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RESEARCH ARTICLE

Exploring Isokinetic Test, Joint Position of Sense and Dynamic Balance in Anterior Cruciate Ligament Reconstruction versus Healthy Subjects

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Abstract
Reduced knee muscle strength, joint position sense (JPS), and dynamic balance are some of the impacts of anterior cruciate ligament (ACL) rupture that remained in patients after surgery. The goal of this study was to assess patients who had finished a sport rehabilitation programme and were back exercising with their healthy partners for the JPS, dynamic balance, and knee muscle strength. In this study, 40 male soccer players—20 participants with autograft reconstruction of the hamstring or surgery, and 20 uninjured participants—took part. By using isokinetic dynamometry, the flexor and extensor peak torque of the knee at angular velocities of 60 deg. s-1, JPS at 60°, and dynamic stability were assessed in the dominant leg by using Y balance test. The independent t-test was utilized to compare the outcomes between the two groups. The findings demonstrated that there were no differences in any of the test parameters for determining muscle strength and JPS between the two groups at 60 degrees per second in the dominant leg. ($p > 0.05$). Furthermore, there was no observed difference in all directions of YBT between Injured and healthy groups in dominant leg ($p > 0.05$). The results of this study allow us to make the conclusion that when a rehabilitation programme has been completed successfully, surgically induced outcomes may be improved and the risk of re-injury in athletes may be decreased.

Keywords
Anterior Cruciate Ligament, Muscular Strength, Joint Position Sense, Dynamic Balance, Soccer

INTRODUCTION

Sports-related knee injuries like anterior cruciate ligament (ACL) injuries are frequent and severe. ACL reconstruction (ACLR) aims to get patients return to playing sports (Ordahan et al., 2015). Anatomical, genetic, hormonal, occupational, and neuromuscular abnormalities are risk factors for ACL injuries. But there were other modifiable factors include neuromuscular control (Ahn & Lee, 2016). On the other hand, ACL injury decreases lower extremity neuromuscular control (Akbari et al., 2016). However, there is no standard test for assessing neuromuscular control following ACLR. The isokinetic test has become useful for ACL injury

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neuromuscular function evaluation. Peak torque is the gold standard in the isokinetic test (Ahn & Lee, 2016). Isokinetic dynamometry is used to assess physical condition, rehabilitation effectiveness, and injury risk factors in athletes, especially soccer players. As a result, either bilaterally or unilaterally, muscle imbalances can be detected using the ratios that are gained. The traditional ratio below 60% suggests hamstring weakness relative to the quadriceps, which increases the risk of hamstring and ACL injury (García-Pastor et al., 2022).

On the other hand, after ACL injury, knee and functional performance are evaluated using a range of clinical outcome measures, including patient-reported outcomes (Lysholm score, subjective score from the International Knee Documentation Committee, etc.), joint instability, muscle strength, and balance. Due to the fact that dynamic stability is one of the many components that must be checked during rehabilitation, it is an important feature to take into account during a knee ligament reconstruction exercise programme. In order to determine knee stabilization during dynamic tasks, normalized dynamic stability tests that incorporate a variety of muscle activations, such as the Star Excursion Balance Test (SEBT) and Y-Balance Test (YBT), have been employed often (Cervenka et al., 2018). The reduced hamstring muscle activation and decreased joint position sense make it difficult to maintain balance following an ACL injury (Kim et al., 2022). Therefore, evaluation of dynamic balance may be a useful strategy for assessing the functionality of the sensory motor system following ACL injury (Lee et al., 2019). The ACL also contributes to proprioceptive activities through the mechanoreceptors found within its structure, in addition to providing mechanical stability (Ordahan et al., 2015).

These mechanoreceptors in the ACL fibres have been demonstrated to monitor changes in tension, velocity, acceleration, movement direction, and knee joint position. ACL deficit reduces proprioceptive and neuromuscular control and delays quadriceps and hamstring muscle response times. Proprioceptive system dysfunction can affect neuromuscular control, protective muscle activity, and joint stabilization(Ordahan et al., 2015). A particular sensory modality called proprioception carries out three functions: awareness of static joint location, detection of joint acceleration (kinesthesia), and efferent activity controlling reflex muscle contractions (Kosy & Mandalia, 2018). In order to prevent these effects, proprioception training may be discussed throughout ACL rehabilitation and preventative programs (Jebreen et al., 2023). Because compensatory activation of other knee joint mechanoreceptors occurred in spite of the loss of local mechanoreceptors caused on by ACL damage, compensatory muscles were activated to stabilize the joint (Akbari et al., 2016).

