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How much volumetric and strength loss of the quadriceps femoral muscle is expected in the post-operative reconstruction of the anterior cruciated ligament?

Quanto de perda volumétrica e de força do músculo quadríceps femoral é esperada no pós-operatório da reconstrução do ligamento cruzado anterior?

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ABSTRACT

Introduction: When injured and/or reconstructed the anterior cruciate ligament, not only occurs decrease in strength, but also less contraction of the quadriceps, in addition to muscle atrophy. Magnetic resonance imaging and isokinetic dynamometry have offered better evaluation of the pre- and post-surgical periods and can better monitor and predict postoperative rehabilitation.

Objectives: To review the role of volume and strength of the quadriceps femoris muscle before and after reconstruction of the anterior cruciate ligament and how these measurements correlate with the predictive variables of pre- and postoperative muscle strength.

Method: Integrative review collecting information on virtual platforms. The texts were selected from SciELO, Google Scholar, Pubmed and Scopus. The descriptors related to the topic were the following: anterior cruciate ligament reconstruction; magnetic resonance imaging; quadriceps muscle in Portuguese and English with AND or OR search, considering the title and/or abstract.

Results: The entire selected texts were read and 61 articles were included.

Conclusion: A loss of volume and strength of the quadriceps muscle was observed after reconstruction. The loss of strength was 4 times greater than the preoperative volume and 2 times greater postoperatively, with improvement 4 months after the operation.

KEYWORDS: Anterior cruciate ligament reconstruction. Magnetic resonance. Quadriceps muscle.

RESUMO

Introdução: Observa-se, quando da lesão e/ou reconstrução do ligamento cruzado anterior, não somente que há diminuição da força, mas também da qualidade e da contração do quadríceps, além de atrofia muscular. A ressonância magnética e dinamometria isocinética têm oferecido melhor avaliação dos períodos pré e pós-cirúrgicos, podendo melhor monitorizar e prever a reabilitação pós-operatória.

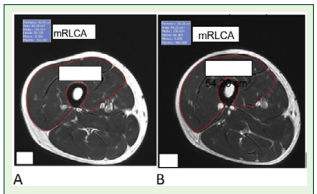
Objetivos: Revisar o papel do volume e da força do músculo quadríceps femoral antes e após reconstrução do ligamento cruzado anterior e como estas medidas se correlacionam com as variáveis preditivas da força muscular pré e pós-operatória.

Método: Revisão integrativa colhendo informações em plataformas virtuais. Os textos foram selecionados do SciELO, Google Scholar, Pubmed e Scopus. Os descritores relacionados ao tema foram os seguintes: reconstrução do ligamento cruzado anterior; ressonância magnética; músculo quadríceps em português e inglês com busca AND ou OR, considerando o título e/ou resumo.

Resultados: Foi realizada a leitura da íntegra dos textos selecionados e incluídos 61 artigos.

Conclusão: Observou-se perda de volume e força do músculo quadríceps após a reconstrução. A perda da força muscular foi 4 vezes maior que a do volume pré-operatório e 2 vezes maior no pós-operatório com melhora após 4 meses da operação.

PALAVRAS-CHAVE: reconstrução do ligamento cruzado anterior; ressonância magnética; músculo quadríceps.



Example of MRI indicating quadriceps reduction preoperatively (A 60.39 cm3) and 4 months postoperatively (B 54.20 cm3)

Central Message

The strength of the quadriceps femoris plays a crucial role in knee stability, with an impact absorption function helping to reduce the load on the joint structures and minimizing the repercussion on the knee. However, its weakness has been the most striking clinical characteristic of this type of injury, strongly associated with the prediction of permanent muscle dysfunction and osteoarthritis. Thus, to evaluate the volume and strength of the quadriceps muscle before and after anterior cruciate ligament reconstruction, and to correlate which variables are predictive of their decrease in the postoperative period, it is necessary to evaluate the volume and strength of the quadriceps muscle before and after anterior cruciate ligament reconstruction. important to estimate the functional deficit that can occur in the patient.

Perspective

The loss of strength of the quadriceps femoris muscle is estimated to be 4 times greater than that of the volume in the preoperative period, and 2 times greater at 4 months postoperatively, indicating improvement and beginning of recovery after 4 months of surgery. The main predictive variable of postoperative muscle strength was muscle strength before the procedure. This, in turn, should be determined mainly by the previous muscle volume and time of injury.

