equally into two experimental and control groups. Subject's muscle torque and proprioception of the injured knee was recorded at the beginning and after eight weeks of selective exercises. The intervention was performed one hour a day on daily basis. Repeated measures variance ANOVA, within the 0.05 level of significance, was used for inferential data analysis and the probable differences between group means.

Results: In both groups, maximum knee flexion and extension muscle torque and proprioception changed significantly ($P < 0.001$ for all three variables). Moreover, between groups differences were significant ($P < 0.001$).

Conclusion: In this study, positive effects of exercise on torque and proprioception of knee in athletes with injured meniscus were reported. It seems that applying proper exercises challenging functional system can be an effective means of progressing knee motor function preoperatively.

Keywords: Meniscus injury; Exercise; Muscle torque; Proprioception

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Introduction

The meniscus is a semicircular structure of fibrocartilage that is an integral part of the long-term health of the knee joint (1). The main role of the meniscus as one of the main components of the knee joint is to withstand the pressure and load applied to the knee joint (2). The meniscus doubles the contact surface area between the tibia and the fibula. Collagen fibers peripherally predispose the spherical surface of the condyle of the femur to absorb heavy load-bearing forces; So that the surface pressure in healthy knees is 50% less than that in knees without meniscus. Therefore, the role of the meniscus is a remarkable protective function (3). More than half of the contact forces are controlled by the knee medial compartment, and about 40 to 70% of the total body weight is borne by the menisci alone. The menisci also play an important role in the stability of the knee in impact (4). The stability of the menisci is necessary to perform their task properly, which is ensured by the meniscus branches and their proper placement (5,6).

The menisci are involved in joint lubrication and proprioception (7). Three functions have been raised for knee proprioception in the research literature. First, it is assumed that proprioceptive information, through feedback, protects the knee from potentially harmful movements (8-11). Second, the accuracy of the knee proprioception is essential for knee stability during static posture (12,13). Third, it is assumed that knee proprioception is important in coordinating complex movement systems and precise movements of the knee joint (12,13).

The knee joint is one of the most vulnerable

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anatomical parts of the body in athletes. One of these injuries is the knee meniscus injury, for which no definitive and complication-free treatment method has been found in athletes (14). Due to the function of the meniscus in creating stability and shock absorption, this structure is exposed to damage and the prevalence of meniscus tears is very high in individuals, especially athletes (4).

Radial, longitudinal, and complete meniscus tears are strongly associated with trauma (15). Meniscus damage is more common in young people during exercise or by changing the meniscus tissue. Additionally, non-contact events such as sudden changes in direction while walking and running, sudden and strong flexion of the leg, or a stress on the leg can cause damage to the menisci (16). Meniscus tears may be longitudinal, often starting at the posterior meniscus and may extend to the anterior meniscus (3,16). It is generally accepted that with 0 to 120° flexion, the medial meniscus moves about 5 mm and the lateral meniscus about 1 mm in the anterior-posterior (AP) direction (17). A small portion of this movement occurs in the posterior branches, predisposing them to shear forces in knees with ligament problems. On the other hand, 10 to 30% of the medial meniscus border and 10 to 25% of the lateral meniscus have almost good blood flow, which has a significant effect on meniscus reconstruction (12).

Meniscus tears affect 60 to 70 out of every 100,000 people annually, and about one-third of these injuries are related to exercise (15). Meniscus damage is more common in young people during exercise or by changing the meniscus tissue. Moreover, non-contact events such as sudden changes in direction while walking and running, sudden and strong flexion of the leg, or a stress on the leg can cause damage to the menisci (16). Previous studies and clinical observations have shown that compressive stresses on the menisci are a major factor in destructive joint injuries (17,18).

Meniscus reconstruction by arthroscopic surgery is a common treatment for knee disability or instability (19). Without a meniscus, articular cartilage and the bones beneath it are exposed to a great amount of pressure. Removal and repair of the meniscus have been shown to lead to premature inflammation of the joints and destruction of articular cartilage (5). Furthermore, one of the complications of meniscus injury that causes limitation in daily activities is decreased function and weakness of the knee muscles due to stiffness, instability, and reduced range of motion (ROM) of the knee (20). Many people limit their ROM due to pain, and this factor can gradually reduce the joint ROM and weaken the muscles involved in movement, causing balance and proprioception problems (21). Factors influencing the success or failure of meniscus reconstruction include preoperative knee laxity, status of anterior cruciate ligament (ACL) and other knee ligaments, knee ROM, and postoperative rehabilitation (22).