According to a recent study, mechanoreceptor impairment caused by ACL injury reduces knee proprioception. In consequently, individuals with ACL injuries frequently report balance deficits, ostensibly for the same reason (Karimijashni et al., 2023). Because, Xu et al (Xu et al., 2022). stated that the ACL is essential for knee joint stability, helping to prevent anterior translation and trigger the "screw home" mechanism. As a result, functional instability and impairment brought on by an ACL rupture can result in meniscal tears and the degradation of articular cartilage. Additionally, Hu et al. discovered that there is a greater link between strength and dynamic stability in patients who have had anterior cruciate ligament restoration. The hamstring/quadriceps ratio may shift further due to consistent muscle weakness, causing dynamic instability and increasing the risk of additional injury. For stability during functional activities, it is typically necessary to have sufficient strength of the agonist and antagonist muscles across the joints (Hu et al., 2023). Lastly, according to Cervenka et al, 2018 research, the involved limb of individuals with ACL injury will have significantly fewer strength and stability than the uninvolved limb (Cervenka et al., 2018). According to previous studies and the lack of research on the isokinetic strength of agonist and antagonist muscles, JPS, and dynamic balance in people who experienced at least one year of ACLR, the goal of this investigation is to compare the dynamic balance, JPS, and isokinetic test results between ACLR and healthy individuals.

MATERIALS AND METHODS

Subjects

The sample size for the current retrospective cohort study was chosen based on relevant earlier studies (Cvjetkovic et al., 2015; Machado et al., 2018). Therefore, 40 male soccer players age 18-30 years were evaluated and then were divided to ACL reconstruction either in isolation or in combination with a meniscal repair (ACLRG: n = 20) and uninjured (UIG: n = 20) groups. The subjects included in the ACLRG were individuals who had undergone ACLR surgery with a hamstring graft in their dominant limb at least a year prior. These individuals had participated in the same ACL rehabilitation program, which comprised a variety of exercises such as range of motion, strengthening, proprioception and balance, agility and coordination, plyometric, core strengthening, and functional exercises. The program was conducted by the same athletic trainer (O.M.) for a minimum duration of six months. In the UIG group, participants were qualified to enter the study if they had not previously participated in any injury prevention programs. Exclusion criteria included being unable to complete the study's tests, feeling discomfort in the lower limb joints, and having a history of quadriceps and/or hamstring injuries in both limbs. The study was authorised by the University of Shahid Bahonar Kerman's ethics committee (IR.UK.REC.1400.015), and all subjects gave written informed consent before enrolling in the study. The subject demographic data have been listed in Table 1. The independent t-test showed that there were no significant differences between the two groups.

Table 1. Demographic characteristics. Mean (SD)

Variables	ACLRG	UIG	P
Age (years)	22.55 (3.99)	21.00 (4.74)	0.27
Height (cm)	177.55 (4.93)	176.60 (6.02)	0.58
Weight (kg)	72.70 (6.44)	71.30 (5.63)	0.46
BMI (kg/m^2)	23.03 (1.40)	22.84 (1.00)	0.62

Note: ACLRG= ACL reconstruction group; UIG= Uninjured group, Significant level set as $p < 0.05$

Procedure

Before starting the study, all eligible subjects were invited and were given aims of current study in details by one of researchers. Then, subjects were instructed how each test is done. A day after education course, the UIG performed tests and then ACLRG performed those a day after UIG. It is noteworthy, the subjects were given 3 trials to practice and familiarize before each test and also to prevent injury, subjects a warm-up for 10 minutes consisted of dynamic stretching for lower limbs and knee flexion and extension 5 times for each leg by isokinetic dynamometer at 60 degrees/second. Moreover, after completion of each test, subjects took a rest for 5 minutes for reducing effect of fatigue and the got ready to perform next test.

Evaluation of tests

Isokinetic test

To evaluate the knee muscle testing (Fig.1a), it was done on Biodex System (Biodex System single Pro, Shirly, New York, USA). The subject was strapped across their chests and sat upright on a dynamometer chair with his dominant hip and knee limb flexed at a 90-degree angle. Attached to the dominant lateral malleolus of leg was the dynamometer attachment. In order to maintain complete ankle dorsiflexion, the resistance pad was placed as far away from the tibia as possible. The ROM was set to fully extend (0 degrees) to flexion of 90 degrees while the knee was being tested(Lim et al., 2019). Variables such as peak torque, maximum total work, average power, and the relationship between the peak torque of the flexor (Flex) and extensor (EX) leg muscles (the hamstrings/quadriceps (H/Q) relationship) were tested and analyzed at 180 degrees per second to evaluate the dominant limb in isokinetic test. In this study, the 60degrees/second was selected because of most commonly used in past studies(Lim et al., 2019; Machado et al., 2018). The subjects performed the isokinetic test in 3 sets and 5 repetitions in each set. 30 seconds were given to subjects after performing each set to take a rest. During the test, by using verbal stimulation, the subjects were encouraged to use their maximum strength. The best results among sets were considered for comparing between groups.