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INTRODUCTION

Anterior cruciate ligament (ACL) injury is a frequent condition, with an estimated incidence in Brazil of 32-78 ACL reconstruction operations (ACLR) per 1,000 person-years, more frequent in men who practice some sports activity.[1,2]

The knee is one of the largest and most widely used joints in the human body, subject to variety of forces and movements during daily activities, sports, and other physical practices.[3] ACL is 1 of the 4 major ligaments of the knee, often more susceptible to injury due to its central position and its vital role in stabilizing the knee. Its main function is to control and limit the rotation and translation movements of the knee, being responsible for 86% of the restriction to the anteriorization of the tibia, preventing it from sliding forward in relation to the femur, in addition to maintaining joint stability during activities that involve rapid changes of direction.[3]

The strength of the quadriceps femoris plays a crucial role in knee stability, with an impact absorption function during activities such as running and jumping, helping to reduce the load on joint structures, including cartilage, and minimizing repercussions on the knee.[3] However, its weakness has been the most striking clinical characteristic of this type of injury, strongly associated with the prediction of permanent muscle dysfunction and osteoarthritis.[1,4-9] It is observed that, when the injury and/or ACLR occurs, there is not only a decrease in strength, but also in the quality and contraction of the quadriceps, in addition to muscle atrophy.[5,10]

It is postulated that ACL injury decreases knee proprioception and recruitment of muscle motor units, leading to atrophy and loss of muscle strength in the injured limb and in the contralateral1,11-16, in addition to the same deleterious effect also determined by immobilization.[17,18] The force production of the quadriceps is highly dependent on its volume, the quality of the neural impulse and the recruitment threshold of its motor units. In ACL injury, the so-called arthrogenic muscle inhibition occurs, which leads to reflex inhibition of the set of its motor units, clinically manifesting itself by muscle weakness, decreased voluntary activation and atrophy of the quadriceps in the injured limb and in the contralateral limb.[1,16]

A motor unit is made up of 1 motor neuron and the muscle fibers it innervates.[19] Reflex inhibition, associated with disuse of the affected limb, also leads to cortical neural reorganization, with reduced corticospinal excitability and cortical impulse, which also contribute to persistent structural atrophy and reduced muscle capacity.[1,6,11-16] Authors also indicate that muscle strength and volume are strongly associated with the size of motor units and that neural inhibition also determines atrophy of these structures.[1,6,11,12,20] Although this muscle response has the function of protecting the injured area, it is also responsible for prolonged muscle dysfunction and less capacity for rehabilitation. Overcoming this arthrogenic muscle inhibition is, therefore, one of the main limiting factors for the recovery of strength and muscle atrophy that follows after ACL and ACLR injury.[1] Thus, knowledge of the behavior of quadriceps volume and strength before and after ACLR may allow better therapeutic guidance and postoperative recovery.

The objectives of this review were to evaluate the volume and strength of the quadriceps femoris muscle before and after ACLR, verifying how these measurements correlate and what are the main determinants of quadriceps femoris muscle strength in the pre- and postoperative periods.

METHOD

This is an integrative review collecting information on virtual platforms. The texts were selected from SciELO, Google Scholar, Pubmed and Scopus. The descriptors related to the theme were as follows: anterior cruciate ligament reconstruction; magnetic resonance imaging; quadriceps muscle in Portuguese and English with AND or OR search, considering the title and/or abstract. Afterwards, considering only those with the greatest relationship, the full texts were read, and 61 articles were included.

DISCUSSION

The anterior cruciate ligament (ACL)

It is an anatomical structure of 30 mm in length and 10 mm in width, composed predominantly of collagen fibers, perfectly aligned, which connect the lateral wall of the femoral intercondylar notch to the anteromedial tibial plateau, ensuring better resistance for continuous and complex movements of the knee joint.[3] Its properties such as length, cross-sectional area, volume, number of bundles, angular orientation, tissue shape, fiber orientation and twist, as well as insertion site properties, among other parameters, are important for the orientation of the surgical therapeutic procedure. ACL cross-sectional area and length, for example, can be used to determine graft size, while angular orientation can inform about the best bone tunnel placement.[3]

