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ORIGINAL INVESTIGATION / ÖZGÜN ARAŞTIRMA

# Examination of Isokinetic Knee Strength and Hamstring/Quadriceps Ratios in Individuals with Anterior Cruciate Ligament Injury: ACL Injured Knee Versus Non-Injured Knee

## Ön Çapraz Bağ Yaralanması Olan Bireylerde İzokinetik Diz Kuvveti ve Hamstring/Quadriceps Oranlarının İncelenmesi: Ön Çapraz Bağ Hasarlı Diz ve Yaralanmamış Diz

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## ABSTRACT

**Objective:** The aims of this study were to compare the isokinetic forces and Hamstring/Quadriceps (H/Q) ratios in individuals with anterior cruciate ligament (ACL) injury sides and contralateral non-injured sides.

**Method:** Twenty-three male patients with unilateral acute ACL injury were included in the study. The isokinetic extension (Ex) and flexion (Flx) forces of both knees were measured using an isokinetic dynamometer. Isokinetic tests were performed with three different angular speeds (60° s/180° s/240° s) with five repetitions for 60° s and 180° s and 15 repetitions for 240° s or concentric contraction.

**Results:** The mean age of the patients was 25.18, the mean height was 176.81, and the mean weight was 77.12. The mean time from ACL injury to the time of measurements was 37.47±11.11 days. When the isokinetic strengths of knees with ACL injury and knees without ACL injury were examined, there was a significant difference in Ex phase at an angular velocity of 60°s ($p=0.012$, 95% CI: 5.95–41.54). No significant difference was detected in both Ex and Flx phases of other angular velocities ($p>0.05$).

**Conclusion:** As a result, the knee with an ACL injury generates less force than the knee without an ACL injury. H/Q ratios were also outside the normal range on the ACL damaged side only at 60 s angular velocity, as expected. The absence of a significant difference in both strength and H/Q ratios at high angular velocities indicates that the movement is performed with less force than at lower angular velocities, and this situation strains the hamstring and quadriceps muscles less.

**Keywords:** Anterior cruciate ligament injury, isokinetic, lateral asymmetry

## ÖZ

**Amaç:** Çalışmamızın amacı, ön çapraz bağ yaralanmalı tarafları ve karşı taraf yaralanmamış tarafları olan bireylerde izokinetik kuvvetleri ve Hamstring/Quadriceps oranlarını karşılaştırmaktır.

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**Yöntem:** Tek taraflı akut ön çapraz bağ yaralanması mevcut olan 23 erkek hasta çalışmaya dahil edildi. Her iki dizin izokinetik kuvvetleri dinamometre yardımıyla ölçüldü. İzokinetik testler üç farklı açısal hızda (60°sn/180°sn/240°sn) 60°sn ve 180°sn için beş tekrar ve konsantrik kasılma için 240°sn için 15 tekrar ile yapıldı.

**Bulgular:** Hastaların ortalama yaşı 25,18 yıl, ortalama boyu 176,81 cm ve ortalama kilosu 77,12 kg idi. Ön çapraz bağ yaralanmasından ölçümlerin yapıldığı zamana kadar geçen süre ortalama 37,47±11,11 gündü. Ön çapraz bağ yaralanması mevcut dizler ile ön çapraz bağ hasarı olmayan dizlerin izokinetik kuvvetleri incelendiğinde, 60°sn'lik açısal hızda Ex fazında anlamlı bir farklılık vardı (p=0,012, %95 GA: 5,95–41,54). Diğer açısal hızların hem Ex hem de Flx fazlarında anlamlı bir fark tespit edilmedi (p>0,05).

**Sonuç:** Ön çapraz bağ yaralanması olan diz, ön çapraz bağ yaralanması olmayan dizden daha az güç üretir. Hamstring/Quadriceps oranları da beklendiği gibi sadece 60°sn açısal hızda ön çapraz bağ hasarı olan tarafta normal aralığın dışındaydı. Yüksek açısal hızlarda hem kuvvet hem de Hamstring/Quadriceps oranlarında önemli bir fark olmaması, hareketin daha düşük açısal hızlara göre daha az kuvvetle yapıldığını ve bu durumun hamstring ve quadriceps kaslarını daha az gerdiğini göstermektedir.

