Education Journal
2023; 12(5): 217-223
http://www.sciencepublishinggroup.com/j/edu
doi: 10.11648/j.edu.20231205.14
ISSN: 2327-2600 (Print); ISSN: 2327-2619 (Online)

Evaluation of Kinematic and Kinetic Variables After Knee Joint Surgery Before and After 8 Weeks of Individual Training (Case Study)

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To cite this article:
Ali Fattahi, Behshad Panjehzadeh. Evaluation of Kinematic and Kinetic Variables After Knee Joint Surgery Before and After 8 Weeks of Individual Training (Case Study). *Education Journal*. Vol. 12, No. 5, 2023, pp. 217-223. doi: 10.11648/j.edu.20231205.14

Received: July 20, 2023; **Accepted**: August 7, 2023; **Published**: October 13, 2023

Abstract: The knee joint is one of the largest joints in the human body that, like all other joints in the body, is affected by defects, injuries and disease processes. The aim of this study was to identify the source of injury, to provide the best way to return to group training and play after knee joint surgery. This case study on a patient with a male gender, age 35 years, right upper leg, futsal sport with inclusion criteria having a history of surgery 3 times on the right knee (ACL, MCL, ALL, external and internal meniscus), Based on the analysis and performance tests, (curve tracking, squat, squat jump, body sway). The increase of the invertor / ankle evertor at the peak of pronation on the left side was excessive and gait pattern was asymmetric, according to the comparison of balance assessments Static and dynamic were observed between the balance in the right and left legs in the body sway test, the rate of balance in the body in the lateral (medial-lateral) direction was not the same (14.63%). The amount of control force in the left foot was more than the right foot, balance in the closed eye position in the right leg is less than the open eye position, control force in the left leg is more than the right leg, productive force on the left and right legs was almost the same. Conclusion, one-legged balance exercises for both sides, deep sensory strengthening of the knee and ankle (especially on the right side) and quadriceps and plantarflexor muscles are recommended. dynamic and static balance, especially in the medial-lateral direction, needs rehabilitation and improvement. The exercises, closed movement chain training techniques, balance, eccentric exercises with high repetition and low resistance, and facilitation of reflexes by reactionary exercises are suggested, respectively.

Keywords: Kinematics, Kinetics, Knee Joint, 8 Weeks of Training, Return to Play

1. Introduction

The knee joint is one of the largest joints in the human body that, like all other joints in the body, is affected by defects, injuries and disease processes [11]. The knee joint is designed to be mobile in addition to being stable [12]. The direction of the forces must be such that the stability of the knee is maintained during dynamic activities [8]. Anterior cruciate ligament (ACL) of the knee is one of the most common knee injuries in athletes [2]. One of the most common sports injuries among young athletes and active individuals is anterior cruciate ligament rupture, which is usually associated with internal meniscus rupture in 85% [17]. ACL ligament injury has a multifactorial mechanism that is generally divided into two groups of internal factors including anatomical, hormonal, neurological and biomechanical differences in posture of men and women, and external factors including physical and visual disturbances, shoe sole type, ground surface [4, 14]. Menisci, on the other hand, have cartilage-like tissues but are much stronger than that and have a lot of elasticity. Their main task is to absorb the shock shocks that enter the knee.

When running, every time the sole of our foot hits the ground, the calf and thigh bones are tightly pressed together at the knee joint, and the meniscus reduces the severity of the impact by being located between the two bones. Meniscus function includes joint fluid distribution, articular cartilage nutrition, shock absorption, joint deepening, and compensation for incompatibility between the femoral and tibial condyles, and load bearing [9]. ACL injury is one of the most common sports injuries with a prevalence of 70-90% associated with the performance of sports skills, with serious consequences for the athlete [3]. These consequences not only include the cost of treatment and waste of time and distance from exercise, but also cause changes in the shape and structure of the joint (early osteoarthritis) [27, 23]. Understanding the biomechanical properties of post-jump landing is important to prevent lower limb injuries [28]. All of the above confirms the fact that the role and position of prevention of all sports injuries is extremely important and irreplaceable. The most important measures to prevent all sports injuries are to identify risk factors and mechanisms and then try to reduce or eliminate them. The most common mechanism for anterior cruciate ligament injury is the non-collision mechanism, which accounts for 72% of all ligament injuries and occurs during activities such as acceleration reduction, jump descent, and shear movements [13]. Jumping from the jump has been reported as the most common mechanism that improper technique during jump-landing maneuver can cause significant force on the ACL and its rupture [24]. Evidence suggests that lower limb position during high-risk activities such as running, shear maneuvers, rotation, or landing may be predisposing factors for anterior cruciate ligament rupture [16, 22]. Lower extremity position, which directly affects the load on the anterior cruciate ligament, is believed to play an important role in increasing the risk of anterior cruciate ligament injury. Most non-collision anterior cruciate ligament injuries occur during exercise, including single-legged landings [7]. Athletes who participate in team jumping, shear and spin sports such as soccer, basketball and volleyball are often 4 to 6 times more likely to have anterior cruciate ligament injury [15]. One of the most important mechanisms to prevent rupture of the knee ligaments is to maintain balance during the run. Then the performance of mental and neuromuscular actions is coordinated and coordinated [19].

