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# Implementing Y-balance test and isokinetic strength testing as return to sport criteria in a footballer after ACL reconstruction: A case report

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**Abstract**
This case report presents an implementation of dynamic balance and isokinetic (concentric) strength testing for a comprehensive assessment of the degree of strength and balance deficits during anterior cruciate ligament (ACL) reconstruction recovery. Tests were performed on the extensors and flexors of an injured and non-injured knee in a professional football player, six months after arthroscopic ACL intervention. The dynamic balance was tested with the Y balance test (YBT) and the results showed a good recovery based on proprioceptive targeted lower limb exercises with values of 100.1% for the non-injured leg and 98.5% for the injured leg with a norm >95% and indicate an appropriate physiotherapy program. According to the peak torque data obtained during isokinetic dynamometry the strength characteristics of the extensors of the injured knee were significantly lower compared to the healthy limb (1.91 Nm/kg vs. norm - 2.67 Nm). The bilateral PT difference of the extensors was 35% and was higher than the recommended 10% difference for safe return to sport. Peak torque values in concentric contractions of the athlete showed deficiencies in strength and risk of re-injury in early return to sport. These results allow an improvement in the training and therapeutic program of the football player and are beneficial for restoring the strength of the knee muscle groups and the unilateral/bilateral balance of strength in both legs in order to avoid re-injury.

**Keywords:** Knee injury, strength asymmetry, ACL reconstruction, isokinetic dynamometry, Y-balance test

## Introduction
Recovery from anterior cruciate ligament (ACL) reconstruction is a complex and multi-step process. Studies have shown that the highest prevalence of ACL injuries occurs in athletes between the ages of 15 and 40, with this type of orthopaedic surgery being the most commonly performed worldwide [1]. For professional athletes, the process of rapid return to sport is a priority and often outweighs actual recovery. The high rate of secondary injury in young athletes returning to sport after ACL reconstruction results in a 30 to 40 times higher risk of injury in this relationship compared to those without a traumatic history [2]. In 2016, Grindem *et al.* [3] found that the rate of re-injury was significantly reduced (51%) for every month of return to sport and was delayed until 9 months after surgery, and that bilateral quadriceps strength before return to sport significantly reduced the incidence of knee re-injury. It has been found that 94% of elite male and younger athletes return to play within 12 months of ACL reconstruction, but 60% to 70% of athletes report an inability to return to their pre-injury level of play [3]. Various studies have demonstrated initial quadriceps weakness and strength recovery with 85% as late as the third year after surgery [1, 4]. Therefore, it is beneficial to the athlete if a comprehensive analysis and assessment of the athlete's condition following ACL reconstruction is performed including tracking the unilateral and bilateral knee flexor and extensor strength coefficient levels in the injured and non-injured leg, as well as comparisons to sport- and position-specific metrics [5]. Isokinetic dynamometry is the reference method for measuring strength and power asymmetry as it provides an objective and comprehensive approach to determining muscle function [6]. It is recommended that athletes return to active sport when quadriceps strength reaches 90% strength symmetry with the contralateral side [3]. A routine approach to assessment is the so-called H/Q factor for unilateral asymmetry, which is calculated as the ratio of the peak torque

of the knee flexors (hamstrings) in concentric contractions to that of the extensors (quadriceps). A number of studies have shown a direct correlation between the H/Q ratio and ACL injuries and tears in footballers. Commonly accepted norms for physiological H versus Q weakness, represented by unilateral asymmetry, are 62%, 72% and 78% at speeds of 60, 180 and 300°/s respectively. However, these values increase in weak extensors [7]. In healthy, untrained individuals, a 15% deviation from these values for unilateral asymmetry is acceptable, but in athletes, deviations above 10% pose a risk of injury due to the dynamic nature of football and its common asymmetric loading patterns on the lower extremities [2, 5]. Another way to measure and assess dynamic balance and motor control is to use the Y Balance Test (YBT). The YBT is a reliable screening tool for identifying people with balance problems and those at risk of lower limb injury. It is also used to assess post-traumatic conditions and monitor rehabilitation progress. It is used to measure dynamic balance and can be used to predict injury in the presence of muscle imbalance. It is used to assess balance in various types of sports injuries [8, 9, 10]. In this case report we evaluate and analyze: - dynamic balance indices, peak torque (PT) of the extensors and flexors of the knee joint of the injured and uninjured limb, H/Q coefficients for unilateral power asymmetry at low, medium and high angular velocity, and coefficients for bilateral asymmetry, in a professional footballer after ACL reconstruction, with the aim of forming an opinion on the return to active sport.