An athlete with a meniscus injury can return to activity quickly with proper treatment and rehabilitation (23). Meniscus injury classification, preoperative planning, and surgical training all play an important role in an individual’s success in this area (24). Research has shown that exercise can strengthen the muscles and proprioceptive receptors and help the injured person return to normal sooner. As a result, the goal of treating meniscus tears with rehabilitation exercises is often to control pain and swelling, restore normal ROM of the knee, and increase the strength of the knee supporting muscles (22). The rehabilitation program should include reducing inflammation, restoring movement, increasing strength, and returning safely to the competitions. This can be started before surgery and progressed with a step-by-step program that allows the athlete to set goals and progress. By identifying the various stages of knee rehabilitation, the athlete and his/her support team will be able to make progress in the appropriate program to return to exercise. During this process, preventive measures can be identified to prevent recurrence of the damage, thereby maximizing the level of performance and safety (23).

The rate of return to the previous level of sports activities is an indicator of the success of treatment for professional athletes. Besides, a proper understanding of the healing and pathology processes in the knee joint after injury and reconstruction is as important as the physiological aspects of the injury to the effects of exercise. If the exercise is performed well, it will lead to obvious changes in the body tissues and systems, which will also lead to improved performance in exercise (25). In the past, little research has been conducted before injured meniscus surgery (26,27) and knee function has often been evaluated postoperatively (23,28,29), focusing more on muscle strength (28) and less assessing joint ROM, balance, and proprioception after a period of exercise (23). While the return of the knee ROM to normal and reduced risk of postoperative dryness, maintained fitness in preparation for surgery, improved balance, strengthened knee function, and increased Quadriceps, Hamstring, and Vastus medialis strength are among the benefits of preoperative exercise program in other knee joint injuries (30-32). In fact, it is believed that the timely use of exercise, in addition to preventing the muscle weakness process in the knee with a meniscus injury, also accelerates its recovery (33). Since preoperative motor function improvement can be an effective step in returning to activity and exercise more quickly, it is necessary to examine the present subject by relying on athletes' exposure to meniscus injury as a common injury. In the present study, the question arose as to whether 8 weeks of selected training had a significant effect on muscle torque and proprioception in athletes with impaired meniscus?

Materials and Methods

This study was an applied clinical trial without blinding with the statistical population consisting of male and female athletes aged 18 to 25 years who referred to orthopedic clinics in Tehran, Iran, in 2019 with a history of meniscus injury. The study inclusion criteria included the diagnosis of meniscus injury in the athletes by a specialist surgeon who were candidates for surgery in the next three months and had been injured a maximum of six months ago. Because in many cases, meniscus injury is associated with injury to other knee ligaments, a complete history of the subjects was collected to be considered if they had injury other than meniscus injury to the knee. The surgeon also reported the severity of the injury, and the subject was excluded from the study if he/she had severe or very minor injuries. Thus, the orthopedic surgeon set an average limit that included third-degree tears in the red meniscus zone. In addition, increased pain, non-participation in exercises for three consecutive sessions and five interrupted sessions, and withdrawal from surgery were considered as other exclusion criteria.

The statistical sample of the study consisted of 24 athletes (12 females and 12 males) with meniscus injury who were selected using the purposive and convenience sampling method. Given the surgeon's decision and availability, half of the subjects participated in the training for 8 weeks (experimental group) and the other half who could not attend the training program did not participate in it (control group). The minimum sample size was obtained as 22 people using the Mead resource equation (E = N-B-T) (34), which in the present study, 24 people were considered. In this equation, E, N, B and T are the component error degree of freedom, the number of subjects, the block component degree of freedom, and the degree of freedom of the treatments, respectively. All stages of the study were approved by the ethics committee in the research of the Ministry of Health and medical Education and before starting the study, the method was registered in the Iranian Registry of Clinical Trials (IRCT) system.