ACL tear and risk factors

This tear is one of the injuries that most affect sports practitioners, accounting for more than half of knee injuries that involve rotations and sudden changes of direction, such as in football, basketball, and American football, occurring in about 68.6/100,000 people per year.[21-23] Most of them (70%) occur without contact, in lateral, rotation and landing movements. ACL injuries have a great personal, financial, and emotional impact, with losses of sports seasons, academic sports scholarships, academic performance, and functional capacity, with a higher risk of developing knee osteoarthritis.[4,23-26] The incidence of this injury, considering male and female athletes, is 2.8%, which is equivalent to 1 ACL injury for every 36 athletes, being 1 for every 29 female athletes and 1 for every 50 men, being, therefore, 1.5 times more frequent in women. This greater predisposition is associated with anatomical peculiarities, hormonal effects, neuromuscular control and female biomechanics that include wider ACL, narrower intercondylar notch, greater inclination of the lateral plateau of the tibia, greater ligament laxity and,

usually, higher body mass index.[27,28] Amateur athletes are the ones with the highest risk of ACL injury, followed by elite athletes and intermediate athletes. The risk of second injury is greater than 20% in both sexes.[29,30]

Its etiology is multifactorial and has been the subject of several studies. Some of them point to morphological variables, others indicate that a family history of ACL injury represents a 2.5 times greater risk of suffering from the same condition.[28-31] Bayer et al32, in a systematic review including 5,834 lesions, observed that the narrowing of the intercondylar notch was the variable most frequently associated with it, with a mean width significantly smaller than in unaffected knees, with a 7-fold greater risk with widths less than 17 mm. The narrow apex incisure shape was also associated with a 2.3-fold higher risk of ACL injury than the wider double-apex shape. Other variables found were also condylar morphology, femorocondylar curvature radius and tibial plateau morphology. These anatomical aspects can be decisive in the choice of graft size and success of ACRL.

American Academy of Orthopaedic Surgeons33 provided a summary of clinical practice guidelines for the management of ACL injuries indicating that: a) ACLR should be performed early, since additional menisci and cartilage injuries begin to appear 3 months after the injury; b) single-beam or multi-beam techniques have similar results; c) preference should be given to autografting; d) ACL injury prevention programs should be encouraged, especially among athletes; e) anterior lateral ligament reconstruction or lateral extra-articular tenodesis should be considered, when reconstructing with hamstring autografts, to reduce graft failure and improve function in the short term; f) aspiration of painful effusions can be considered, when necessary; g) ACLR is considered low risk, especially in young and more physically active patients; and h) associated meniscal injuries must also be corrected.

ACL reconstruction

In the last 20 years, there has been a significant increase in the number of ACLR cases, rising from 32.9/100.00 in 1994 in the United States of America32 to 74.6/100.00 in 2014[32], with more than 175,000 ACLR performed per year.[34] Conservative treatment is indicated for those individuals with little physical activity and without other associated injuries, but functional improvement after ORR seems to be greater than after conservative treatment. Conservative treatment can result in persistent joint instability and meniscal injury. In addition to immediate postoperative complications such as infection, deep thrombosis, and anesthetic complications, surgical surgery may result in recurrent instability, arthrofibrosis, neurovascular injury, knee pain, and contralateral ACL injury. The choice of treatment depends on multiple factors such as age, comorbidities and desire to maintain sports physical activity.[35]

It is therefore suggested that autografts be used, considering the main criteria of patient characteristics, age and need for physical activity, for such a decision.[33]

Volume and strength of the quadriceps femoris muscle

ACLR of the knee is an important operation to restore knee stability and allow the resumption of daily and sports activities after severe ligament injury. However, it can lead to impairment of quadriceps strength and function and biomechanical performance.[21]

Quadriceps strength is among the important variables for restoring physical activity and sports practice safely and with a lower risk of recurrent injuries. Strength deficits of this muscle group are associated with a higher risk of graft rupture in the order of 10 times for every 10% reduction in the ratio between the strength of the hamstring and quadriceps muscles.[36]

Many authors report that there is a loss of quadriceps muscle strength after ACLL, which has a negative impact on postoperative recovery and return to physical and sports activities.[18,21,23,37] The atrophy and decrease of this strength occurs quickly after immobilization of the lower limbs, with loss of muscle mass observed after 5 days of immobilization, reaching its maximum point at 2 weeks. Curran et al21 and Garcia et al18 observed that quadriceps muscle strength asymmetry is greater than 20% at 9-12 months after ACLR, decreasing to 10% at 18-24 months. At the same time, the immobilization indicated in the postoperative period of ACLR has the primary purpose of protecting the graft.

