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Consensus Delphi study on guidelines for the assessment of anterior cruciate ligament injuries in children

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Abstract

Background: Knee examination guidelines in minors are intended to aid decision making in the management of knee instability.

Clinical question: A Delphi study was conducted with a formal consensus process using a validated methodology with sufficient scientific evidence. A group consensus meeting was held to develop recommendations and practical guidelines for use in the assessment of instability injuries in children.

Key findings: there is a lack of evidence to analyse anterior cruciate ligament injuries in children and their subsequent surgical management if necessary. Diagnostic guidelines and clinical assessment of the patient based on a thorough examination of the knee are performed and a guide to anterior cruciate ligament exploration in children is developed.

Clinical application: In the absence of a strong evidence base, these established guidelines are intended to assist in that decision-making process to help the clinician make the most optimal treatment with the aim of benefiting the patient as much as possible. Following this expert consensus, surgical treatment is advised when the patient has a subjective sensation of instability accompanied by a pivot shift test ++, and may include an anterior drawer test + and a Lachman test +. If these conditions are not

present, the conservative approach should be chosen, as the anatomical and functional development of children, together with a physiotherapy programme, may improve the evolution of the injury.

INTRODUCTION

1. PHYSIOPATHOLOGY OF THE ANTERIOR CRUCIATE LIGAMENT

The anterior cruciate ligament (ACL) has a viscoelastic capacity that provides the possibility of dissipating the energy received through adjustments in its length and in the internal distribution of loads[17,113], that is, it has the capacity to generate microscopic adjustments in relation to the internal stresses it has to withstand[31].

ACL injury occurs as a result of excessive force in the anterior translational direction of the tibia or rotation of the femur on the tibia[25].

The most common mechanism of ligament failure is the sequential rupture of bundles of collagen fibres distributed throughout the ligament and not located in a specific area. As it does not have the plastic capacity to deform, ruptures of the ligament are defined as total or partial. There is controversy regarding what is a partial rupture, and there are studies that define it as a hemorrhage in the femoral insertion while others define it as a rupture of the AM or PL fascicles. The American Medical Association establishes a classification in which partial tears correspond to second-degree ligament injuries. Another way of estimating the type of injury is in relation to the percentage of the ligament injured. Partial tears are considered to be between 25 and 75%[20,55,78,89]. Partial tears in turn can be classified as high grade when more than 50% of the fibers of the ligament are involved or low grade when the involvement is less than 50% [20].

In general, a partial ACL injury can be defined as a combination of factors [20].

- Asymmetrical Lachman test result.
- Pivot Shift negative.
- Measurement with KT-1000 Less than or equal to 3 mm.
- Arthroscopic evidence of partial ACL injury.

Adults more frequently suffer ruptures in the medial substance while lesion settlement in children is more frequently observed between the layers of mineralized and non-mineralized fibrocartilage[104].

Once the histological rupture occurs, the ACL goes through four phases: inflammatory, epiligamentous regeneration, proliferative and remodeling. These states are similar to those occurring in other connective tissues but with peculiarities, probably related to two facts: firstly, the ACL is immersed in the synovial fluid which, due to its characteristics, modifies cell metabolism and the inflammatory response, also preventing the formation of the fibrin clot necessary for the union of the ends of the rupture; furthermore, the vascularization of the ACL after rupture is compromised as the vascular branches that irrigate it also break [3,14,80,114]. The flow of synovial fluid is responsible for the fibrin clot not forming by dispersing the blood in the form of hemarthrosis[3]. As a consequence of this lack of fibrin clot there is a decrease in proteins of the extracellular matrix and cytosines such as fibrinogen and fibronectin and Willebrand factor within the ACL wound [81,82].

In injuries of tibial eminence fractures it has been observed that ACL fibers suffer plastic deformation with permanent elongation of the fibers. This fact may be responsible for residual clinical laxity even in cases where surgical reduction or healing has occurred (110).

2. ETHIOPATHOGENESIS OF ANTERIOR CRUCIATE LIGAMENT INJURIES

The mechanisms of injury are multifactorial and include both extrinsic and intrinsic causes [11,44,50,54,76,86,97,99].

The type of pattern of ACL injury depends on the degree of skeletal maturity, this fact may be related to differences in skeletal rigidity and conditions the type of injury in both groups. Tibial avulsion injuries and partial ACL ruptures are more frequent in patients with skeletal immaturity and complete ruptures are more frequent in mature or partially mature patients[73].