The researcher first talked to several orthopedic surgeons, and some of them expressed their readiness to introduce patients with appropriate study conditions (subjects). Due to the limitation in selecting patients with all the conditions to participate in the study, a 12-month period was considered for the patient to be introduced by the orthopedic specialist. During this period, whenever a patient with the desired characteristics who wished to participate in the project was referred to the researcher. The subjects read the form of familiarity with the study stages and if they agreed to cooperate, signed the consent to participate in the study. After the presence of the subjects in the laboratory of pathology and corrective exercises (Noor Afshar Subspecialty Hospital, Tehran), first their personal characteristics were recorded and then, the amount of muscle torque and proprioception of the injured knee of the subjects were recorded at the beginning of the study and after 8 weeks of the selected rehabilitation exercises before surgery. The subjects in the experimental group performed the training protocol individually for 8 weeks under the supervision of the researcher. It should be noted that the time of referral of the patients by the orthopedic surgeon and also, the time of meniscus surgery of patients were different, performed in a period of 12 months. The objective of these rehabilitation exercises was to achieve a higher preoperative functional state, which led to increased strength and decreased stressors (35). Then, the amount of the muscle torque and proprioception of the injured knee of all subjects were recorded again before surgery. In order to avoid the effect of the test repetition confounding factor, the order of the tests was randomly selected and a 5-minute break was given between the two consecutive tests.

The isokinetic dynamometer (Biodex system 3 isokinetic dynamometer, USA) was calibrated before the tests were performed to ensure the accuracy of the output results. The subject under test sat on the dynamometer seat, with the seat backrest angle considered 85°. The axis of the dynamometer was aligned with the axis of rotation of the knee (to perform this pattern, the external epicondyle of the thigh was used as a bone marker as the axis of rotation of the knee). In order to prevent the blockage of the arteries, a suitable space was considered between the chair and the area behind the knee. The knee connection pad was placed in the proximal part of the medial malleolus and fixed with a strap (36).

The test was performed in the 90° ROM of flexion to full extension of the knee. In this experiment, first the subject warmed up with 15 repetitions of knee flexion and extension and then they were tested in two stages with five repetitions (to reduce the test error) and had a 60 second rest between the repetitions. This test consisted of obtaining maximum flexural and extensor torque at a speed of 30°/s. For all subjects, first the maximum flexural torque and then the maximum extensor torque were recorded at 30°/s. For this purpose, the subject's leg was fully extended, so that the person had no contraction in the knee, then it was released, and the device recorded the weight of the person's leg. The person's leg was then brought to a 90° angle of flexion, and the person was asked to open and bend his/her leg with maximum force upon hearing the device horn sound (37). The device recorded information about the maximum torque of the flexor and extensor muscles of the knee regardless of the subject's weight, the maximum torque of the flexor and extensor muscles of the knee considering the subject's weight, torque at an angle of 30°, maximum work of the subject in each contraction and time to reach the maximum torque, the maximum torque angle, the stress expansion rate, the total muscle strength, the work to body weight ratio, the total work, the fatigue due to working, average power, ROM, acceleration increase and decrease time, the agonist to antagonist muscle torque ratio, and the torque with the gravity effect. In the present study, the maximum torque of the flexor and extensor muscles of the knee was employed, regardless of the person's weight.

In order to ensure the accuracy of the device output data during the test, the graphs were reviewed by the researcher according to the results of previous studies. Besides, in order to reduce the noise, the signals were filtered by the device software and the data processed were used for further analysis. After all the necessary measures were taken to determine the muscle torque value, the subject was asked to actively place his/her leg at the target angle once to get acquainted with how to test the proprioception. The speed of the device was set at 180°/s so as not to create resistance. For the main test, the target angle was 30° of knee flexion, to which the subject was first asked to bring their leg with the eyes open. When the subject's leg angle reached 30°, the device fixed the leg and held it in that position for 5 seconds. The person's leg then returned to the starting position, and this time, the person was asked to close his/her eyes and reconstruct the desired target angle, and when he/she placed his/her leg at 30° of flexion, he/she pressed the control button of the device. This was performed three times and the mean angle reconstruction error (joint proprioception) was recorded as the absolute active angle reconstruction error (38).