However, some other factors can contribute to greater or lesser loss of strength of this important knee muscle group. Femoral nerve block and intraoperative tourniquet appear to increase atrophy and decrease quadriceps strength, whereas training with blood flow restriction and supplementation may have the opposite effect.[17,38]

Other authors relate muscle loss to the type of surgical technique used.[39-42] Some studies point to atrophy and decreased quadriceps muscle volume after ACLR17,18,21,34 and few postulate that area and volume correlate with their strength.[7,25] Hunnicut et al43 reported a reduction in voluntary movement of quadriceps volume associated with 60% of the variation in their muscle strength at 6 months postoperatively. In the systematic review conducted by Birchmeier et al34 It was observed that of the 11 studies selected, only 4 found differences between the limbs and between the pre- and postoperative periods. It was found that there is a small decrease in the area and volume of the quadriceps, with no relevant clinical significance and no significant association with postoperative muscle weakness in ACRL, indicating that other variables such as muscle fiber composition, muscle fat content, and innervation may be involved. They also pointed to the importance of ischemic and resistance training to improve the function of this muscle group.[44] Muscle weakness is thus considered one of the main sequelae of ACLR, which may be responsible for causing decreased functional performance, changes in the walking pattern, decreased thickness of the knee cartilage and, thus, increasing the risk of recurrence of the injury.[45]

Reflex muscle inhibition is the main determining cause of muscle atrophy and weakness14,16 that follows after ACL injury. This injury, with consequent ACLR and immobilization, leads to decreased corticospinal excitability and inhibition of the arthrogenic muscle reflex,

with reduced recruitment of motor units. This phenomenon, associated with the action of inflammatory cytokines, increases the number of denervated fibers and, over time, there begins to be replacement of fast fibers by slow fibers, fatty infiltration, with the development of atrophy and muscle weakness, responsible for prolonged muscle dysfunction and lower rehabilitation capacity, which leads, again, to corticospinal inhibition and arthrogenic muscle reflex, in a vicious circle (Figure 1).[1,6,11,13-16,20,46]

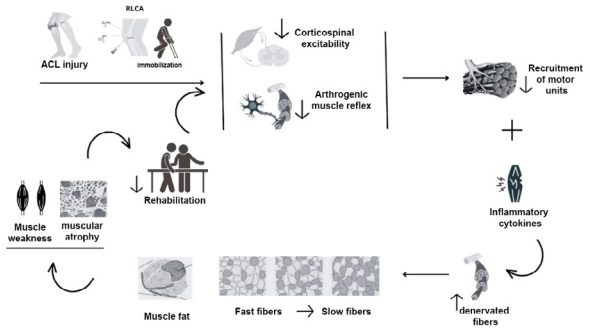

FIGURE 1 — Infographic illustrating the mechanism of muscle atrophy and weakness after ACL injury and the mechanism of persistent muscle atrophy and weakness

Quadriceps volume measurement obtained by magnetic resonance imaging is an imaging method that allows the evaluation of quadriceps muscle volume and composition without exposure to ionizing radiation. This method provides detailed information on muscle anatomy and physiology, including fat and connective tissue distribution, allowing for more complete assessment of muscle imbalances (Figure 2).[34]

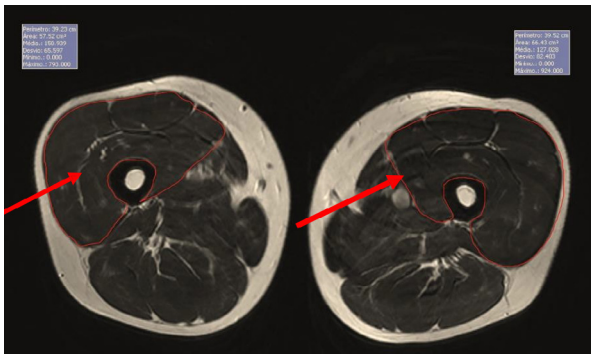

FIGURE 2 — MRI of the quadriceps femoris muscle excluding bone and subcutaneous fat, with the arrows indicating the volumes circumscribed by the red lines in the limb with ACL injury (left) and contralateral limb (right) in the preoperative period.