Simultaneous contraction of the knee muscles is an important mechanism to protect the joint from injury. Joint stability with the participation of sensory receptors is achieved through the gamma muscle system for the permanent regulation of muscle activity around the knee. Proximal muscles have been shown to play a more important role in maintaining balance than distal muscles. ACL ligament damage leads to functional and mechanical disability that makes it difficult for athletes to fully recover. Due to the presence of mechanical receptors, ACL ligament damage can cause profound impairment, joint stability, and inability to perform useful daily activities [18]. It is hoped that the results of the study, while increasing human knowledge, will increase our knowledge of impact, study of kinematic, kinetic variables and knowledge of the source of injury and provide the best way to return to group training and play after knee joint surgery after 8 weeks of training. Which is a case study and answers the questions of whether the subject can return to group exercises and games.

2. Research Methodology

The present study was conducted as a case study on a 35-year-old male patient (with anthropometric characteristics including height of 1.75 meters, weight of 70 kg, and lower limb length of 92 cm), upper right leg in futsal sports. The present subject has a history of right leg knee surgery in three stages: 1- partial external meniscectomy operation, reconstruction of ACL and MCL of the right leg in 2013. 2- Partial internal and external meniscectomy and reconstruction of the ACL of the right leg in 2016. 3- He had a partial meniscectomy and strengthening (ACL) and (ALL) of the right leg in 2017. Before entering the research, he was able to walk and run independently, without the use of aids, and six months had passed since his third surgery. At the beginning of the research, an explanatory meeting was held with the presence of the researcher and the subject. This meeting was held to familiarize the subject with the way of conducting the research and to specify the day and time of the test. Also, a written consent form was obtained from the subject to perform the test. In this research, in order to collect kinematic data before presenting the suggested exercises for 8 weeks, three cameras of Vaikan company model Vero with light emitting diodes with a frequency of 120 Hz were used. For this purpose, with the 6-DOM marking method and QTM model, 24 light-reflecting markers with a diameter of 15 mm are placed directly on the skin of certain areas by double-sided adhesive with a thickness of approximately 5 mm, and in order to investigate the three-dimensional movements of the pelvic segments. Thigh, leg and foot were used, for this purpose, according to the Qualysis standard, the markers were placed separately on the subject's half-naked body as described. Two markers in the highest part of the right and left iliac crests, two markers in the right and left upper anterior iliac spine, two markers in the right and left upper posterior iliac spine, two markers in the center of the right and left greater trochanter of the thigh, two markers on both sides of the line. right knee joint (inner and outer condyles of the femur), two markers in the inner and outer malleolus of the right foot, two markers in the base and head of the fifth metatarsus of the right foot, one marker in the head of the first metatarsus of the right foot, one marker in the most prominent part of the back of the heel Right leg, 8 markers known as cluster markers (a special page with 4 markers placed in its 4 corners) in the lower and outer third of the leg and the outer second of the right thigh. In order to apply a stable marker, the excess hair at the electrode junction was shaved. The markers were attached to the person's body while bearing weight (standing) so that the difference in the position of the marker on the skin during static and dynamic time is as small as possible [26]. Also, the calibration of the running motion analysis system was done in two stages: 1) static calibration. 2) Dynamic calibration. A treadmill (Mr. Pro. MT.9000) made in Taiwan was used for running. Anthropometric variables in this research were recorded as follows: height and weight with the help of a digital scale and height meter, length of the lower limb: (leg, knee width, distance between left and right upper and front sacral spine, right and left ankle width) were measured by a flexible tape measure. In order to collect kinetic data from the dynamic and static balance tests and to evaluate the maximum muscle force in the left and right leg from the curved line tracing test, squat, jump squat, swinging the body on a 40-dimensional Niro Bartak plate. * 60 cm, made in the USA with a sampling rate of 1000 Hz was used by the software (KistlerMARS). All data were filtered with a low-pass filter with a frequency of 10 Hz. To analyze the data, one-sided t-test was used in SPSS-19 software and ($p<0.05$). After calibrating the cameras and installing the markers, the subject started walking and running on the treadmill with Nike sports shoes (Figure 1) at a selected speed of 10.3 km/h for 4 minutes, then the subject was asked to take the test on the screen. Force should be placed and Kistlermars software functional tests including (curve line tracking, squat, squat jump, body swing) were taken from him. Each test was repeated 5 times because in case studies, if the number of tests exceeds a certain limit, these 5 repetitions can be used [20]. Also, to prevent fatigue, 30 seconds rest was given between repetitions. After 8 weeks of the suggested exercises, (presented in Table 1) functional tests (static balance with eyes open and closed, assessment of maximum muscle force (concentric and eccentric) and squat jump in the left and right leg), kinetic and kinematic tests of the subject was taken.