**Anahtar kelimeler:** İzokinetik, lateral asimetri, ön çapraz bağ hasarı

## INTRODUCTION

The anterior cruciate ligament (ACL) is the strongest of the four main ligaments that stabilize the knee joint. The ACL structure is sufficient to adjust the stiffness of the knee muscles, perform reciprocal movements such as knee extension (Ex) and flexion (Flx) safely, and ensure its stability.[1] Injury to the ACL results in both acute and chronic impairment. Quadriceps weakness is common, and activity levels and quality of life decline significantly during the early phase.[2] In the late phase, chronic quadriceps dysfunction result in the development of osteoarthritis.[2,3]

ACL injuries have many negative effects on thigh muscle function, including reducing muscle strength and causing instability in strength due to torque formation.[4,5] After ACL rupture, Ex and Flx strength reciprocally applied by the knee, peak torque (PT), total work, and average power values depending on the number of repetitions can be measured objectively with isokinetic dynamometers.[6] At the same time, the strength ratios of the hamstring (H) and quadriceps (Q) muscles during the Ex and Flx phases are of great importance in determining the susceptibility to disability. Asymmetric strength for the lower extremities can be defined as the unequal strength between the right and left Q and H muscles in similar types of contractions. The ratio of strength between H and Q muscles (H/Q) increases as the test velocity increases in isokinetic dynamometers.[7] This ratio differs by 50–80% depending on the test velocity, and a level of 60% at an angular velocity of 60° $s^{-1}$ is considered normal.[8] Although this accepted ratio is generally acceptable for everyone, it may sometimes vary depending on the physical activity, workload, and muscle structure of the person. Especially in athletes, these ratios may produce different results.

The aim of our study was to determine the isokinetic knee Ex and Flx strength at different angular velocities between the injured knee and the non-injured knee and to compare both knees depending on the H/Q ratios from these strengths. We hypothesized that the knee with an ACL injury will produce less strength than the non-injured knee and will be out of normal norm values in terms of H/Q ratios.

## METHOD

### Experimental Design and Subjects

Our study was carried out retrospectively in accordance with the ethical standards of the Ondokuz Mayis University Clinical Research Ethics Committee and the 1975 Declaration of Helsinki, which was revised in 2013. Ethics committee approval was obtained (Decision No. 2021-189, 04/05/2021). All patients signed an informed consent form stating "I voluntarily agree to participate in the clinical trial." Inclusion criteria were to have a unilateral acute ACL injury (3 months maximum) and a contralateral uninjured knee. Patients who had previous lower extremity surgery for any reason, patients with chronic ACL rupture longer than 3 months, patients with neurological disease, and patients with cartilage or concomitant meniscus pathology were excluded from the study.

### Isokinetic Knee Strength Measurement

Subjects visited the laboratory twice. At the first visit, subjects were briefed about the study and measurements. At the second visit, isokinetic Ex and Flx e forces of both knees were measured by a sports physician. construction scale model Imports Cybex Humac Norm isokinetic dynamometer was used to measure isokinetic knee Ex and Flx strength. The limb to be measured of the subjects was fixed to an isokinetic seat with a belt. Isokinetic tests were carried out at three different angular velocities (60° $s^{-1}$/180° $s^{-1}$/240° $s^{-1}$) with five repetitions for 60° $s^{-1}$ and 180° $s^{-1}$ and 15 repeti-

| Table 1. Demographic data of patients | | | |
|---|---|---|---|
| **Variables** | **Mean±SD** | **Min** | **Max** |
| Age (year) | 25.18±5.94 | 18.00 | 36.00 |
| Weight (kg) | 77.12±13.56 | 58.00 | 114.00 |
| Height (cm) | 176.81±6.73 | 168.00 | 193.00 |
| BMI (kg/m$^2$) | 24.70±4.31 | 18.31 | 35.19 |

BMI: Body mass index

tions for 240° s$^{-1}$ for concentric contraction (Con/Con) (Table 1). A warm-up was performed with ten repetitions at 300° s$^{-1}$ angular velocity on an isokinetic dynamometer before the measurements and the rest interval between each angular velocity was set to 45 s for both sides. Each subject was informed about basic push/pull and the number of remaining repetitions, and loud verbal encouragement was given continuously to help the PT values of the subjects to reach the highest level during testing.

### Statistical Analysis

SPSS version 22.0 (SPSS Inc., Chicago, IL) program was used for statistical analyses. The data were expressed as the mean and standard deviation. The Shapiro–Wilk test was used to assess normality. A paired-samples t-test was used to analyze the differences between the ACL injured and non-injured sides. Significance was defined as $p \leq 0.05$.

