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Case report

MUSCLE STRENGTH EVALUATION AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION USING ISOKINETIC DYNAMOMETRY

Maria Ganeva[1], Miglena Tsvetkova-Gaberska[1], Iliya Kanelov[2], Nevena Pencheva[1]
1) Department of Anatomy and Physiology, Faculty of Public Health, Health Care and Sports, South-West University "Neofit Rilski", Blagoevgrad, Bulgaria.
2) Department of Theory and methodology of physical education, Faculty of Pedagogy, South-West University "Neofit Rilski", Blagoevgrad, Bulgaria.

ABSTRACT:

Purpose: The aim of this report is to measure and analyse the isometric and isokinetic (concentric) peak torque (PT) of knee extensors and flexors of the involved and uninvolved limb of twin professional football players over one year post anterior cruciate ligament reconstruction (ACLR). To calculate the unilateral and bilateral asymmetry indexes and compare the athlete's PT values with sport-specific and position-specific data.

Case description: Strength measurements of the knee extensors and flexors were conducted on two ACLR football players (twins) on the involved and uninvolved limbs in isometric and concentric modes of muscle contractions, and unilateral/bilateral asymmetry indexes were calculated.

Results: The peak torque isometric data indicated that the strength characteristics of the involved leg extensors in both patients were significantly lower compared to the uninvolved limb and were indicators of higher secondary injury risk. The first athlete's concentric peak torque values showed relatively good return-to-sport results, while the second football player returned to sport having not met the recovery criteria. Both athletes require additional specific muscle strength exercises on the extension and flexion muscle groups to reach the ACL reconstruction recovery targets.

Conclusions: In this case report, the possibilities of isokinetic dynamometric testing in an isometric and concentric mode of football players to more accurately assess the extent of the muscle strength deficiency and asymmetry are demonstrated. This more precise information allows to the creation of correct training and therapeutic program to recover the knee muscle groups' strength and unilateral/bilateral strength balance to avoid reinjury.

Keywords: football players, strength asymmetry, ACL reconstruction, isokinetic dynamometry, H/Q ratios, bilateral pear torque ratios,

INTRODUCTION:

The recovery from anterior cruciate ligament reconstruction (ACLR) is a complex and multistep process. Anterior cruciate ligament (ACL) tears account for a significant proportion of sports-related injuries and are associated with various functional adaptations, leading to muscle weakness, functional deficits, reduced participation in sport and an increased risk of knee re-injury and osteoarthritis. For professional athletes, there is a demand for a fast return-to-sport (RTS) process, which often outpaces actual recovery. RTS is defined as returning to normal sports training. Recovery of neuromuscular function in patients following ACLR is critical in determining the appropriate time to for RTS. The high rate of secondary injury in young athletes who return to sport after ACLR equates to a 30 to 40 times greater risk of an ACL injury compared with uninjured adolescents [1]. To reduce the risks of reinjury, it is suggested that RTS goals should be criteria-based, not time-based. ACL injuries disrupt complex interactions within the neuromuscular system, resulting in impaired kinesthesia and proprioception, abnormal muscle activation and decreased dynamic stability. Patients undergoing ACLR demonstrate impaired neuromuscular control in both the operated and unoperated legs up to 1 year postoperatively [2]. In 2016, Grindem et al. state that the reinjury rate was significantly reduced (51%) for each month RTS was delayed until 9 months after surgery, and that symmetrical bilateral quadriceps strength (>90%) prior to return to sport significantly reduced the knee reinjury rate [3].

Athletes usually undergo six to eight months of rehabilitation after ACLR before returning to the pre-injury rate of physical activities. But often, athletes require additional rehabilitation time in order to reach a safe return-to-sport state. A full examination after ACLR should include bilateral comparisons, unilateral ratios and comparison to sport-specific and position-specific data. The most accurate way to evaluate the aforementioned factors is by using isokinetic dynamometry, as it is a gold standard in measuring strength as torque and presents an objective way to determine muscle asymmetry and the degree of risk of injuries. The application of isokinetic dynamometry in healthy and clinical populations is supported by an abundance of studies confirming its validity and reliability [4-7]. Numerous studies have shown the significance of quadriceps strength and power in the avoidance of re-injuries and restoration of prior-injury levels of performance [3, 8-10].