3. Research Findings

According to the results of analysis (3D-Gait) and software performance tests (KistlerMARS), before 8 weeks of individual training, the increase in invertor / ankle evertor of the pronation flag on the left side was statistically excessive ($p < 0.05$). Because (0.03) is less than 0.05), and the gait pattern was asymmetric, statistically ($p < 0.05$ because (0.01) is less than 0.05) (Table 3). The peak pronation time of the left ankle was statistically longer than the right ankle ($p > 0.05$ because (0.06) was longer than (0.05). Left foot collapse was statistically less than right foot (p (0.06) is greater than 0.05) and left foot was faster than right foot ($p > 0.05$) because (0.07) was greater than (0.05). The peak of rotation of the right foot was less than the left foot, statistically ($p > 0\ 0.05$) because (0.06) is larger than (0.05). In the hip joint, the peak of extension in the left leg and the right leg increased statistically ($p > 0.05$ because (0.01) is less than 0.05), the peak of the collapse of the right leg was higher than the left leg, in terms of Statistically ($p > 0.05$ because (0.06) is greater than 0.05) and the peak rotation of the right foot was less than the left foot, statistically ($p > 0.05$ because (0.08)) Is greater than 0.05). The range of motion of the ITB gait pattern decreased in the left hip joint (The Figures 2-4). Based on the obtained results and considering the comparison of static and dynamic balance assessments and assessment of maximum muscle strength, significant values were observed between the balance in the right and left legs in the body sway test (14.63%). The amount of balance in the body in the lateral direction (medial-lateral) was not the same (14.63%) which can be due to improper muscle control. The amount of control force in the left leg is more than the right leg, which can be due to the relative weakness of the quadriceps muscles in the right leg. The amount of productive force in the right and left legs was not equal (Table 2). According to the results of software performance tests (KistlerMARS) after 8 weeks of individual training, no significant difference was observed between the balance in the right and left legs. The amount of balance in both legs (medial-lateral) is the same, which is due to proper muscle control. The amount of balance in the closed eye position in the right leg is less than the open eye position, which indicates a decrease in depth in the joints of the right leg. The amount of control force in the left leg is more than the right leg, which is due to the relative weakness of the quadriceps muscles in the right leg. The amount of productive force on the left and right legs was almost the same. When landing, the amount of shock absorption in the left foot is too normal, which can be due to poor performance or reduced shock absorption in the knee during landing.