The protocol used in the present study was taken from the Lennon and Totlis' study training program entitled "Rehabilitation and Return to the Play Following Meniscus Repair" and modified (35), which was published in a booklet entitled Surgical Techniques. This program consisted of 8 weeks of daily training for one hour per day, which was modified by the researcher using the principles of frequency, intensity, time, and type (FITT) of training with the discretion of the specialist physician to be applicable to the subjects. These exercises included stretching, strengthening, and balance exercises (Figure 1).

Descriptive statistics and statistics such as mean and standard deviation (SD) were applied to summarize and organize the data. The data distribution was assessed by the Shapiro-Wilk test. Repeated measures analysis of variance (ANOVA) was used to inferentially analyze the data and express possible differences between the mean values of the groups. Data were analyzed in SPSS software (version 22, IBM Corporation, Armonk, NY, USA) taking into account $P < 0.050$ as the data significance level.

Results

The dropout of participants in both experimental and control groups is presented in figure 2. Based on the Shapiro-Wilk test results, in all study variables by group, the variables followed a normal distribution ($P > 0.050$). Therefore, the use of a parametric approach in analyzing the results was logical. A comparison of the demographic characteristics of the subjects based on the results of the Independent titest is presented in table 1. The t value did not show a significant difference in any of the variables measured ($P > 0.050$). Thus, in general, the two groups of control and experimental can be considered demographically homogeneous. It should be noted that the number and grouping of the male and female subjects in the study were equal.

The Box test (39) results presented in table 2 indicated that the observed covariance matrices related to the dependent variables in the two study groups were identical (without significant differences). Therefore, repeated measures ANOVA was used for inferential analysis of these data.

The Mauchly's test of sphericity (40) suggested that the sphericity condition was met [Indicators (F) of the Greenhouse-Geisser effect were reported]. Table 3 represents the results of the repeated measures ANOVA parametric test for the study variables. The differences in the knee flexor and extensor muscle torque and proprioception were significant when the mean scores between the groups in the pre-test and post-test were compared.

Do not use resistance for the first 6 weeks.
Use inactive movements for the first 2 weeks of the training period, due to the patient's pain and to avoid further inflammation.
For the first 6 weeks while walking, use the Long Knee Cage brace, which is locked in the knee extension position (full knee extension applicable for each person).
Do not strengthen the hamstrings for the first 6 weeks due to the connection of the Semimembranosus and Popliteus muscles to the medial and lateral menisci.
From the sixth week, the patient should be able to bend the knee passively to a 120-degree angle without pain and improve quadriceps neuromuscular control.
The ROM of the knee joint during the training weeks should be based on the patient's pain response to prevent effusion:
First week: 0 to 90°, second week: 0 to 100°, third week: 0 to 120°, fourth week: 0 to 135

3- Reconstruction stage (weeks 7-8)
The patient must have complete inactive ROM of the knee (without effusion), normal gait, adequate lower limb strength, and the ability to control the knee in single-leg activities in order to enter this stage.
Stretching
As in the past
Strengthening
Increasing intensity (with weight) and decreasing the number of movements
Increasing the depth of the closed chain movements
Balance and proprioception
Using Bosu ball or Wobble Balance Boards for balance
Starting exercises with eyes closed
Squats on Bosu ball (safe ROM)
Improving movements related to single-leg exercises
Increasing the time and intensity of the exercise bike
Swimming and exercises in the water, except for breaststroke
Cryotherapy

2- Strengthening stage (weeks 3-6)
Stretching
In addition to the previous muscles, the Psoas, Priformis, and Tensor fascia lata should also be stretched.
Strengthening
Start of the squat movement chain (from 90° to above)
Lounge, going up and down the stairs
Starting foot press (from 90° to more)
Starting strengthening hamstring (from isometric to isotonic exercises)
Stepping to the side
Wall squat (70°)
Deadlift
Continuing to strengthen the central muscles
Balance and proprioception
Beginning of weight transfer (both feet)
Single-leg movements
Practice on unbalanced surfaces
Walking exercises (focusing on the heel-toe pattern)
Starting training with an exercise bike (when flexion is 110° without pain)
Cryotherapy