Knee-musculature balance plays an important role in stabilising the knee ligament apparatus. In order to limit excessive quadriceps activity, a contraction of the hamstring musculature is initiated. This phenomenon improves knee joint stability and may reduce excessive abduction during landing motor tasks [11]. Isokinetic variables related to muscle strength, such as peak torque (PT) and the conventional hamstring/quadriceps (H/Q) torque ratio, are traditionally extracted from isokinetic testing. Peak torque is a good indicator of joint function and relative muscle strength in comparison to other individuals. However, it has been recommended that the assessment of muscle imbalance should not be limited to strength, but should also include parameters that may provide additional information for injury prevention and management [12]. Inadequate hamstring strength and activation impair these muscles' ability to preserve the knee ligaments [13]. Dynamometric testing allows for the calculation of the traditional hamstring-quadriceps ratio (H/Q), which plays an essential role in monitoring muscle balance and preventing injuries and re-injuries in sports, particularly those with sudden and fast changes of direction like football. Isokinetic testing is an objective way to evaluate dynamic stability of the knee joint that estimates the quality of rehabilitation outcome after ACLR. Additionally, bilateral dynamometric strength assessment between homologous muscle groups is widely used to determine the magnitude of interlimb strength asymmetry [14-15], to establish relationships between the degree of strength asymmetry and injury susceptibility [15], and to make return-to-sport decisions [3, 17].

The purpose of this report is to evaluate the isokinetic dynamometric criterion for RTS by measuring and analysing the isometric and isokinetic (concentric) PT of knee extensors and flexors of the involved and uninvolved limb of twin professional football players over one year post ACLR and calculate the unilateral and bilateral asymmetry indexes. As well as compare the athlete's PT values with sport-specific and position-specific data.

CASE DESCRIPTION AND METHODOLOGY:

Subjects: twin professional football players (age 27 y., height twin 1 - 1.69 and twin 2 - 1.71 m, body mass twin 1 – 69.2 and twin 2 – 70,6 kg). Both football players underwent ACLR one year prior to the current testing. Twin one has sustained three ACL injuries and ACL reconstructions (2014, 2015 and 2020 year), all on the same limb, while twin 2 underwent only one ACLR (2020). Both athletes have returned to their usual physical activities but experience pain symptoms and show indications of strength deficiency of the extensors and flexors of the knee. Isokinetic dynamometry: Isometric and isokinetic (concentric) tests were performed on both the involved and uninvolved quadriceps and hamstrings muscle groups. Athletes were asked to perform three maximal repetitions of knee extension and flexion for each leg at 30° and 90° knee flexion in the isometric mode of muscle contractions and for the isokinetic mode of action 5, 10, 15 repetitions at 60°/s, 180°/s, and 300°/s angular velocities. A Biodex dynamometer (Biodex System 4 Pro^{TM}, USA) was used to record peak torque, hamstrings to quadriceps ratios and calculate bilateral peak torque ratios. The testing was conducted at the Center for Functional Research in Sport and Kinesitherapy at SWU "Neofit Rilski", Blagoevgrad. H/Q ratios (unilateral asymmetry indexes) were calculated from the concentric peak torque of the flexors (hamstrings) divided by the concentric peak torque of the extensors (quadriceps). Bilateral symmetry indexes were calculated as differences between the stronger extensors and the weaker divided by the stronger extensors. Presented as percentages.

