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A Comparison of Knee joint Isokinetic Profile between Healthy Military Personnel and Individuals with Reconstructed Anterior Cruciate Ligaments

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ABSTRACT

Background: Considering the prolonged recovery process from anterior cruciate ligament (ACL) injuries, the occurrence of secondary problems post-surgery, and the lack of adherence to rehabilitation programs after surgery, there is a risk of recurrent tears in this ligament. Ignoring the isokinetic strength in individuals with reconstructed ACL can be one of the main reasons for re-injury. **Objective:** Therefore, this study aimed to compare the isokinetic profile of knee joint parameters in healthy military personnel and those with reconstructed ACL. **Methods:** The present study was a cross-sectional study. 28 male military personnel in two groups with healthy and reconstructed anterior cruciate ligaments (ACLR) participated in this study voluntarily. The Biodex isokinetic dynamometer was used to measure the parameters under study. Isokinetic measurements were performed at an angular velocity of 60°/s. Based on the research objective, the concentric strength of flexor and extensor muscles, average power, the strength ratio of agonist to antagonist muscles, and knee joint proprioception were evaluated. An independent t-test was used to examine the significant differences between the healthy and injured groups. **Results:** According to the independent t-test results, the peak extensor torque in the ACLR group was lower on average compared to the healthy group, but no significant relationship was observed between the two groups ($p = 0.132$). Additionally, the peak flexor torque, average extensor and flexor power, hamstring-to-quadriceps ratio, and proprioception in the ACLR group were significantly lower compared to the healthy group ($p = 0.000$, $p = 0.001$, $p = 0.003$, $p = 0.000$, $p = 0.003$). **Conclusions:** Based on the results of this study, it is recommended that rehabilitation exercises focus on improving the strength and proprioception of the acting muscles and teaching proper techniques during rehabilitation training to reduce the risks associated with recurrent anterior cruciate ligament injuries.

Key words: ACL, Anterior Cruciate Ligament Reconstruction, Isokinetic Profile, Proprioceptive, Knee Joint, Military Personnel

INTRODUCTION

The power and stability of a country are closely linked to its armed forces' health, physical fitness, and combat readiness. Physical fitness in military personnel can play a significant role in determining victory or defeat. Since military personnel require higher levels of physical and combat readiness than the general population, they undergo intense physical training such as combat drills, long runs and hikes with backpacks, obstacle courses, rappelling, artificial climbing, shooting, and jumping from various heights during their training periods (Whittaker et al., 2017). Physical activity and sports are highly popular worldwide due to their strong association with physical, physiological, and psychological fitness. However, injuries are an inseparable part of sports and physical activities, with lower limb joints being more susceptible to injuries compared to other joints (Aziminia & Riahy, 2022). The intense, strenuous, and prolonged training of soldiers and military personnel can lead to various injuries (Kaufman et al., 2000). A study by Najafi et al. (2010) on military personnel indicated that the most common reason for military personnel visiting the clinic was due to physical injuries (72%), with musculoskeletal injuries to the lower limbs being the most common type (Najafi Mehri et al., 2010). The prevalence of injuries among Iranian military personnel is reported to be 27.4%, with an incidence rate of 10.2 injuries per 100 soldiers per month (Zarei & Johari, 2022). Research conducted in the Department of Physical Medicine of the US Army on patients hospitalized due to

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physical injuries revealed that these injuries were caused by training periods and physical activities of the personnel, with the knee and then the ankle being the most frequently injured sites (Lauder et al., 2000).

The knee joint, like all joints, is prone to numerous injuries. It bears the body's weight during activities and strenuous maneuvers, making it more critical and unique compared to other joints like the shoulder, elbow, and wrist. One of the most common injuries to the knee joint in athletes and military personnel is the anterior cruciate ligament (ACL) tear (Pallis et al., 2012b). Knee injuries, particularly ACL injuries, are among the most significant knee injuries, occurring during physical and sports activities, both through contact (30%) and non-contact (70%) mechanisms (Sigward et al., 2012). Pallis et al. (2012), in a four-year study conducted at the US Military Academy, reported an incidence of 3.24 per 100 men and 3.51 per 100 women (Pallis et al., 2012a). One of the most common treatments for ACL tears is surgical reconstruction (Zarei & Johari, 2022). ACL reconstruction surgery is a standard method for restoring knee joint stability and function (Rahardja et al., 2019). A study by King et al. (2019) showed that only 82% of patients who underwent reconstruction could resume their previous activities, with only half regaining their pre-injury functional level (King et al., 2019). ACL injuries require extensive rehabilitation, which can keep individuals away from specialized training for up to 12 months and increase the risk of joint disorders such as knee osteoarthritis by 50% within 10 years post-surgery (Weir et al., 2019). Physical injuries like ACL tears significantly impact the combat readiness and ability of military personnel to perform future missions, consuming substantial operational budgets annually. Identifying ACL injury risk factors to pinpoint soldiers susceptible to injury and re-injury is crucial for developing and designing preventive training programs to prevent personal and operational issues such as decreased combat readiness, disability, and high healthcare costs (Najafi et al., 2020). Knee injuries, especially ACL tears, cause muscle weakness, atrophy, and dysfunction in muscle and joint mechanoreceptors, leading to increased extra force on the joint and exacerbating the condition (McNair et al., 1995).