1- Protective stage (weeks 1-2)
Manual therapy
Patellar mobility at different angles
Early return to ROM in knee extension with force (avoidance of hyper extension in anterior branch repair)
Stretching
Stretching gastrocnemius, hamstrings, and quadriceps muscles (in the protected ROM)
Quadriceps neuromuscular retraining
Quadriceps sets with feedback or sequential mode
(Burst mode) and isometric exercises of the quadriceps at different angles
Power
Raising the leg
Active knee extension
Strengthening central muscles
Practicing walking with crouches
Strengthening the muscles of the upper body with the help of an ergometer
Cryotherapy
20 minutes (to control pain and swelling)

Figure 1. Ttraining protocol used in the present study
ROM: Range of motion

In other words, when the score changes of each of the two groups are considered separately, the significance level changes and the pattern of internal changes of the groups can be considered significant. To compare the amount of group changes, refer to the next column in table 3.

Referred by the orthopedic surgeon (n = 24)

Assigned in control group (n = 12)
Assignment of individuals
Assigned in experimental group (n = 12)

Absence from exercises and tests (n = 0)
Interventions and tests
Absence from exercises and tests (n = 3)

Analyzed (n = 12)
Analysis
Analyzed (n = 9)
(Two due to fear of further injury and pain and one due to cancellation of surgery)

Figure 2. Study process flow based on consolidated standards of reporting trials (CONSORT)

Table 1. Demographic characteristics of the subjects

Variable	Group	Mean ± SD	t-statistic	P
Age (year)	Control (n = 12)	22.16 ± 2.48	0.566	0.891
	Experimental (n = 9)	21.55 ± 2.40		
Weight (kg)	Control (n = 12)	80.00 ± 15.06	0.572	0.098
	Experimental (n = 9)	83.22 ± 8.68		
Height (cm)	Control (n = 12)	183.50 ± 9.85	0.145	0.702
	Experimental (n = 9)	184.11 ± 9.04		

SD: standard deviation
Data are reported as mean ± SD.

This column shows that the intra-group changes were significant for the variable of the knee flexor and extensor muscle torque and not significant for the variable of proprioception. In the last column, the interaction of the intra-group changes (slope of the change line) was significant.

The general conclusion that can be inferred from the data in table 3 is that the knee flexor and extensor muscle torque, as well as the knee proprioception, changed significantly in both groups (significant intra-group changes) and the trend of these changes in both groups was significantly different from each other. Therefore, 8 weeks of selected training affected the knee flexor and extensor muscle torque and proprioception of athletes with damaged meniscus. The attrition rate of the subjects in the present study was 12.5% and belonged only to the experimental group. After conducting the intention-to-treat (ITT) analysis, no effect was observed on the extensor torque, but a significant change was observed in the flexor torque and proprioception. The ITT size was respectively 0.0035 and 0.767 for the flexor torque and proprioception. The repeated measures ANOVA test results indicated that the selected exercises had a significant effect on the maximum flexor torque of the knee muscles. Additionally, based on the results, a significant difference was observed between the maximum torque of the knee extensor muscles in the control and experimental groups. Given the findings, the selected exercises had a significant effect on knee proprioception. In fact, in the control group, a significant decrease in torque (on average 1% decrease compared to the pre-study conditions) and a significant increase in the absolute error of the active angle reconstruction (about 2.5% increase), albeit being clinically small and negligible, confirmed the deterioration of the functional status of the athlete's knee during exercise; Whereas in the experimental group, an 8 to 13% improvement in muscle torque and a 16% reduction in the reconstruction error, which was clinically observable confirm the value of the exercises studied in improving the condition of the knee joint.

Discussion

The present study compared the effect of using a specific training program on the knee flexor and extensor muscles and proprioception of athletes with meniscus injury who were candidates for surgery. The exercises seem to be effective in improving the torque of these muscles and improving the proprioception to the initial position of the knee and also compared to the control group.

Changes in knee flexor and extensor muscle torque: Although the flexor and extensor muscle torque of the knee changed significantly in both experimental and control groups, the trend of these changes in the two groups was significantly different from each other. Therefore, it seems that 8 weeks of selected training has a positive effect on the torque of the knee muscles of athletes with damaged meniscus.

A study was conducted with the aim to find a suitable rehabilitation program for knee function of athletes undergoing lateral meniscus surgery and its subjects consisted of 30 athletes aged 18 to 35 years who were equally divided into two groups of neuromuscular training and strength training. All surgical symptoms improved significantly in both groups after 4 and 8 weeks after surgery, and subjects in both groups showed a significant increase in endurance and muscle strength (28).