Isokinetic dynamometry (Figures 3A, B, C) is considered the best method for assessing muscle strength after ACLR. The tests carried out at high speeds simulate the situation of sporting activity, while at low speeds it allows the detection of strength deficits.[36] It is a technique that allows you to quantify muscle strength, work and power in different positions and can be performed in 3 different ways: isometric, dynamic and isokinetic. Isometric dynamometry measures maximum force in different joint positions, while dynamics evaluates force during concentric or eccentric contractions, being useful for simulations of activities of daily living. In isokinetic dynamometry, the speed is constant and predetermined, allowing the maximum force that can be generated by the muscle in each position to be evaluated.[47] During the isokinetic assessment, the patient is asked to perform movements at a constant speed, with a predefined range of motion. The exam allows you to verify the effectiveness of rehabilitation in patients with musculoskeletal injuries, monitor muscle recovery and assist in clinical decision-making, such as the right time to return to sports activities.[48]

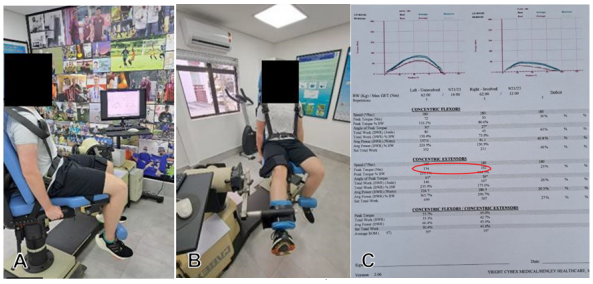

FIGURE 3 — Isokinetic dynamometry with a patient in the flexo-extensor chair performing: A) eccentric and concentric work; B) isokinetic dynamometry in movement; C) result of isokinetic dynamometry

The restoration of quadriceps muscle strength is among the 6 criteria for allowing a return to sports activities, and supervised physiotherapy seems to play a fundamental role in this. Czamara et al49 indicated that 6 months of supervised physical therapy with 60 or more sessions resulted in better recovery of the knee flexor and extensor muscles.

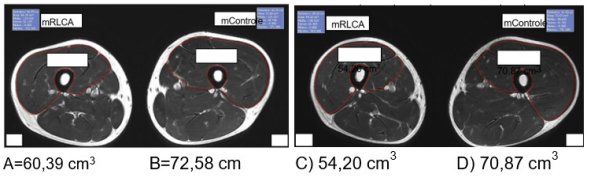

FIGURE 4 — Example of magnetic resonance imaging of a patient indicating quadriceps volume in the preoperative period (A and B) and 4 months in the postoperative period (C and D)

Figure 4 illustrates MRI of the same patient 4 months postoperatively, with quadriceps volume of 54.20 cm3 in the mACLR and 70.87 cm3 in the mControl, indicating a reduction of 6.19 cm3 in the mACLR and 1.71 cm3 in the mControl.

There is ample discussion in the literature about the size, volume, and strength of the quadriceps muscle before and after ACRL. This is because the failure rates, whether due to lack of full functional recovery (25% to 60%)[32,43], impossibility of returning to amateur and/or professional sports activities (17% to 65%)[28,37,50,51], osteoarthritis (33% to 51%)[26,50,52], recurrence of ACL injury (3% to 35%)[27,36,50-52] or correlated ligaments (8%)51, are high.

Thus, in the recent literature, there is a search for a better understanding of the factors and mechanisms that may be associated with these types of failures, marked by at least 21 systematic reviews in the last 5 years. [3,17,22,27-32,34,41,50,53-62]

CONCLUSION

The loss of strength of the quadriceps femoris muscle is estimated to be 4 times greater than that of the volume in the preoperative period, and 2 times greater at 4 months postoperatively, indicating improvement and beginning of recovery after 4 months of surgery. The main predictive variable of postoperative muscle strength was muscle strength before the procedure. This, in turn, was mainly determined by the previous muscle volume and time of injury.

Authors' contributions

Conceptualization: André Luis Menezes Schwansee Thiele
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Writing (original draft): All authors
Writing (proofreading and editing): All authors

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