## RESULTS

In total, 23 sedentary male subjects who have an ACL injury in their right or left knee (mean age, 25.18 years; mean height, 176.81 cm; and mean weight, 77.12 kg) participated in the study voluntarily. The mean time from the patients' ACL injury to the time the measurements was made during the examination was 37.47±11.11 days on average. The examination of isokinetic knee strengths in the subjects on injured and non-injured sides showed a statistically significant difference in angular velocity of 60° s$^{-1}$ during the Ex phase (p=0.012, 95% CI: 5.95–41.54) among 60, 180, and 240° s$^{-1}$ angular velocities of the Ex and Flx phases. No significant difference was detected in both Ex and Flx phases of other angular velocities (p>0.05) (Fig. 1). The H/Q ratios obtained from isokinetic Ex and Flx knee strengths in angular velocities of 60, 180, and 240° s$^{-1}$ on injured and non-injured sides are shown in Figure 2. There was a significant difference only in the angular velocity of 60° s$^{-1}$ (p=0.008, 95% CI: −10.90–−1.98). There was no significant difference in other angular velocities (p>0.05).

## DISCUSSION

Our study aimed to reveal the isokinetic knee Ex and Flx strength on the injured and non-injured sides of individuals with an ACL injury, as well as to present the strength asymmetries resulting from these strengths as the H/Q ratio. For this purpose, our study has revealed two major findings. The first finding is that the non-injured side produces high PT during the Ex phase of the angular velocity of 60° s$^{-1}$ compared to the injured side, and the second finding is that the injured side has a higher H/Q ratio than the non-injured side in the angular velocity of 60° s$^{-1}$. Tsepis et al.[9] measured Ex and Flx strength of the knee at an angular velocity of 60° s$^{-1}$, and they found that, especially with the ACL, the injured side had higher frequencies during the generation of strength than the non-injured side. This result clearly shows that the ACL injured side displays further oscillation, causing massive fluctuations in the torque time curve, and means that the injured side cannot maintain endurance during the generation of the strength. In our study, it was concluded

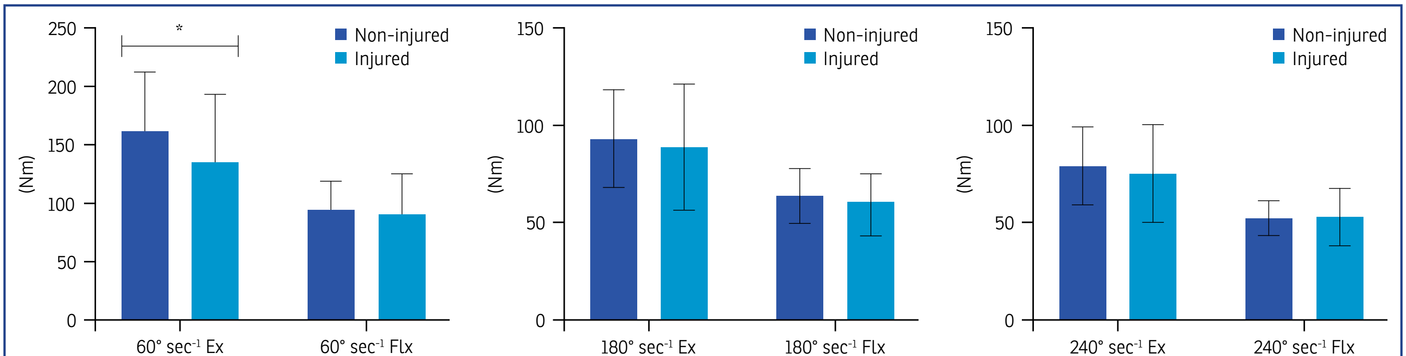


**Figure 1.** Comparison of knee isokinetic Ex and Flx strengths of injured and non-injured sides

*p<0.05; Ex: Extension; Flx: Flexion

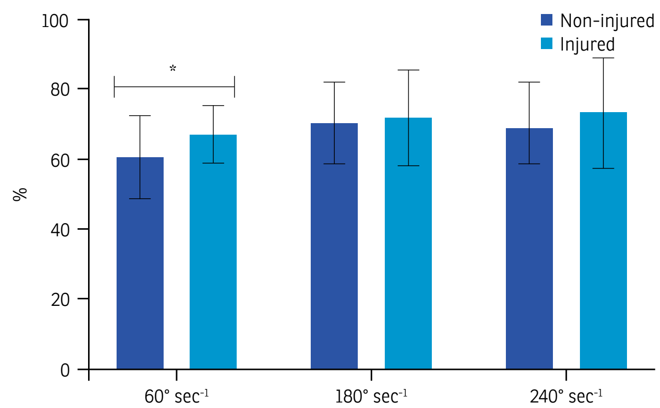


**Figure 2.** Comparison of Hamstring/Quadriceps ratios of injured and non-injured sides

*p<0.05

that this may occur due to neuromuscular wear that characterizes the isokinetic strength curve on the ACL injured side, and therefore, the generation of the strength may be lower compared to the non-injured side.