Joint position sense (JPS) test

To measure joint position sense (absolute angular error) at the threshold of passive motion detection at 60°, an isokinetic dynamometer (Biodex System single Pro, Shirly, New York, USA) was utilized (Kalimuthu & Mokhtar, 2017). The rotation axis for the dynamometer was chosen to be the lateral femoral epicondyle. (Fig.1b). The range of motion was calculated to be from 0° (full extension) to 90°. (flexion). The dominant leg was in the first 90° flexion position and rested for 10 seconds. The subject was then instructed to remember this position after the device had passively flexed it into a 60° angle at a 2°/sec angular speed. The leg was brought back to its starting position after a 10-second resting period the participant was then instructed to fix the dynamometer to the target angle after being certain that he had reached it passively (Kalimuthu & Mokhtar, 2017).

Y balance test (YBT)

The YBT was employed as a dynamic balance test to assess the function of the lower extremities. In both clinical and research settings, this test is often employed. Performance on this exam can be measured as the maximum reach distance in a particular direction (anterior (ANT), posteromedial (PM) and posterolateral (PL)) or a a calculated composite score (average reach distance across all directions) (Bulow et al., 2021). All subjects completed YBT with using YBT kit (Tavan Gostar Company, Tehran, Iran). After the practice trials, the first test trial's distance from the YBT apex of the most proximal edge of the reach indicator was measured, while Participants moved in three directions: ANT, PM, and PL. The support leg was the dominant limb (Fig.1c). From the anterior superior iliac spine to the farthest point of the ipsilateral medial malleolus in a supine position, all reach distances were measured and normalised as a percentage of each participant's stance-limb length (%LL)(Bulow et al., 2021). In this study, each direction three times was repeated and the average of them was calculated.

Normalized reach distance = (reach distance / limb length) x 100

Fig. 1. Measurement of tests; A: Isokinetic test, B: JPS test and C: YBT

Statistical analysis

To ensure that the results were distributed normally, the Kolmogorov-Smirnov test was applied. The independent t-test was applied to analyze the data between ACLRG and UIG. The statistical analysis was conducted using SPSS 26.0 for Windows (SPSS Inc., Chicago, IL, USA), and the level of statistical significance was established at α values 0.05. The effect sizes of 2-independent groups were tested usingCohen's d [$d = (M1 – M2 / \sqrt{((SD1^2 \times SD2^2)/ 2)}$], (0.1, 0.3, and 0.5 as small, medium,and large effects, respectively)(Alimoradi et al., 2021).

RESULTS

The significance of the difference between the ACLRG and UIG evaluated variables was assessed using an independent t-test, and the findings are shown in Table 2. It is important to mention that the Kolmogorov-Smirnov test results revealed that the data distribution for all research variables was normal (p>0.05). Thus, the use of independent t-test was possible. The obtained isokinetic results were compared and showed in EX (t= 0.48, p= 0.63, Cohen's *d* = 0.78), Flex (t= 0.69, p= 0.49, Cohen's *d* = 0.64) peak torques, max total work (EX: t= 0.62 , p= 0.53, Cohen's *d* = 0.55; Flex: t= 0.79 , p= 0.43, Cohen's *d* = 0.59), average of power (EX: t= 0.74 , p= 0.46, Cohen's *d* = 0.88; Flex: t= 0.64 , p= 0.52, Cohen's *d* = 0.65) and H/Q ratio (t= 1.04, p= 0.30, Cohen's *d* = 0.67) between ACLRG and UIG no significant difference was found. The comparison of proprioception results indicated the ACLRG participants, who had participated in ACL program sessions, had no significant difference in knee dominant leg proprioception with UIG ones (t= 1.33, p= 0.19, Cohen's *d* = 0.71). Moreover, in YBT test, the findings showed there is no significant difference in YBT directions between two groups (ANT: t= 0.38, p= 0.70, Cohen's *d* = 0.53; PM: t= 1.64, p= 0.10, Cohen's *d* = 0.60; PL: t= 0.49, p= 0.62, Cohen's *d* = 0.49) and also in YBT- total scores, the results showed no significant difference between ACLRG and UIG (t= 1.15, p= 0.25, Cohen's *d* = 0.56).