Table 2. Box covariance matrix identity test

Variable	M Box	F factor	Degree of freedom 1	Degree of freedom 2	P
Maximum torque of the knee flexor muscles	2.682	0.788	3	28762.796	0.500
Maximum torque of the knee extensor muscles	31.827	9.357			0.094
Absolute active angle reconstruction error	7.281	2.141			0.093

Table 3. Findings related to repeated measures analysis of variance (ANOVA)

Variable	Group	Pre-test	Post-test	Percentage of progress	Intergroup degree of freedom (1,19)	Intra-group degree of freedom (1,19)	Interactive degree of freedom (2,19)
Maximum torque of knee flexor muscles (BW/Nm)	Control	120.33 ± 9.74	118.08 ± 8.62	-1.90	F = - 58.219 *P < 0.001	F = 11.593 *P = 0.003	F = 4060.375 *P < 0.001
	Experimental	127.44 ± 8.42	137.88 ± 9.72	8.20	η^2 = 0.754 β-1= 1.00	η^2 = 0.379 β-1= 0.898	η^2 = 0.80 1-β = 1.00
Maximum torque of knee extensor muscles (BW/Nm)	Control	252.33 ± 29.89	250.25 ± 28.52	-0.80	F = 36.122 *P < 0.001	F = 70.159 *P = 0.015	F = 1784.465 *P < 0.001
	Experimental	267.44 ± 19.80	303.11 ± 37.98	13.30	η^2 = 0.655 β-1= 1.00	η^2 = 0.274 β-1= 0.719	η^2 = 0.989 1-β = 1.00
Absolute active angle reconstruction error (degrees)	Control	3.63 ± 0.81	3.72 ± 0.95	-2.50	F = 20.275 *P < 0.001	F = 0.002 *P = 0.967	F = 374.895 *P < 0.001
	Experimental	3.99 ± 0.98	3.34 ± 0.74	16.30	η^2 = 0.522 β-1= 0.991	η^2 = 0.010 β-1= 0.050	η^2 = 0.952 1-β = 1.00

*Significant difference at the level of P < 0.050

In another study, a comparison was made on the effect of exercise therapy versus arthroscopic meniscectomy for knee function in middle-aged patients with degenerative meniscus tear. In 96% of the subjects, there was no accurate radiographic evidence of osteoarthritis. The interventions included 12 weeks of exercise therapy or arthroscopic meniscus surgery. The objective of the analysis was to determine the difference between the two groups in changing knee injury, thigh muscle strength, and the score of the Knee Injury and Osteoarthritis Outcome Score (KOOS) within two years. No significant difference was observed between the two groups in KOOS indices during the two years and no serious side effects were reported in either group; While three months after the intervention, muscle strength improved in the training group compared to the control group. Overall, the differences due to surgery observed after two years of follow-up were small, but exercise therapy compared to surgery had positive effects on improving the thigh muscle strength (41), which is consistent with the results of the present study.

In another study on 70 patients over a four-month period to evaluate two rehabilitation approaches (exercise therapy and non-exercise) after meniscus arthroscopy, it was revealed that after three months of exercise therapy, the experimental group had better results in pain and function compared to the control group. These results remained similar to the post-test results after a 12-month follow-up (42). The findings of a review study on 25 articles showed that knee function and ROM in patients undergoing partial meniscus arthroscopy improved with outpatient physiotherapy for a home exercise program (43). The results suggested that the four-month functional training program had a positive effect on functional performance, endurance, and thigh strength in middle-aged patients after meniscectomy, and the more treatment sessions, the more positive effects of exercise (44). Since many studies have used the maximum muscle torque to measure strength (45-49), it can be said that the results of all the above studies (42-44) were somewhat consistent with the findings obtained due to the exercises of the present study, which stated that the knee joint torque increased after 8 weeks of selected exercises. The use of isokinetic dynamometer is the gold standard in the evaluation of muscle strength (50). Measuring muscle strength in this way, by evaluating and comparing normal and abnormal conditions, establishes goals for recovery and rehabilitation, allowing for quantitative follow-up of disease status and response to treatment (51).