**Case report**

The testing of a footballer with ACL reconstructed right knee was conducted at the Center for Functional Research in Sport and Kinesitherapy of Southwest University "Neofit Rilski", Blagoevgrad. The research subject was a 27-year-old athlete - central defender with 10 years of training experience in a professional football team. In November 2020, arthroscopic reconstruction was performed after rupture of ACL of left (non-dominant) lower limb. In May 2023, he underwent a right (dominant) lower extremity ACL reconstruction. The strength and dynamic balance testing was performed six months after the arthroscopic intervention, on both limbs to functionally assess the status of the knee joint flexors and extensors and return to competitive activity. Dynamic balance was assessed with YBT using an FMS experimental set-up. This device measured the following parameters: - Absolute Reached Distance (ARD), represented as the average of 3 repetitions in 3 mutually perpendicular directions, called Anterior (ANT), Posteromedial (PM) and Posterolateral (PL); and - Normalized Reached Distance (NRD) in percentage, relative to the length of the lower limb. Both limbs were 98cm. This gives the Composite Score (CS) as a percentage of the sum of the NDRs, according to the formula:

$CS\ (\%) = NRD_{ANT}+NRD_{PM}+NRD_{PL} / 3 \times limb\ length \times 100.$

The strength of knee extensors and flexors was measured with a Biodex 4S Pro isokinetic dynamometer in concentric mode at three angular velocities: low - 60°/s, moderate - 180°/s and high - 300°/s and presented as peak torque. Bilateral strength asymmetry was assessed by a coefficient that evaluated the differences in strength of the injured and non-injured knee extension muscle groups. Bilateral asymmetry for a given muscle group was calculated at a velocity of 60°/s, when the greatest PT is generated, with the following formula:

$$\frac{(\text{PT stronger leg} - \text{PT weeker leg})}{\text{PT stronger leg}} \text{x}100$$

where PT is the peak torque in Nm. Dai *et al* (2019) [7] state values up to 15% as the norm for the bilateral asymmetry coefficient in healthy, untrained individuals or as a threshold distinguishing norm from pathology, but it is accepted that in athletes the threshold for power bilateral asymmetry should be up to 10%. The unilateral asymmetry quotient, better known as the ratio of the peak torque of the flexors (Hamstrings) to that of the extensors (Quadriceps) or the H/Q ratio, is informative about the balance between the flexors and extensors of the knee on the same leg. The unilateral asymmetry coefficient (%), was calculated using the formula: (PT of H /PT of Q) x100, at the three angular velocities.

The results of the YBT performed (Table 1) show a lack of asymmetry in the distance reached in the three different test directions. The dynamic balance of both legs and the values of the reached distance was symmetrical and no pathological deviations were observed. In the anterior direction with a left supporting leg, the achieved distance was 69.6 cm, which was within the normal values (51.1-80.1 cm). The values with right supporting leg were also within the satisfactory range of 69.9 cm (with a norm of 50.3-93.6), with no difference between the averaged distance values in the anterior direction. In the other two directions of the test, the differences between left and right leg were relatively low (within PM direction =2 cm and PL direction =3 cm. Balance is crucial for agility and turning ability in footballa XDS, i.e., for abrupt changes in movement direction. Its tracking is crucial for recovery after lower limb injuries and the prevention of re-growths and injuries.

The relative peak torque (peak torque/kg weight) of the extensors of the injured leg at a speed of 60 °/s was 1.91 Nm/kg and for the uninjured leg -2.93 Nm/kg (norm - 2.67 Nm). The PT of the extensors of the leg with reconstructed ACL was 35% lower than the PT of the extensors of the uninjured leg. The data showed bilateral force asymmetry (<10%) in the extensors.

This extensor deficit of the injured (kicking) leg is a serious problem because it leads to unilateral and bilateral asymmetry. It registers at low speed when greater force is required. Bilateral asymmetry in the flexor groups of both legs was not observed (<10%), with peak torque/kg of 1.53 Nm/kg for the unimpaired and 1.44 Nm/kg for the impaired (with a norm for the trained of 1.35 Nm/kg).

The ratio of the strength of the posterior thigh muscle group to that of the quadriceps (H/Q) is an important and widely applied criterion in the rehabilitation process after ACL reconstruction surgery and plays a determining role in knee stability. At a velocity of 60 °/s it is in the norm about 61%, but due to the weak quadriceps of the kicking leg, the ratio is 80.1% (Table 2). This is a serious and common problem after ACL reconstruction of the knee joint. At higher velocities, the trend persists, but the deficit is less pronounced, as shown in Table 2.

**Table 1:** Dynamic balance scores after arthroscopic anterior cruciate ligament intervention in the injured and uninjured leg of a professional soccer player.

| Standing with left leg supported | | | | Standing with right leg supported | | | |
|---|---|---|---|---|---|---|---|
| **Parameters** | **Directions** | | | **Parameters** | **Directions** | | |
| | **ANT** | **PM** | **PL** | | **ANT** | **PM** | **PL** |
| Distance at Trail 1 (cm) | 69 | 115 | 111 | Distance at Trail 1 (cm) | 70 | 108 | 108 |
| Distance at Trail 2 (cm) | 70 | 112 | 111 | Distance at Trail 2 (cm) | 69 | 112 | 108 |
| Distance at Trail 3 (cm) | 70 | 113 | 113 | Distance at Trail 3 (cm) | 70 | 114 | 110 |
| **Calculated values** | | | | | | | |
| ARD (cm) | 69.7 | 113.3 | 111.6 | ARD(cm) | 69.6 | 111.3 | 108.6 |
| NRD (%) | 71.0 | 115.0 | 113.0 | NRD (%) | 71.0 | 113.0 | 110.0 |
| CS (%) | 100.1 | | | CS (%) | 98.5 | | |