Special attention to the strength of the muscles acting on the knee joint, the ratio of agonist to antagonist muscles, and knee joint proprioception are important factors that, if neglected, can predispose an individual to ACL re-injury (Monfaredian et al., n.d.). Studies show that inadequate rehabilitation post-ACL reconstruction reduces strength and neuromuscular control in individuals (Akbari et al., 2015). Improving muscle strength increases physical readiness capacity and significantly reduces the likelihood of muscle strains and increases joint stability, thereby reducing injury vulnerability. The ratio of maximum torque of agonist to antagonist muscles (Hamstring/Quadriceps) is a crucial indicator in ensuring knee joint stability and preventing injuries, particularly ACL injuries (Ahn & Lee, 2016). Muscular imbalance in the agonist and antagonist muscles of the knee joint is a major cause of ACL injury and re-injury (Monfaredian et al., n.d.). Proprioception refers to the messages received by mechanoreceptors in joints, ligaments, and muscles, communicating with the central nervous system through afferent and efferent neural pathways to report the joint's status (Angoules et al., 2011). Proprioceptive impairment and reduction lead to walking and running difficulties, loss of joint stability, and a lack of motor control (Bonfim et al., 2003). Research shows inconsistencies regarding the improvement of ligament mechanoreceptor function and proprioception post-surgery. Some studies show improved proprioception and no discrepancy with the healthy leg, while others indicate differences even upon return to activity. For instance, Furlanetto et al. (2016) showed no difference in proprioception and balance between post-surgical and healthy individuals six months after surgery (Furlanetto et al., 2016). However, studies indicate that even 24 months post-surgery, proprioception in reconstructed individuals differs and is reduced compared to healthy individuals (Laboute et al., 2019) (MacDonald et al., 1996).

Despite the high prevalence of anterior cruciate ligament (ACL) injuries and the research conducted on individuals with ACL reconstruction (ACLR), many aspects remain unknown. Recent insights and studies on the evaluation of isokinetic strength of lower limb joints, considering the performance of military personnel and research objectives, can help develop and enhance skills related to physical fitness and movement as well as injury prevention. Therefore, assessing isokinetic parameters may improve our understanding of risk factors associated with ACL injury and its recurrence. The aim of this study was to compare the isokinetic profile of knee joint parameters in healthy military personnel and those with reconstructed ACL.

METHODS

Participants and Study Design

The present study is an analytical and cross-sectional study. Using G-Power (Version 3.1 software) at a significance level of p =0.05 and a power of 0.8, 28 male military personnel in two groups of healthy (N: 15, Age: 27.35±3.21 years, mass: 72.05±5.71 kg, height: 177.10±4.42 cm, BMI: 22.78±1.02 kg/m2) and ACLR (N: 13, Age: 25.60±2.41 years, mass: 70.28±9.34 kg, height: 176.90±5.83 cm, BMI: 23.13±1.89 kg/m2, Period after injury: 17.10±4.01 months) participated in the present study by convenient sampling (Table 1). For the control group, the inclusion criteria included no surgical history, absence of visible abnormalities, and no chronic musculoskeletal pain affecting the trunk and lower limbs. Military personnel in the experimental group (ACLR) met specific criteria to be included in the study, such as using hamstring autograft in surgery at least one year after surgery, completing a full rehabilitation course aimed at improving balance and strengthening the quadriceps muscle, increasing agility, performing complex military maneuvers, returning to normal activity, and actively participating in military operations. All participants were determined to be right-limb dominant, as determined by asking about their preferred limb for activities like landing from a jump or initiating walking. All