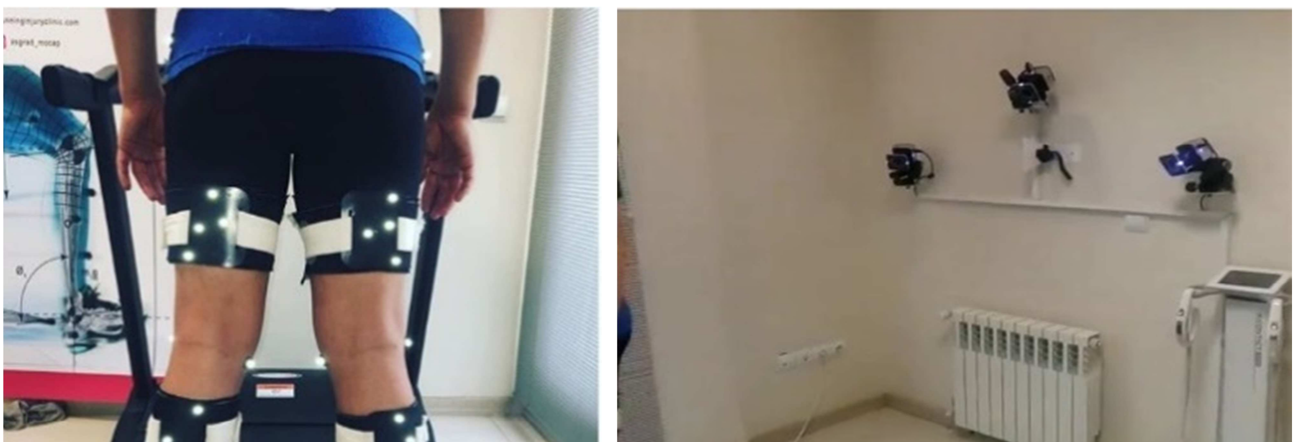

Figure 1. *The subject during the evaluation.*

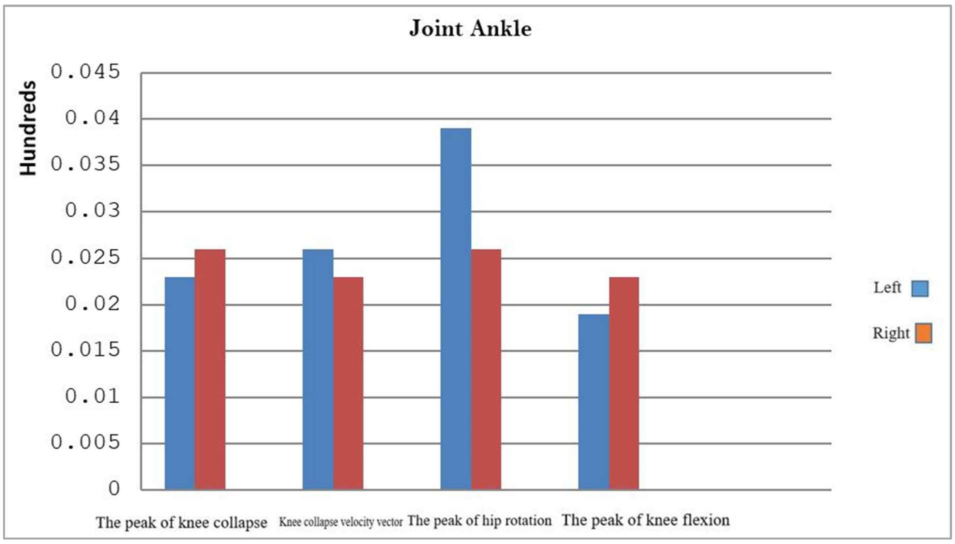

Figure 2. *Analysis (3D-Gait) before 8 weeks of training (Joint Ankle).*

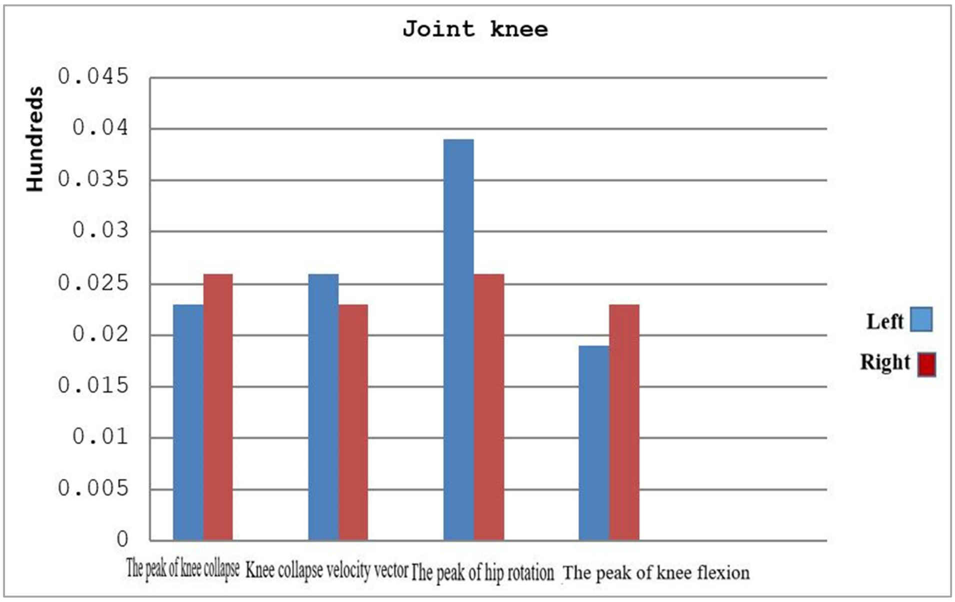

Figure 3. *Analysis (3D-Gait) before 8 weeks of training (Joint Knee).*

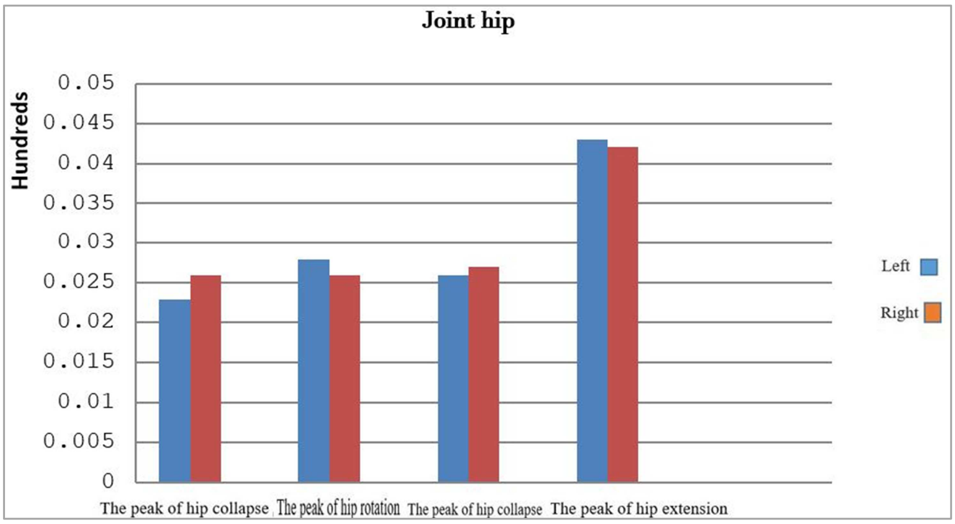

Figure 4. *Analysis (3D-Gait) before 8 weeks of training (Joint Hip).*

Table 1. *Suggested individual exercises and performance tests of the software (KistlerMARS).*

R	Number of sessions	Type of exercise	sets	Repetition	considerations
1	Three sessions in the first and second week	Y- test	3 sets for each leg	3 repetitions	Perform the exercises after warming up
2	Three sessions in the first and second week	Side lunges	3 sets for each leg	10 repetitions	
3	Three sessions in the first and second week	Skater lunges	1set for each foot	8 repetitions	One side lunges and one back lunges in a row
4	Three sessions in the third and fourth week	Single leg star	2 sets for each leg	1 repetitions	
5	Three sessions in the third and fourth week	Lunges with knee drive	1 sets for each leg	10 repetitions	This movement is a combination of bending the thighs and knees and turning the same leg into a dorsal lounge without the foot hitting the ground.
6	Three sessions in the third and fourth week	Single leg dead lift and reach	1 sets for each leg	10 repetitions	
7	Three sessions in the third and fourth week	Bird Dog	10 sets on each side	8 seconds	This exercise should be done with the hands and feet in agreement
8	Three sessions in the fifth and sixth weeks	Single leg star	2 sets for each leg	1 repetitions	