Table 2. Comparison Mean (SD) in dominant leg between two groups (ACLRG and UIG)

Variables	ACLRG	UIG	CI
EX- peak torque 60°/s (Nm/kg)	176.81 (46.81)	182.84 (30.44)	(-19.24) – (31.31)
Flex- peak torque 60°/s (Nm/kg)	99.86 (19.42)	104.94 (26.66)	(-9.84) – (20.02)
EX- max total work	166.21 (53.63)	174.42 (25.16)	(-18.60) – (35.02)
Flex -max total work	107.20 (32.07)	114.85 (28.61)	(-11.81) – (27.10)
AVG- EX power	105.16 (34.72)	112.20 (24.11)	(-12.09) – (26.17)
AVG- Flex power	69.15 (19.13)	73.10 (19.37)	(-8.38) – (16.27)
H/Q ratio (%)	56.54 (9.89)	60.72 (14.87)	(-3.90) – (12.27)
Proprioception (Degree)	2.81 (1.75)	3.67 (2.28)	(-0.44) – (2.16)
YBT- ANT (cm)	87.38 (4.38)	88.01 (5.71)	(-2.64) – (3.88)
YBT- PM (cm)	88.12 (3.81)	90.36 (4.73)	(-0.51) – (4.99)
YBT- PL (cm)	91.37 (3.98)	92.07 (4.89)	(-2.15) – (3.55)
YBT- total (cm)	93.38 (5.98)	95.62 (6.33)	(-1.70) – (6.18)

Note: ACLRG= ACL reconstruction group, UIG= uninjured group, CI= Confidence interval of difference, EX= Extension, Flex= Flexion, max= Maximum, AVG= Average YBT- ANT= Y balance test- anterior direction, YBT- PM= Y balance test – posteromedial, YBT – PL= Y balance test – posterolateral. Significant level set as p < 0.05

DISCUSSION

The results of the current study showed that in the isokinetic test at 60°/s, JPS test, and YBT, there was not a significant difference between athletes with ACLR who followed a specific rehabilitation regimen and athletes who were in healthy condition.

Our results in isokinetic test showed that athletes who received rehabilitation after an ACL reconstruction did not exhibit muscle imbalance in their knee flexor and extensor muscles. These outcomes are consistent with findings of Konishi et al(Konishi et al., 2012). showed after 18 months ACLR surgery, patients who followed rehabilitation process had no significant difference with uninjured group in knee muscle torque at velocity of 60°/s.They indicated that the results may be impacted by the restoration of high threshold motor unit recruitment at 18 months following ACL surgery.. Çınar-Medeni et al(Çınar-Medeni et al., 2019). also compared isokinetic knee muscle strength six months after ACLR between injured and uninjured limbs. They no observed difference between two limbs due to the fact that athletes performed their ACL rehabilitation protocol(Çınar-Medeni et al., 2019). Furthermore, despite the fact that Hoffman et al. (1999) used a different surgical procedure (patellar tendon graft), our findings disagree with their findings. Additionally, the ratio of hamstring to quadriceps strength has been utilized to determine the proper balance of knee flexors and extensors.(Cvjetkovic et al., 2015). It is a very important factor in determining when a person can return to sporting activity.. Our ACLR athletes after at least a year of the rehabilitation have the required H/Q ratio level(Cvjetkovic et al., 2015) which allows them to go back into sports activities. Previous studies showed when ACL injury happens, the afferent feedback to nervous system decreases and it causes reduced motor unit recruitment. Thus, at least 18 months after ACLR are needed that motor units to be restored completely(Konishi et al., 2012). In addition, after ACL injury In addition, after ACL injury, the strength of muscles around knee joint is reduced, especially quadriceps muscle, or length of muscles owing to muscle imbalance are shortened(Kim & Lee, 2018; Vairo et al., 2008). However, after reconstruction surgery and following rehabilitation exercises help muscles to be activated and to be returned to initial length(Sharifi & Esmaeili, 2020). Due to current study's results, it seems a year after reconstruction surgery and performing neuromuscular trainings at rehabilitation process improve the deficit in somatosensory system and active motor units around knee joint. These factors may cause no difference between injured and uninjured athletes.

However, we all know that quadriceps recovery is very slow and up to two years may be needed to obtain normal quadriceps muscle performance following ACLR(Cvjetkovic et al., 2015). Even though, our results demonstrate that there are no significant differences in quadriceps strength muscle between ACLRG and UIG.