Table 1. Mean and standard deviation of participants' demographic characteristics

Group	Number (people)	Age (years)	Body mass (kg)	Height (cm)	BMI (Kg/m²)	Time period after injury (months)
Healthy	15	27.35±3.21	72.05±5.71	177.10±4.42	22.78±1.02	---------
ACLR†	13	25.60±2.41	70.28±9.34	176.90±5.83	23.13±1.89	17.10±4.01

†: Anterior Cruciate Ligaments Reconstruction Group

participating military personnel were thoroughly informed about the research protocol and completed the informed consent form before commencement. Furthermore, all stages of the study were reviewed and approved by the Ethics Committee (Ethics ID: IR.AJAUMS.REC.1402_133) at the Army University of Medical Sciences, Islamic Republic of Iran.

Procedures

Initially, the participants were given necessary explanations in the biomechanics and movement analysis laboratory to familiarize them with the biomechanical movement evaluation equipment, the working methods, and the correct execution of the test. They were then asked to complete a personal information questionnaire and an informed consent form if they wished to participate in the research. To determine the anthropometric characteristics, the height and weight of the participants were measured using a stadiometer with 1 mm accuracy and a digital personal scale with 100 grams accuracy, respectively. The dominant functional leg of the military personnel was determined by asking the participants which leg they used to kick a ball (Aziminia & Riahy, 2022). To prevent injury during the test, participants performed a 5-minute warm-up, which included dynamic movements.

After preparing the participants, the concentric strength of the knee flexor and extensor muscles was measured using a Biodex isokinetic dynamometer (Biodex Medical Systems Inc., New York, NY, USA). Isokinetic measurements were conducted at an angular velocity of 60°/s. To measure the desired variables in the knee joint, participants were seated on the adjustable chair of the dynamometer. The rest of the body was secured with special straps to prevent unnecessary movements. The height, angles, rotation, and positioning of the chair and dynamometer were adjusted according to the individual characteristics of each participant. The final adjustments ensured that the axis of rotation of the dynamometer was aligned with the center of the axis of rotation of each joint. The lever arm, designed specifically for the dominant leg (right), was adjusted so that its cushion was positioned 2.5 cm above the inner ankle. Thus, following all the standard protocols mentioned in the Biodex dynamometer user guide, the concentric strength of the knee flexor and extensor muscles was evaluated (Kabacinski et al., 2022). The range of motion for each joint was individually set for each participant. Additionally, to eliminate the effect of gravitational torque, the weight of the limb was calculated by the system. To ensure proper execution of the movement and familiarize the participants with the device, they were asked to perform the required skill several times within the determined range of motion; then, each participant executed the required skill five times with maximum strength. It is worth noting that a 2-minute rest period was given to each participant between each execution to prevent potential fatigue effects (Figure 1).

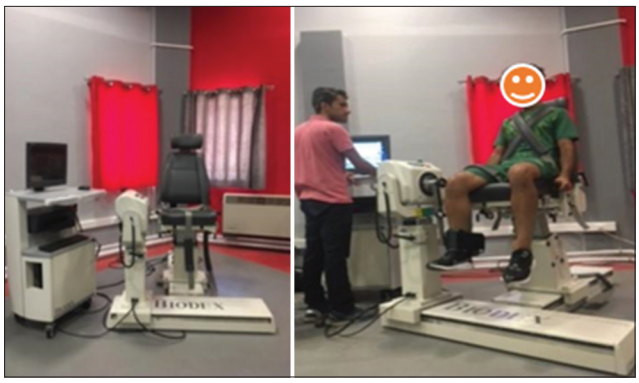

Figure 1. Overview of the laboratory and performing isokinetic testing

Statistical Analysis

The statistical methods employed in this study included descriptive and inferential statistics. The means and standard deviations were calculated for participant characteristics using descriptive statistics. The Shapiro-Wilk test was used to assess the normality of data distribution, and an independent t-test was utilized to compare means between the healthy and ACLR groups at a significance level of 0.05. The Cohen's d effect sizes were calculated and defined as small ($d \leq 0.2$), moderate ($d > 0.2$ to ≤ 0.5), or large ($d > 0.5$ to ≤ 0.8) (Cohen, 2013). Statistical calculations were performed using SPSS version 27 software.