RESULTS:

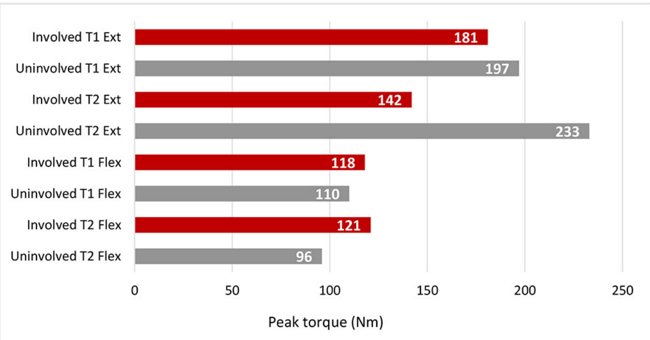
The results from the isometric testing (table 1) are presented as peak torque values (Nm) and bilateral asymmetry indexes (%). The isometric strength of the knee muscle groups is maximal in the 90-100° range. In this case, for all the muscle groups tested in the two angular positions - 30° and 90° - the isometric strength is within the norm for football players, except for the extensors of the left (supporting) leg, which have a peak torque of 150 Nm, with a norm of 300 - 340 Nm, which represents a reduction in strength of about - 55% in T1. This results in a very high bilateral asymmetry of 45% between the involved and uninvolved leg extensors in the position where maximum force is generated. In the T2, an isometric strength deficit of the affected limb is observed in both extension positions and a large asymmetry is generated, which is 35.4% and 46.7% for 30 and 90° knee angle, respectively. The flexors of the ACL reconstructed limb produce higher values than the uninvolved limb, which also produces bilateral differences (asymmetry - 25.8% and 24.1%, respectively, for 30 and 90°).

Table 1. Isometric peak torque and coefficients of bilateral asymmetry during knee joint extension (Ext) and flexion (Flex) (angle positions 30° and 90°) in both football players, one year post ACL reconstruction.

Isometric dynamometric variables	30° Ext	90° Ext	30° Flex	90° Flex
Peak torque (Nm):				
Involved limb Twin 1 (ACLR)	116	150	120	90
Uninvolved limb Twin 1	105	271	130	10
Involved limb Twin 2 (ACLR)	95	144	132	87
Uninvolved limb Twin 2	147	270	98	66
Bilateral asymmetry (%):				
Twin 1	9.5	44.7	7.7	11.8
Twin 2	35.4	46.7	25.8	24.1

The RTS values are observed in the bilateral comparison of flexor strength at 30 and 90° knee angle in T1 (7.7 and 11.8%). The T2, an isometric strength deficit of the affected limb is observed in both extension positions and a large asymmetry is generated, which is 35.4% and 46.7% for 30 and 90° knee angle, respectively. The flexors of the ACL reconstructed limb produce higher values than the uninvolved limb, which also produces bilateral differences (asymmetry - 25.8% and 24.1%, respectively, for 30° and 90°) (Fig.1).

Fig. 1. Concentric peak torque during knee extension (Ext) and knee flexion (Flex) at an angular velocity of 60°/s in twin football players (T1 and T2) with ACL reconstructed limbs (involved) and healthy limbs (uninvolved).



The peak torque of the uninvolved right knee extensors at a velocity of 60°/s and 300°/s was reduced within the normal range. The unilateral asymmetry of the same leg is, with a few exceptions, within the normal range (180 °/s), but the asymmetry is reduced when the flexors of the right knee are specifically trained. The peak torque of the involved left knee extensors (support leg with ACLR) was reduced at all velocities as follows: at 60°/s by approximately 18%, and at 180°/s and 300°/s by 23.0% and 24.5% respectively. The decrease in left leg extensor strength at all measured velocities did not result in unilateral asymmetry, but did result in a slight bilateral extensor asymmetry that was greater than 10% at velocities of 180°/s and 300°/s. T2 generates greatly decreased torque values during extension (143 and 125 Nm) at 60 and 180°/s compared to the uninvolved limb (233 and 150 Nm).

Table 2. H/Q ratios during concentric testing of knee extensors and flexors of twin football players with ACL reconstructed limbs (involved) and healthy limbs (uninvolved).