9	Three sessions in the fifth and sixth weeks	sway leg sway	Each foot is in 1 each direction	10 repetitions	
10	Three sessions in the fifth and sixth weeks	Skater lunges backward and forward	1 sets for each leg	10 repetitions	Move forward lunges and backward lunge in a row with one target foot without hitting the ground
11	Three sessions in the fifth and sixth weeks	Tree pose with arms	2 sets for each leg	15 to 20 seconds	
12	Three sessions in the seventh and eighth week	Skater hops with reach	2 sets for each leg	10 repetitions	
13	Three sessions in the seventh and eighth week	Step up with balance	2 sets for each leg	10 repetitions	
14	Three sessions in the seventh and eighth week	Surfersquat	1 set	15 repetitions	
15	Three sessions in the seventh and eighth week	Co-contraction test	5 set	2 repetition s	

Table 2. *Resultes of software (KistlerMARS) performance tests before 8 weeks of traning.*

Indicators of return to play			
R	**Test**	**Variable**	**Statistical analysis results**
1	Curved tracking*	Average absolute error (%)	55.99%
2		Absolute standard devition (%)	37.81%
3	Squat*	Maximum relative force (%)	4.24%
4	Squat jump*	Maximum relative strength (%)	4.21%
5		Maximum relative force (%)	2.30%
6	Body sway*	Total - Oscillation path (%)	3.83%
7		Anterior-posterior oscillation (%)	5.32%
8		Medial-lateral oscillation path (%)	14.63%
9		Total - vertical path (%)	3.83%
10		Vertical-Anterior-Posterior Path (%)	5.27%
11		Vertical-Anterior-Posterior Path (%)	14.63%

*According to the results of statistical analysis of software (KistlerMARS), the natural average is equal to 12 to 8%.