Decreased knee muscle torque following meniscus injury has been reported in some studies (52,532). In athletes, performing basic rehabilitation exercises to repair a torn meniscus after an injury not only offers potential benefits for recovery, but also prevents post-injury consequences for the affected limb, such as muscle atrophy and loss of proprioception that may delay return to normal postoperative conditions (38). Mechanical stabilization through surgery is recommended, but it is not sufficient to achieve normal knee function, and appropriate exercise is recommended as a way to improve neuromuscular function (54). In particular, meniscectomy does not appear to be superior to exercise therapy in terms of pain and overall function, and conservative therapies are as effective as surgery (54). The findings of the present study confirmed the clinical position of exercise in improving the function of knee muscles in meniscus injury.

To ensure the lack of interruption in torque progression following exercise, it is necessary to increase the intensity of the exercise gradually. These changes must be controlled in such a way as to create both a dynamic stability, and at the same time, prevent these fluctuations from causing displacement and damage to the joint. Thus, improving muscle strength will enhance the joint stability and at the same time, increase the angular torque of the muscles. The exact mechanism of strength enhancement due to exercise is still unknown, but its basic principles are known. In sum, the two processes of muscular hypertrophy and neural adaptations, which promote neuromuscular interactions, are responsible for this increase. Since the training program used in the present study included various strengthening exercises with different types of muscle contractions, it can be assumed that neurological factors such as increased muscle recruitment or change in excitability reflex are the reason for improving muscle torque (55,56). It is also important to note that the smaller change in knee flexor torque in the present study may be due to the connection of the semimembranosus muscle to the posterior branch of the medial meniscus. This muscle is one of the main muscles involved in knee flexion, and since the injury occurs in the medial meniscus and this muscle is attached to the medial meniscus, the position of the muscle and the condition of the injury may not allow sufficient change in torque by making restrictions and less change in the amount of the knee flexor torque is due to this issue.

Proprioception and active angle reconstruction absolute error: Based on the results of the current study, it seems that the 8-week selected training had a favorable effect on the knee proprioception of athletes with damaged meniscus. Clinically, proprioception is assessed by the amount of passive movement or the ability to move the joint to a predetermined position (38). A study evaluated the effect of coordination exercises on the proprioception errors of the injured knee, including in cases of meniscus injury of professional male footballers (57). The exercises used in the experimental group were somewhat consistent with the exercises used in the present study and the control group performed traditional stretching and strengthening exercises. The proprioception error for the right and left knee joints in the experimental group was significantly reduced after the coordination training program (57). These findings were in line with the results of the present study. Based on a study of 20 patients with a history of knee pain and functional limitations and degenerative meniscus tears, the subjects performed a neuromuscular and strength training program for 12 weeks, which resulted in improved muscle strength and functional tests immediately after the study. In most subjects, these effects lasted up to one year after the intervention, and although some participants complained of pain during the study, none of the patients underwent surgery after one year (58).

It is claimed that one to two years after a partial meniscectomy, the proprioception and ability of the knee muscles on the operated side decreases compared to a healthy knee, and this significant deficiency indicates the importance of improving muscle function and proprioception in these patients (59). Even the absence of a small portion of the meniscus can damage the proprioception in the knee (60). The joint, muscle, tendon, and skin receptors are responsible for receiving the information related to proprioception and position sense (61); while the muscle spindles are the primary source of proprioceptive information (62). When the information received from the muscle spindles decrease, the joint receptors play a more important role in the awareness of the brain of the joint conditions; although in these conditions, the accuracy of the position sense decreases dramatically. Skin afferents are also involved in proprioception, but they are not the primary terminal for this sense. Generally, the muscle spindle afferents, and perhaps golgyi tendon organ (GTO) are the initial receptors of proprioception, and in the next step, this information is originated from capsule, ligament, and skin and subcutaneous tissues (63). The maximum sensitivity of muscle spindles and GTO take place in the final ROM of the joint movement (38,64). For this purpose, the proprioception assessed using the active angle reconstruction method in the present study, was measured in the final ROM to highlight the role of the receptors associated with muscle spindles and GTO.