Li et al.[10] measured the isokinetic knee strength of individuals with ACL injury and reactively exercising at angular velocities of 60° $s^{-1}$ and 180° $s^{-1}$ and found a strong correlation between the H/Q ratio and the knee with ACL injury. The researchers supported this result with their functional ability tests and reported that the ability to function in the non-injured knee increases as the strength increases. In the same study, it was concluded that as the angular velocity increases during isokinetic tests, the strength generation of the knee with ACL injury may increase. This outcome corresponds exactly with our study. In our study, there was no significant difference between injured and non-injured knees in terms of strength and H/Q ratios in 180° $s^{-1}$ and 240° $s^{-1}$ angular velocities. Besides, researchers found that not only PT values at different angular velocities in the knee with an ACL injury but also the fluctuations in time to PT, reciprocal delay, or repetitive measurements. Angular velocities also revealed the idea that the ACL would reveal different variations between injured and non-injured knees.[9,11]

Kannus et al.[12] measured isokinetic muscle strengths at angular velocities of 60° $s^{-1}$ and 180° s–1 in 40 individuals with ACL injury who had not been treated for 8 years. They found a significant Q and H strength deficiency in the injured knee compared to the non-injured knee. Unlike our study, this study reported that the difference in strength occurs from low angular velocities to high angular velocities, and therefore, specific high-speed Ex and Flx exercises are needed to prevent tibial anterolateral subluxations and painful symptoms of the injured knee during rehabilitation. From a mechanical point of view, anterolateral subluxation of the tibia may occur if it is not treated for a long time due to excessive looseness in the knee with ACL injury. At low angular velocities, it may inhibit the generation of Ex and Flx strength of the knee. Some studies indirectly support this argument.[13] However, in our study, the lack of difference in strength or H/Q ratio in the tests at high angular velocities may be due to the fact that subjects were tested 2 months after the diagnosis of ACL injury.

Hohmann et al.,[4] in their evaluations of isokinetic strength in patients with ACL injury and undergoing reconstruction, reported that the H/Q ratio is not a direct reflector of knee function in patients with ACL injury but is a subjective indicator of knee function in patients undergoing reconstruction. These results are supported by the fact that the values obtained by the subjects at all angular velocities in our study are in the percentage ranges that do not carry a risk of disability. For example, our subjects showed an average H/Q ratio of 60–65% for both knees at an angular velocity of 60° $s^{-1}$. This result is considered normal for the angular velocity of 60° $s^{-1}$ among the norm values. However, it is a fact that knee function on the ACL injured side produces a higher H/Q ratio than the non-injured side and tends to be toward risk.

In the meta-analysis conducted by Kim, several studies investigating the isokinetic strength changes in ACL injuries were examined in detail. It was reported that an ACL injury caused power loss in both the Ex and Flx phases, the loss of strength in the Q muscle was approximately 3 times higher than in the H muscle, and these decreases in strength caused a slight increase in H/Q ratios.[14] These results are exactly consistent with the findings of our study. Our study findings generally coincide with the results of individuals with ACL injuries at low (60° $s^{-1}$) and high (180° $s^{-1}$ and 240° $s^{-1}$) angular velocities. In addition, in the studies conducted after ACL reconstruction, it was seen that the non-injured side produces higher results compared to the operated side.[15] However, in different autograft transplants, it was seen that differences, although not significant, occurred in knee strength at different angular velocities.[16]

As a result, the knee with an ACL injury generates less force than the knee without an ACL injury. H/Q ratios were also outside the normal range on the ACL damaged side only at 60 s angular velocity, as expected. The absence of a significant difference in both strength and H/Q ratios at high angular velocities indicates that the movement is performed with less force than at lower angular velocities, and this situation strains the H and Q muscles less.

## Disclosures

**Ethics Committee Approval:** The study was approved by the Ondokuz Mayıs University Clinical Research Ethics Committee (No: 2021/189, Date: 04/05/2021).

**Informed Consent:** Written informed consent was obtained from all patients.

**Peer-review:** Externally peer reviewed.

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**Conflict of Interest:** No conflict of interest was declared by the authors.

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