Absolute reach distance (ARD) (cm) = (Reach 1 + Reach 2 + Reach 3) / 3
Relative (normalized) reach distance (NRD) (%) = Absolute reach distance / limb length * 100
Composite reach distance (%) (CS) = Sum of the 3 reach directions / 3 times the limb length * 100

**Table 2:** Isokinetic dynamometry of knee joint extensors and flexors: coefficients for unilateral force asymmetry of the injured and uninjured leg at three angular velocities

| **Lower extremity** | **H/Q ratio (%)** | | |
|---|---|---|---|
| | **Angular velocities** | | |
| | **60 °/s** | **180 °/s** | **300 °/s** |
| Injured leg (right, dominant) | 80.1 | 83.3 | 87.5 |
| Uninjured leg (left, nondominant) | 58.8 | 56.6 | 63.5 |
| Norms | 61 - 62 | 72 | 78 |

## Discussion

Isokinetic dynamometer and YBT testing has been shown to be a good indicator of safe return to sport. Following an ACL injury, athletes reduce their participation in sport, which can lead to bilateral muscle strength deficits. No difference was found between the injured and uninjured leg in dynamic balance performance in each of the test directions when performing the balance test. The CS for the uninjured leg was 100.1% and 98.5% for the injured leg indicating good recovery of the athlete and no preconditions for re-injury as a result of incomplete recovery of the neuromuscular control shown in the dynamic balance and lower extremity muscle strength testing [8, 10]. According to literature data, when this indicator is below 89% in football players, there is a possibility of injuries and joint sprains, which is not detected for this footballer and the training protocol created for recovery was built and implemented correctly [9]. Quadriceps strength deficits reported in the literature are an important predictor of ACL re-injury after return to sport, with a 3% reduced risk of re-injury for every 1% increase in quadriceps strength symmetry [4]. A putative characteristic of atrophic quadriceps femoris changes following ACL injury is the accumulation of denervated fibres in the affected muscles. This directly differentiates this type of muscle atrophy from immobilization muscle atrophy and has significant implications for training and rehabilitation activities [2]. Extensor PT 6 months after ACL reconstruction surgery can vary widely depending on several factors, including the athlete's pre-injury strength, the type of surgical technique used, the intensity and consistency of rehabilitation, and the occurrence of complications during recovery [1]. It is important to note that achieving full recovery of extensor strength may take more than 6 months for some individuals, and in some cases full recovery may not be achieved [1, 4]. Factors such as persistent pain, muscle weakness, neuromuscular deficits and graft healing can affect the speed and extent of recovery.

The ratio of the strength of the posterior thigh muscle group to that of the quadriceps (H/Q) is a widely applied criterion in the rehabilitation process after ACL reconstruction surgery and plays a determining role in knee stability. Achieving an appropriate balance between these muscle groups is critical to reducing the risk of re-injury and restoring optimal joint mechanics [2]. In recovering individuals after ACL reconstruction, the strength of the extensors is usually disproportionately lower initially compared with the strength of the flexors. This imbalance may result from factors such as quadriceps inhibition, muscle atrophy, and altered neuromuscular control after surgical intervention. The ideal ratio of quadriceps strength to hamstring strength varies depending on factors such as the age of the individual, activity level and functional demands, as well as the strength profile of the flexors. However, the commonly cited H/Q ratio is a ratio approximately equal to 2:3 or 40% hamstring flexor strength to 60% quadriceps strength [5]. This ratio is thought to ensure knee stability and reduce the risk of ACL graft damage or other knee injuries [4].

Tracking knee joint flexor and extensor strength after ACL reconstruction using objective quantification via isokinetic dynamometry provides valuable information about muscle recovery and guides specialists on the progress of the rehabilitation program. As a result of the detailed analysis of the dynamic balance and strength of the flexors and extensors of the footballer's both legs, the following recommendations were made: (1) it is of paramount importance to work on restoring neuromuscular control of the quadriceps of the injured (right leg) in order to get out of the stage of long-term weakness that is observed after ACL reconstruction; (2) work in parallel and with caution on quadriceps strength of the injured leg (in eccentric mode, squats, etc.), which will affect unilateral and bilateral strength asymmetry; (3) maintain the strength of the ischiocrural musculature of both legs to prevent anterior cruciate ligament injuries; (4) maintain the explosive strength of both knee muscle groups, through elements of plyometric training, more carefully in the injured leg and after reaching a certain level of torque. All of this is critical to address residual deficits and optimize functional outcomes, reducing the risk of re-injury.

## Conclusion

This case report demonstrates the ability of YBT and isokinetic dynamometric testing indices to comprehensively assess the degree of deficits in dynamic balance, muscle strength, and strength asymmetry following arthroscopic ACL intervention in a professional football player. The data obtained are an objective criterion for making a return to competitive activity decision. They allow to design an adequate training and therapy program to restore the strength of the knee muscle groups and unilateral/bilateral strength balance in both legs to avoid re-injury.

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## Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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