As expected, all variables related to motor function showed a significant increase due to rehabilitation exercises in the experimental group and not in the control group. In cases where meniscus injury occurs due to trauma, as is often the case in athletes' knees, due to the activation of the inflammatory cascade, fluid accumulation in the area leads to physical pressure on the nerve endings in the area (65). Besides, in the acute phase, with the accumulation of waste substances due to injury, the secretion of histamine increases and with increasing the diameter of blood vessels in the area of injury, nerve sensitivity also increases (65). The resulting set of pain and inflammation causes a protective spasm of the muscles around the knee. Therefore, in the first days after the injury, the person experiences severe movement limitations (66).

The severity of the pain and limitation of movement is often so great that in the first one to two weeks, the person cannot even bear the weight (23,67). With a gradual reduction in inflammation and spasm, the pain subsides and the injured person makes good progress in motor function at this stage, even if he/she rests and does not exercise (68).

Since in the present study, the pre-test was performed after the acute stage of the injury (the condition for entering the study was at least 6 months from the time of injury), the subjects had undergone the inflammatory reaction and had reached a stability in symptoms and performance. However, the relative decline observed in the indices studied in the control group, which was statistically significant, although not clinically significant, indicates a gradual decline in sensory-motor function of the knee. While the use of the proposed exercise program not only prevented this gradual decline, but also significantly improved the knee function of the individual with a clinically significant value over 8 weeks.

Limitations

The subjects' mental condition was not assessed before surgery. Dealing with metnal effects following a physical decline can be a major challenge, and mental health is very effective in rehabilitation of the injured person (69). Lack of motivation to perform the rehabilitation, fear of re-injury, constant denial of the severity of the injury, etc., are some of the cases that the injured person faces (70).

The age range for selecting subjects was 18 to 25 years, which the number of subjects increased to only 24 in about 12 months, and this number decreased during the study (the number of subjects reached 21 at the end of the study). Although the power of the present study is acceptable, it would still be desirable to conduct a study of a higher volume. Lack of use of random sampling and division method is also one of the limitations of the present study. The researcher intended to examine the measured variables after surgery in order to perform a follow-up in the study, which was not possible due to the prevalence of the coronavirus disease-2019 (COVID-19) and the lack of interest of the subjects to continue the cooperation.

Recommendations

It is suggested that in future studies, the durability of this training method be examined by performing follow-up tests and also examining the knee muscle torque and proprioception after surgery. Furthermore, future studies are recommended to perform investigations on other knee injuries for other age groups and non-athletes, in addition to conducting comparisons with other protocols.

Conclusion

On the basis of the findings of the present study, it can be declared that 8 weeks of the selected training had an effect on muscle torque and knee proprioception of athletes with damaged meniscus. The use of rehabilitation exercises by providing conditions to challenge the functional system, can be an effective way to improve the motor function of the knee and, consequently, facilitate and accelerate the process of surgery and return to exercise in athletes.

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None.

Authors' Contribution

Seyede Mona Hosseini: study design and ideation, attracting financial resources for the study, study support, executive, and scientific services, providing study equipment and samples, data collection, analysis and interpretation of results, specialized statistics services, manuscript preparation, manuscript evaluation in terms of scientific concepts, approval of the final manuscript to be submitted to the journal office, responsibility for maintaining the integrity of the study process from the beginning to publication, responding to the referees' comments; Gholamali Ghasemi: study design and ideation, study support, executive, and scientific services, analysis and interpretation of results, manuscript preparation, specialized evaluation of manuscript in terms of scientific concepts, approval of the final manuscript to be submitted to the journal office, responsibility for maintaining the integrity of the study process from the beginning to publication, responding to the referees' comments; Vahid Zolaktaf: study design and ideation, study support, executive, and scientific services, analysis and interpretation of results, specialized evaluation of the manuscript in terms of scientific concepts, approval of the final manuscript to be submitted to the journal office, responsibility for maintaining the integrity of the study process from the beginning to publication, responding to the referees' comments.

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Conflict of Interest

The authors declare no conflict of interest. Seyede Mona Hosseini is a PhD student in Sports Pathology, Faculty of Sports Sciences, University of Isfahan, who has been studying at this university since 2014. Dr. Gholamali Ghasemi and Dr. Vahid Zolaktaf are associate professors in the Department of Pathology and Corrective Exercises, School of Medical Sciences, University of Isfahan.

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