RESULTS

The results of the Shapiro-Wilk test indicated that the distribution of the variables in both the healthy and ACLR groups was normal ($P > .05$). Descriptive and inferential data collected from the measurement of isokinetic parameters and variables are presented in Table 2, categorized by group. The results of this study showed, that there was no significant difference in the peak extensor torque for the healthy and ACLR group ($p = .132$). There were also significant differences between the two groups in peak flexor torque ($P = .003$), average extensor power ($P = .000$), average flexor strength ($P = .003$), hamstring to quadriceps ratio ($P = .001$), and proprioception ($P = .000$) and they were reduced in the ACLR group compared to the healthy group.

Table 2. Descriptive and inferential statistics for the study parameters in two groups

Variables	Group	Means±Standard Deviation	P-value
Peak Torque Extensor (Newton-Meters)	Healthy	179.85±28.45	0.132
	ACLR	173.85±44.85	
Peak Torque Flexor (Newton-Meters)	Healthy	101.95±24.67	0.003*
	ACLR	96.87±17.43	
Average Extensor Power (Watts)	Healthy	109.21±22.12	0.000*
	ACLR	102.17±32.73	
Average Flexor Power (Watts)	Healthy	70.11±17.38	0.003*
	ACLR	66.16±17.14	
Hamstring-to-Quadriceps Ratio (%)	Healthy	57.73±12.88	0.001*
	ACLR	53.55±9.90	
Proprioception (Degrees)	Healthy	4.68±3.29	0.000*
	ACLR	3.82±2.76	

*Indicates a statistically significant difference between groups (P<0.05). †: Anterior Cruciate Ligaments Reconstruction Group

DISCUSSION

The aim of this study was to examine the isokinetic parameters and variables of the knee joint in healthy military personnel and those with surgically reconstructed anterior cruciate ligaments (ACLR). The results of the present study indicated that peak flexor torque and the mean extensor and flexor power in the ACLR group were significantly lower compared to the healthy group. Following ACL surgery, the strength of the quadriceps and hamstring muscles decreases significantly due to the instability and lack of sufficient mobility. This reduction in strength reaches its maximum in the first few months after surgery (McHugh et al., 2002). Studies show that without proper rehabilitation, weakness in the hamstring and quadriceps muscles can persist for up to two years after ACL reconstruction, especially compared to the healthy leg (Gillet et al., 2022). The proper functioning of the hamstring muscles is crucial for protecting the anterior cruciate ligament (ACL) and preventing anterior displacement of the tibia relative to the femur. Findings from various studies suggest that the proper activity of the muscles acting on the knee joint is essential for providing dynamic stability to the knee joint. Therefore, restoring muscle volume and strength after ACL reconstruction is of particular importance (Solomonow et al., 1987).

Reduced strength in the knee joint muscles, which are the primary joints responsible for bearing body weight during activity, can impair the ability of individuals with ACLR to respond quickly in challenging conditions, such as military maneuvers. Clinically, this weakness may affect neuromuscular mechanisms, reducing the ability of these individuals to respond to challenging tasks and maintain stability, potentially leading to re-rupture of the ACL (Armitano-Lago et al., 2020). Therefore, strengthening the flexor and extensor muscles of the knee joint is a crucial and necessary component of rehabilitation to improve joint function. Additionally, the results of the present study showed a significant decrease in the H/Q ratio in individuals with ACLR compared to healthy individuals. The H/Q strength ratio is one of the most important indicators for ensuring knee joint stability and preventing injury, particularly anterior cruciate ligament (ACL) injury. It is defined as the ratio of maximum concentric strength of the hamstring muscles to the maximum concentric strength of the quadriceps muscles (Barber-Westin et al., 2009)(Nilstad et al., 2014).

The H/Q ratio is related to ACL injury due to its connection with the muscular balance between the agonist and antagonist muscles around the knee joint. A lack of muscle balance in the knee joint can lead to injury and re-rupture of the ACL. For example, when the quadriceps muscles are significantly stronger than the hamstrings, the ACL is subjected to greater anterior displacement and shear force (Li et al., 1996). Anterior shear force is a critical factor in determining the load placed on the ACL, and its increase is directly related to the imbalance of the muscles acting on the knee joint (Aziminia & Abbasi, 2022). Evaluating isokinetic parameters in the knee joint can be used to assess the strength of the hamstring and quadriceps muscles, providing indices to quantify the torque generated by these muscles and, consequently, the hamstring-to-quadriceps ratio.