JPS deficit of a knee with an ACL tear has been widely described in earlier studies (Angoules et al., 2011; Jerosch et al., 1996).This is probably caused by the degeneration of ligamentous mechanoreceptors, which also causes the loss of proprioceptive feedback.(Angoules et al., 2011). As a result, in addition to the mechanical interruption, the knee suffers from instability(Angoules et al., 2011). After ACLR the cortical activity is altered. For instance, scientists observed reduced JPS before ACLR surgery and improved JPS after ACLR(Baumeister et al., 2008). It has been reported rehabilitation exercises can be effective to enhance JPS in knee joint after ACLR(Muaidi et al., 2009). Moreover, another factor is enhancement of static mechanic is provided by graft. The graft builds a stable environment for joint that improves sensorimotor complex activity(Muaidi et al., 2009). The findings of the present investigation are consistent with Sharifi et al(Sharifi & Esmaeili, 2020). and Rostami et al(Rostami Haji-Abadi et al., 2014). Sharifi et al. evaluated the knee JPS in dominant and non-dominant legs between basketball players with experience of ACL surgery with autograft reconstruction hamstring and healthy ones. They found no significant difference in two legs(Sharifi & Esmaeili, 2020). Rostami et al. also compared knee JPS in injured and uninjured legs in athletes that had been underwent ACLR by hamstring graft and had followed the rehabilitation process. Their findings showed there was no significant difference in knee JPS in two legs. However, the results of Laboute et al(Laboute et al., 2019). were differential. They reported the knee JPS in injured limb's athletes that it had taken three to nine months after ACLR was lower than uninjured leg. The reasons such as study design, sex, type of graft that athletes had been had surgery and the period time after surgery the JPS had been assessed can be explained to clarify different results between present study and Laboute et al(Laboute et al., 2019).

Dynamic balance has been identified as a risk factor for sports-related soft tissue injuries, including ACL tears(Myers et al., 2018). One of functional tests that is used by clinicians for assessing dynamic balance is YBT(Gonell et al., 2015). Soccer players were discovered to be nearly two times more likely to suffer injuries if their scores fell below the mean in each directions.(Gonell et al., 2015). Poor balance, impaired motor control, and a lack of neuromuscular control are all factors that put athletes' lower limbs at risk of injury(McGuine et al., 2000). In addition, it has been shown if the dynamic balance is poor, it would increase the ACL re-injury(Paterno et al., 2010). In the current research, athletes who had ACLR had not significant differences with healthy ones in all directions of YBT. Akbari et al(Akbari et al., 2016). evaluated the effect of balance training on dynamic balance in individuals who had ACLR(Akbari et al., 2016). Their results showed could partially enhanced balance stability in initial stage of ACLR rehabilitation. Therefore, they recommended include these exercises in the rehabilitation process after ACLR (Akbari et al., 2016). One of causal factor that may effect on YBT in the current study is increased strength in lower limbs, especially quadriceps muscle, following balance exercises in rehabilitation program after ACLR because balance training may improve neuromotor recruitment, thus enhancing strength muscle(Cooper et al., 2005; Nunes et al., 2018).

Limitations

The current study has limitations, just like any other study. Due to the fact that this study was conducted as a retrospective cohort. Thus, This design can only investigate associations, not causality. The study's second limitation was small sample size, and also all subjects were males. Because of this, caution should be taken when applying the study findings to a larger heterogeneous population. The YBT and SEBT (Star Excursion Balance Test) are closely related, although they are not interchangeable. Since the SEBT may be more clinically feasible than the YBT, caution must be taken when applying the study's findings to performance on the SEBT. Similar to this, as one repetition maximum and hand-held dynamometry were excluded from the current investigation, comparisons of these alternative methods of strength testing should be done with caution.

Conclusion

Based on the findings of the present study, athletes who undergo the complete rehabilitation process and subsequently return to sports would be able to restore muscle strength and neuromuscular control in the injured limb. Since muscle strength and neuromuscular control are critical components for participating in sport, athletes can train in maximum condition and also the risk of re-injury is reduced.

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Conflict of interest

The authors affirm that they have no relevant financial or non-financial interests to disclose with regard to this work.

Author Contributions

Study design: OM and MA; Data collection: OM, MA, MA; Data interpretation: MA and MA; Manuscript preparation: OM and RB; Literature review: AM and RB. All authors have read and approved the published version of the manuscript.

Ethical Aspects of The Study

Approval was granted by the Research Ethics Committees of Shahid Bahonar University of Kerman (IR.UK.REC.1400.015. Approval Date:2021-07-27). Written authorization was received from the patent holders of the scales, and informed consent was obtained from the patients who participated in the study.

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