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Ligamento Cruzado Anterior: Anatomia e Biomecânica

Anterior Cruciate Ligament: Anatomy and Biomechanics

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Abstract

The Anterior cruciate ligament (ACL) is a unique structure and one of the most important ligaments for knee stability, serving as primary restriction for the anterior tibial translation on the femur and secondary restriction to the knee external and internal rotation that is not sustaining weight. The objective of this study was to demonstrate the anatomy and biomechanics of anterior cruciate ligament as well as demonstrate the importance of the anterior cruciate ligament in the stability of the tibial-femoral joint. Literature review was performed using the data bases *Scielo*, Pubmed and *Lilacs* having as descriptors: “Anterior Cruciate Ligament”, “LCA”, “Anatomy” and “biomechanics” from the year 2008 to 2018. The LCA stability for the femorotibial joint and realization of the movement amplitude are in the ability of the anteromedial and posterolateral bands of the same in absorbing the entire load and traction of the joint when in antagonistic movements of the knee flexion and extension, favoring the stability of the tibial-femoral joint.

Keywords: Anterior Cruciate Ligament. Anatomy. Knee.

Resumo

O Ligamento Cruzado Anterior (LCA) é uma estrutura única e um dos mais importantes ligamentos para a estabilidade do joelho, servindo como restrição primária para a translação anterior da tíbia relativa ao fêmur e restrição secundária à rotação externa e interna do joelho que não está sustentando peso. Este estudo teve como objetivo demonstrar a anatomia e a biomecânica do ligamento cruzado anterior bem como demonstrar a importância do ligamento cruzado anterior na estabilidade da articulação tíbio-femoral. Foi realizado revisão da literatura usando as bases de dados Scielo, Lilacs e Pubmed tendo como descritores: “Ligamento Cruzado Anterior”, “LCA”, “Anatomia” e “biomecânica” a partir do ano de 2008 a 2018. A estabilidade do LCA para a articulação femorotibial e realização da amplitude de movimento estão na capacidade das bandas ântero-medial e póstero-lateral do mesmo em absorver toda a carga e tração da articulação quando em movimentos antagônicos de extensão e flexão do joelho, favorecendo na estabilidade da articulação tíbio-femoral.

Palavras-chave: Ligamento Cruzado Anterior. Anatomia. Joelho.

1 Introduction

knee joint is an important and complex joint, consisting of three bones (femur, tibia and patella) and presents two joints: the Tibiofemoral articulation between the tibia and femur and the patellofemoral joint between the patella and the femur. Its stability and movement are controlled by six ligaments, among them is the anterior cruciate ligament (ACL), and by muscles and articular capsule[1]. LCA is a central ligament of the knee, considered synovial extra despite being intra-articular. The main functional role of LCA is to provide stability against the anterior tibial translation and the knee internal rotation[2], primarily by restricting the previous sliding of the tibia on the femur, consequently preventing the knee hyperextension[3].

LCA contains proprioceptive properties that are mechanoreceptors that will provide information of the joint position to the central nervous system[4].

The objective of this study was to demonstrate the anatomy and biomechanics of anterior cruciate ligament, as well as demonstrate the importance of the anterior cruciate ligament in the stability of the tibial-femoral joint.

2 Development

2.1 Methodology

It is a descriptive study through narrative review. The online bibliographic survey was conducted in the databases of Medline (Medical Literature Analysis and Retrieval System Online), Latin American and Caribbean Literature in Health Sciences (Lilacs) and Scientific Electronic Library Online (SciELO). Search for articles, the following descriptors and their combinations in Portuguese and English languages were used: “Anterior Cruciate Ligament”, “LCA”, “Anatomy” and “Biomechanics”. Duplicated or incomplete articles were excluded. The inclusion criteria established for the articles selection were: articles published in Portuguese and English, articles in their entirety that portrayed the theme regarding the topic and articles published and indexed in those databases between the years 2008 and 2018. Then, all bibliographies deemed relevant and pertinent to the research objective were carefully selected, which together totaled information necessary for the development of the theme proposed in this study.

All stages of the search were performed by two evaluators, with the supervision of another reviewer who sometimes intermediated the process in an attempt to equalize the capture process and acceptance of the works. Initially, they performed the titles screening related to the topic in question. At the end of the search, the duplicated articles were excluded, in addition to the editorials and abstracts which did not discuss on the theme or involving experimental animal models. Then, a detailed reading was performed of the abstracts of articles in order to select those which addressed only the anterior cruciate ligament, anatomy and biomechanics.

The result of the initial search was 1,561 articles and after the first selection 102 remained. Of these, only nineteen studies comprised the themes proposed for this review, which present the main findings in the studies.