Table 3. *Results (3D-Gait) Running on a treadmill before 8 weeks of training.*

R	The dependent variable	Clinical testing		Treadmill running test *	
		Right	Left	Right	Left
1	The peak of pronation	M	M	E-A	N-A
2	Pronation velocity vector			N	N
3	The peak time of pronation			N	N
4	The peak of Tibial rotation			N	N
5	Rotation velocity vector			N	N
6	The peak of knee collapse			N	N
7	Knee collapse velocity vector			N	N
8	The peak of knee rotation	-	-	N	N
9	The peak of knee flexion	-	-	R- A	N-A
10	The peak of hip collapse			N-A	N-A
11	The peak of hip rotation			N-A	N-A

R	The dependent variable	Clinical testing		Treadmill running test *	
		Right	Left	Right	Left
12	The peak of pelvic collapse			N	N
13	The peak of hip extension	-		E	E
Painful areas:					
normal :N * Decrease :R * Additive :E * Asymmetry :A * medium :M*					

4. Discussion and Conclusion

The aim was to evaluate the variables (kinematic and kinetic) and identify the source of the injury, to provide the best way to return to group training and play after knee joint surgery during 8 weeks of individual training as a case study. Functional tests are designed to measure the strength and coordination of the neuromuscular system and can assess the ability of the lower limb to perform actions that challenge knee stability. These tests are used as a tool to measure the level of motor function of patients with injury or reconstruction [30]. Researchers observed earlier onset of activity in the hamstring muscles of individuals after anterior cruciate ligament reconstruction surgery than in healthy individuals [29]. Increased instability in the knee joint forces the patient to change the gait pattern and use a compensatory gait pattern [1]. The time delay can be attributed to a sensory defect that persists even after anterior cruciate ligament surgery, and because the correct position of the joint is not properly diagnosed, the central nervous system cannot activate the muscles in time and start functioning. And the time to reach maximum muscle activity in the leg that underwent anterior cruciate ligament reconstruction surgery is delayed compared to a healthy leg [5]. People with a ruptured anterior cruciate ligament cause them to use special compensatory mechanisms when the foot hits the ground. In this strategy, they try to first apply pressure from the injured knee joint to the hip joint on the same side. They do this by reducing the extensor torque of the knee and increasing the extensor torque of the thigh, and also by reducing the overall pressure from the injured foot, they transfer it to the healthy foot [21] and thus They use inter-limb compensatory strategy sequences [25]. Thus, the load on the healthy leg increases. In fact, ACL rupture; It causes sensory changes in the body, decreased muscle strength, impaired balance and function, and biomechanical changes on both involved and healthy sides, which are not necessarily the same intensity on both sides [6].

Some researchers have found that the maximum vertical force of the ground reaction during landing on the operated limb was less than the non-surgical limb, and the time to reach the maximum vertical force of the ground reaction of the operated limb was significantly longer than the non-surgical limb. 10 weeks of perturbation training also significantly increased the maximum vertical force of the ground reaction during landing [21]. Defects in balance and function and biomechanical changes are involved and healthy on both sides, and the severity of these changes is not necessarily the same on both sides [10]. Lack of profile of biomechanical variables to return to play On the one hand, the non-uniformity of the type of tests and the manner of implementation in studies conducted in other studies has made it impossible to compare the results of this study with other studies. However, due to lack of information, more research is needed. In this regard, it is felt that it is hoped that the results of this test can be based on awareness and help to increase knowledge.

According to the results obtained before 8 weeks of training, dynamic and static balance, especially in the medial-lateral path, needs rehabilitation and improvement. Accordingly, in order to improve these factors in the exercises, closed movement chain training techniques, balance exercises, eccentric exercises with high repetition and low resistance, and facilitation of reflexes by reactionary exercises are suggested, respectively. After 8 weeks of training and the results obtained, the following exercises are recommended to return to group exercises and play: do one-legged balance exercises for both sides, deep sensory strengthening of the knee and ankle (especially on the right side) and Strengthen the quadriceps and plantar flexor muscles.

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