H/Q ratio (%):	60 (°/s)	180 (°/s)	300 (°/s)
Twin 1 Involved a limb	55.6	60.4	67.8
Twin 1 Uninvolved limb	65.2	76	82.8
Twin 2 Involved a limb	42.2	53.8	68.5
Twin 2 Uninvolved limb	85	75.5	85.3

The uninvolved limbs of both footballers show unilateral asymmetries where the hamstring muscles don't generate enough PT (Table 2). In the involved limb, the first athlete has a relatively good unilateral asymmetry ratio (65%), whereas the second athlete has an H/Q ratio of 85%, indicating a greatly reduced quadriceps strength.

DISCUSSION:

The recovery evaluation with isokinetic dynamometry consists of a comparison between the strength characteristic of the involved and uninvolved limbs. The first footballer shows good recovery status of the extensors at position 30° but generates great strength deficit of the involved limb at the extension from a 90° knee angle. The corresponding bilateral asymmetry at a 90° angle (44.7%) is a lot higher than the goal for return-to-sport recovery (<10%). Good RTS values are observed from the bilateral strength comparison of the flexors strength at 30 and 90° knee angle in twin 1 (7.7 and 11.8%). As for the second footballer, an isometric strength deficit of the involved limb is observed in both extension positions and great asymmetry is generated, which is 35.4% and 46.7% for 30 and 90° knee angle, respectively. The flexors of the ACL reconstructed limb generate higher values compared to the uninvolved, which also generate bilateral differences (asymmetry - 25.8% and 24.1%, for 30 and 90°, respectively).

The first football player presents good bilateral symmetry during concentric testing at 60°/s for the flexors and extensors muscle groups (fig.1). The involved leg shows a great reduction of the torque values compared to the uninvolved leg but only at velocities 180 and 300°/s. Even though some RTS criteria don't include velocities of 180 and 300°/s, their use provides a more complex evaluation of dynamic knee strength. The second athlete (twin 2) generates greatly decreased torque values during extension (143 and 125 Nm) at 60 and 180°/s compared to the healthy limb (233 and 150 Nm). This data indicates the need for prioritised training of the involved limb extensors. In twin 1, the flexors do not demonstrate great differences between limbs. Interestingly the flexors in both athletes show increased torque values of the involved limb. Studies of people with ACL reconstructed knees observe a phenomenon of a higher hamstring co-activation in the involved limb during voluntary knee extension compared to the uninvolved [18]. This compensatory mechanism may be the reason for the increased hamstring strength of the involved leg. One of the important components of early rehabilitation after ACLR is restoring the strength of the quadriceps and hamstring muscles before patients return to sporting activities. Quadriceps muscle strength is often associated with good patient satisfaction and self-reported knee function after ACLR. Given that asymmetric quadriceps strength is associated with risk of re-injury, low quadriceps strength in the non-dominant group may be associated with low patient satisfaction [1-3].

Another important factor in knee stability is the strength comparison of the hamstring muscles and the quadriceps muscle group (H/Q ratio). The H/Q ratios of healthy football players during slow to intermediate angular velocities (12–180°/s) are expected to be around 60% [19]. Both footballers' uninvolved limbs have unilateral asymmetries where the hamstrings muscles don't generate enough PT (table 2). As for the involved limbs, the first athlete shows a relatively good unilateral asymmetry ratio (65%), while the second has an H/Q ratio of 85%, which proves greatly reduced quadriceps strength. Adequate restoration of hamstring and quadriceps strength after ACLR is considered an important parameter for RTS readiness [20]. Interestingly, during the concentric mode, the first footballer shows low bilateral asymmetry and a H/Q ratio that is close to the normative values for football players (fig.1). When comparing this athlete's results to the criteria for RTS, he covers most of the strength goals. The reason for this footballer's recurring ACL rupture may also have a more biomechanical nature. According to King et al. [21], players who are more prone to a secondary injury indicate differences on the ACLR side, primarily in the sagittal plane for the double-leg drop jump and greater asymmetry, primarily in the frontal plane during unplanned change of direction during 3D biomechanical analysis. There are studies that show conflicting results regarding the return of hamstring strength after ACL reconstruction [6-10]. Some of them show a relatively fast recovery of hamstring strength, as early as 12-14 weeks postoperatively to pre-injury levels [6]. On the other hand, Brunst et al reported that hamstring strength in the reconstructed limb was significantly lower in patients after ACL reconstruction even five years after surgery [17].