2.2 Discussion

Because of the high incidence of injury in the population, ACL has been object of many contemporary studies[5, 6]. The cruciate ligaments arise in the embryo around the forty-fifth day, along with the collateral ligaments, appearing as a set of targeted cells, simulating the cruciate ligaments in adult form[7].

ACL in its most distal portion is irrigated by the middle genicular artery. It has collagen fibers, nerves and mechanoreceptors and play an important role in the joint proprioception[8]. The ligament is extrassinovial and intra-articular composed of fibers that go from the anterior intercondylar region of the proximal tibia to the medial femoral condyle inside the intercondylar groove[9]. They have a main stabilizer function to the anterior tibial translation and secondary involvement in the restriction of the knee internal rotation[10]. In the study of Śmigielski that analyzed the anatomical structure of LCA of 111 knees of human cadavers, found that the femoral insertion and medial portion of LCA were thinner than previously and also determined the width of 11-17 mm and a thickness of about 3 mm[11]. In addition, the location of tibial insertion is described as a C-shaped structure[12]. ACL is roughly triangular in cross section and narrows along its length from both ends to the midsection.

The fibers of the LCA are arranged into two bundles, known as antero-medial bundle (AM) and posterolateral surface (PL), in accordance with the tibial insertion. The AM bundle falls into an upper and medial aspect of the femoral condyle, while the PL bundle falls into a more distal and lateral aspect of the lateral femoral condyle. The measure from the center of origin of the AM bundle to the deep cartilage of the femur is approximately 6mm and 10mm of the PL bundle. The center of the tibial insertion of the AM bundle is approximately 20mm from the anterior edge of the tibia and from the PL bundle to 30mm. The distance between the center of the origin of the PL bundle to the lower cartilage is close to 5mm[10].

These two bundles were associated with different roles in the anteroposterior and the joint complex-rotational stabilization [14]. The femoral origin was described as oval shaped and longitudinal diameter of 18 mm and a width of approximately 11 mm[15]. The AM bundle is tense during the bending and the PL bundle is tense during the joint extension[16]. The average thickness of ACL in its middle third was 4.5 mm in anteroposterior plane and 4.3 mm in the mediolateral plan[17].

In the study of Hwang[18] the anatomy of the tibial insertion of ACL was examined and evidenced that the anatomical center of the tibial insertion of ACL is 15 mm anteriorly to the posterior cruciate ligament and two-fifths of the width of the mid-lateral plane of inter-spinous distance. Finally, the medial-lateral location of the centroid of LCA was approximately two fifths of the total inter-spinous distance[12].

In the study of Tran[19] about the anatomy of the anterior cruciate ligament in Vietnamese adults, two bundles were observed: AM bundle and PL bundle, with the average length of 30.6 mm and 25.6 mm, respectively. Both bundles are similar in size, with average width of 5.0 ± 0.7 mm and 5.3 ± 0.7 mm in the intermediate substance[20]

The LCA anatomy and biomechanically functional bundles have been evaluated in several studies[14, 21]. A 2009 systematic review of 20 studies by Kopf [22]observed that only one study compared the anatomy of the ACL in men versus women and found greater length and the LCA area in men, but there was no statistically significant difference on the basis of sex in relation to the LCA width.

According to Tittel[23], in his biomechanics of the knee is a rotatory articulation and in hinge that allows the execution of two independent movement from one another: flexion and extension around a transverse axis that passes through the femoral condyles; rotation around a longitudinal axis which crosses the femur.

The oval/plan structure of ACL plays an important role in the knee stabilization under different angles[22.24]. The PL bundle has a stabilizing effect on the anteroposterior and rotational strength in positions close to the extent smaller than 30°, while the AM bundles becomes tense and functional in higher flexion angles[14, 24].

knee is a complex articulation with variable points of contact, pressures and axes that are affected when a ligament is injured. LCA, as one of the intra-articular ligaments, has a strong influence on the resulting kinematics[25].

However, there are more proprioceptive elements involved around the knee, as other ligaments, muscles and the capsule. For normal walk, in situ forces of 169 Newton (N) wereobserved. Downstairs, there were certain forces of 445N. The LCA force varies between 600 and 2300N. The knee rotation center knee varies in relation to the flexion angle. For the first 30° flexion, the femoral condyle undergoes minimal anterior translation. Between the first 30° flexion, the femoral condyle undergoes major anterior translation. The highest shear forces on the ACL occur in the hyperextension (-5° flexion) of the knee joint[13].

ACL is not configured only as a mechanical restrictor but provides sensory information by activating the reflex muscular stabilization[26.27].

3 Conclusion

Anatomically when seen frontally the ACL is situated in the center of the femorotibial joint, possesses the flexion and extension movements around a transverse and intercondylar axis, whereas in rotation it will present a longitudinal plane passing through the femur, favoring the stability of the tibial-femoral joint in the joint movements.

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