The results of the present study showed a significant decrease in proprioception in individuals with reconstructed anterior cruciate ligaments (ACLR) compared to healthy individuals. Proprioception is the ability to sense or perceive the spatial position and movements of the body without relying on vision. This sense involves receptors such as muscle spindles, Golgi tendon organs, and joint receptors, which transmit information about proprioception to the central nervous system. These receptors are responsible for creating awareness of movement and coordinating the various parts of the body relative to each other (Ruzik et al., 2020). In other words, proprioception is a comprehensive term for the sense of movement, receiving sensory input from muscle spindles, tendons, and joints to determine the position and movement of joints, as well as accurately identifying the direction, intensity, and speed of joint movements (Amiri et al., 2020). Proprioceptive deficits in the knee joint have been widely described in relation to ACL injuries. Studies indicate that proprioceptive receptors are present within the ACL and play a crucial role in optimal muscular contraction

around the knee joint (Valeriani et al., 1999). When the ACL is torn, sensory stimuli from these mechanoreceptors in the knee fail to reach the central nervous system, which can lead to instability in the lower limb joints, particularly the knee joint. Therefore, a significant reduction in proprioception in individuals with ACLR can result in knee joint instability and make the individual more susceptible to re-injury of the anterior cruciate ligament (Angoules et al., 2011).

Limitation

Considering the present study's findings on the isokinetic profile of the knee joint between healthy and reconstructed ACL military personnel, however, some limitations must also be considered for future research. Firstly, since military personnel are exposed to various military and operational maneuvers in difficult conditions and at different speeds, measuring the isokinetic strength of these individuals at various speeds and other types of contractions (such as concentric-eccentric) can provide more comprehensive results regarding the prevention of injury and re-rupture of the ACL. Secondly, assessing the activity of the muscles acting in the knee joint using an electromyography device during specialized military maneuvers can be effective in designing rehabilitation exercises. Finally, given that changes in movement patterns in ACLR individuals are one of the most important factors influencing re-injury in these individuals, evaluating other biomechanical parameters, including kinematic and kinetic variables, in ACLR individuals can play a fundamental role in correcting undesirable movement patterns in rehabilitation protocols.

Strengths and Practical Implications

Despite the limitations, this research contributes to the depth of information on the isokinetic profile of the knee joint between healthy and reconstructed ACL military personnel. That is more than relying on only theoretical assumptions. This can lead to identifying risk factors for ACL injury and re-tear, as well as help design rehabilitation exercises after surgery in ACLR patients.

CONCLUSION

The results of the present study indicated that military personnel with ACLR exhibit altered muscle torque and proprioception compared to healthy individuals. These changes may be due to the weakness of the muscles acting on the lower limb joints and inadequate rehabilitation following surgery. Neglecting these factors could lead to re-rupture of the ACL in these individuals. Therefore, it is recommended that the muscles involved be strengthened, neuromuscular coordination improved, and proper training in techniques and movement patterns is provided to minimize the risks associated with ACL re-injury. Based on the findings of this study, it can be concluded that the reduction in muscle strength and proprioception in the knee joint of individuals with ACLR leads to undesirable changes in extensor, flexor, and neuromuscular parameters. These changes may play a significant role in ACL injury and re-rupture. Therefore, it is recommended to include exercise protocols aimed at increasing muscle strength and proprioception of the knee joint in rehabilitation programs. Since soldiers and military personnel often face various military maneuvers and specialized activities during experimental and combat operations, physical fitness and increased muscle strength play a crucial role in correcting movement control patterns and adapting to challenging and hazardous conditions. Therefore, continuous assessment of biomechanical variables in both healthy and injured individuals within these organizations could enhance our understanding of the risk factors associated with musculoskeletal injuries, particularly anterior cruciate ligament injuries and their re-rupture.

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DATA AVAILABILITY

The data used for analysis in the biodex isokinetic dynamometer during the blocking study are available from the corresponding author upon reasonable request.

AUTHOR'S CONTRIBUTION

Omid Monfaredian: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Investigation, Data collection. Mohammad Aziminia: Writing – review & editing, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Data analysis. Sharif Najafi: Supervision, Conceptualization. Simin Riahi: Writing – review & editing, Writing – original draft, Visualization, Conceptualization

ETHICAL APPROVAL

The study was approved by the ethical committee of the Army University of Medical Sciences, Islamic Republic of Iran (Ethics ID: IR.AJAUMS.REC.1402_133). The procedures of the study were explained to all the participants and collected the data with the guidelines of the Declaration of Helsinki for human research.

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