Isokinetic dynamometry testing has proven to be a good indicator of safe RTS. However, the use of the uninvolved limb as a reference for the involved limb causes some concerns, as the bilateral asymmetry index may overestimate knee function. Following ACL injury, athletes reduce their sports participation which can lead to bilateral muscle strength deficits. Compared to the sport specific normative data for concentric knee extension srength in football players, the uninvolved leg of the first athlete (twin 1) generates slightly reduced torque values.

Both athletes are midfielders, and according to their position, the values of the generated PT at 60 ̊/s of the extensors and flexors of the uninvolved limbs should reach 266±27 Nm for the quadriceps muscles and 159±34 Nm for the hamstrings muscles [21]. The muscle strength of twin 1 is greatly reduced for both limbs compared to the position specific peak torque data. The second athlete's uninvolved limb extensors PT values are close to the normative data for midfielders (233 Nm), while the flexors PT is lower than the normative data. It is recommended that both athletes participate in muscle strengthening programs in order to reach the sport-specific and position-specific normative values for football players.

For a safe return to sport, athletes should be able to reach 90% and more between limb symmetry. According to this criteria, the first footballer passes the isometric and isokinetic strength testing and the bilateral asymmetry test at 60°/s, while the bilateral asymmetry at 180 and 300°/s and the H/Q ratios don't match the RTS criteria. Of concern is the fact that despite currently being in good strength balance, this athlete has undergone three ACL injuries. It would be beneficial for him to strengthen knee flexors and extensors on both legs to reach the sport-specific peak torque values. The second footballer requires strengthening of the extensors of the involved limb as he didn't pass the goal of 10% at any of the tested velocities (21, 15 and 17% for velocities of 60, 180 and 300 °/s, respectively). The second athlete's flexor strength was higher in the involved limb, which generates bilateral asymmetry. Because twin 2 did not meet the specific RTS criteria, he has a four times greater risk (73%) of sustaining an ACL graft rupture [10], while those who returned to their sport after passing the RTS criteria have significantly reduced risk (27%). An athlete with such parameters should consider strengthening the knee musculature and then return to sport as the risk of reinjury in this physical condition is high. Leg dominance is an overlooked factor in ACL injuries. Although leg dominance is not a significant aetiological factor in ACL injuries, some studies have shown that patients who injure their non-dominant leg have a higher risk of future ACL injury in their contralateral dominant leg [1, 3-8]. In addition, neglecting leg dominance may affect the successful return to sport of a patient with ACLR, as the muscle strength of the dominant leg is greater than that of the non-dominant leg [15-22]. To optimise rehabilitation and enable patients to return to their pre-injury activity level after ACLR, it will be important to compare changes in the neuromuscular status of the dominant and non-dominant legs of patients. If there are differences in the postoperative recovery of muscle strength and neuromuscular control between the dominant and non-dominant legs, different rehabilitation protocols would be applied according to leg dominance.

CONCLUSION/S/:

In this case report, the possibilities of isokinetic dynamometric testing in an isometric and concentric mode of football players to more accurately assess the extent of the muscle strength deficiency and asymmetry are demonstrated. Isokinetic testing of the dynamic stabilizers of the knee is necessary in the diagnosis and management of thigh muscle imbalance after ACL injury and surgery. It is an objective parameter for deciding on return to sports activities after ACL reconstruction. This more precise information allows to create of correct training and therapeutic program to recover the knee muscle groups' strength and unilateral/bilateral strength balance to avoid reinjury.

Abbreviations:

ACL - Anterior cruciate ligament
ACLR - Anterior cruciate ligament reconstruction
RTS - Return-to-sport
PT - peak torque

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Address for correspondence:
Maria Ganeva,
South-West University "Neofit Rilski",
66, Ivan Mihailov Str., Blagoevgrad, Bulgaria.
E-mail: ganeva_swu@abv.bg,