The ACL can be injured by two mechanisms, direct contact or non-contact. Approximately 70% of them are due to non-contact injury mechanisms [54,73]. Not all authors define ACL contact injuries in the same way; while some authors define them in relation to those that occur in the absence of contact between players, others define them as the absence of direct blow to the knee. In fact, there are authors who define "non-contact injuries with disturbance" by referring to injuries resulting from body-body contact, but without direct trauma to the knee[73]. Contact injuries involve injurious mechanisms of hyperextension or excessive valgus stress while the mechanisms that occur in non-contact injuries occur during the development of rapid decelerations or rotations performed in gestures involving pivoting on a fixed foot[116]. In addition, non-contact injuries are often accompanied by an internal hip rotation. This body position in non-contact injuries leads to a collapse in knee valgus or "dynamic knee valgus" [12,27,45,46]. It has also been observed that in non-contact injuries the centre of body mass is delayed in relation to the supporting base [54]. And although, as indicated above, the type of injury may be influenced by the degree of skeletal maturity, the injury mechanisms are the same in children and adults[73].

Several studies have shown that non-contact injuries from team ball sports occur at a bending angle of less than 30°. Modifications of the knee valgus angle were observed: in basketball there was an increase from 4° to 15° in 30 ms., in handball from 3° to 16° in 40 ms., these periods coincide with the maximum vertical forcé[52,90,106]. From this it can be deduced that the valgus position in a relatively straight leg (15°-40°) may be a key factor in the risk of ACL injury. It has also been observed that female athletes with a higher risk of injury land in a position of higher dynamic valgus and high loads of separation. In alpine skiing, other situations are observed such as phantom foot mechanisms, boot-induced anterior drawer mechanisms or external valgus-rotation mechanism[53,84].

It is also important to know the injury mechanisms affecting the posterolateral complex (PCL) of the knee as they represent 16% of all ligament injuries of the knee; of the total PCL injuries only 28% occur in isolation, the rest being associated with ACL injury[58, 59]. The common mechanisms of injury of this complex are related to forces in the posterolateral direction of the tibia, hyperextension of the knee and elevated external rotation of the tibia when the knee is in a position of partial flexion. The most frequent contexts in which these injuries occur are sports injuries, road accidents and falls[21].

3. *BIOCHEMICAL AND STRUCTURAL CHANGES FOLLOWING INJURIES TO ACL:*

After an injury at the level of the ACL, a significant increase in metalloproteinases and interleukins at the level of the matrix is observed. Due to the existence of poor vascularization of the articular cartilage and tendons of the knee, the possibility and capacity to eliminate these inflammatory cytokines is diminished. The effects of this difficulty in elimination, causes an increase in the activity of the same that can be translated with irreversible alterations at the level of the collagen and the anchorage points of the ACL[96].

Modifications have also been observed in terms of muscle mass and volume, with significant atrophy in the knee musculature of the injured extremity, mainly in the quadriceps, which may be related to the presence of edema in the knee joint[115]. Altered quadriceps activation and the appearance of asynchronous contractions of the medial and lateral ischiotibial muscles have been reported after these injuries[115]. The changes produced in the quadriceps muscle mass may be due to adaptations of the muscle fibres together with the formation of alternative substances at the level of the matrix[39]. Some of the adaptations that occur at the level of the muscle fibre are the transition from type I to type IIa or IIb muscle fibres. These adaptations are not suffered in the same way by the different muscles[96]. Together with this, the lack of use decreases the size of the myofibre and stimulation at the level of the motor neuron[96].

At the biochemical level, alterations have been found in: alpha-2 macroglobulin, myostatin, protein-72, mecane GF-C24E, synovial fluid and histochemical alterations at the level of collagen and cartilage[96].

In relation to the alteration of collagen after ACL injury, studies by Hong Li *et al* reveal that the degradation of collagen after ACL injury is irreversible and is replaced by another type of less structured collagen, thus affecting the integrity of the structure as a whole. This alteration in the synthesis of the correct collagen may be related to a greater probability of developing post-traumatic osteoarthritis[65].

Most knees with ACL injury experience altered levels of anti-inflammatory chemotactic cytosines causing longer periods of inflammation. In addition, pro-inflammatory and proteoglycan chemicals have been identified with the consequent deterioration of the knee joint in patients with ACL injury[65]. Variations in the levels of certain chondrocyte-degrading interleukins have also been observed[60]. In addition, these biochemical modifications can also influence the level of bone tunnels in ACL reconstructions[10]. Therefore, the synovial fluid will have a significant and important effect on knee recovery[65].

4. RISK FACTORS FOR ANTERIOR CRUCIATE LIGAMENT INJURY:

Risk factors for injury are classified into extrinsic and intrinsic causes[11,76,44,45,50,99]. Intrinsic causes are related to factors specific to the individual such as genetic, hormonal, anatomical factors, gender, neuromuscular and cognitive function, as well as previous injury to the knee. Extrinsic causes are external to the individual and among these factors the most studied are the level and type of activity, the type and surface of play, environmental conditions and the material used for the development of the sport or activity[103].

It is interesting to know that trained athletes have a high risk of breakage[94]. This fact may be related to situations in which there is an increase in joint efficiency. This fact occurs in situations where the individual acquires a greater degree of skill after practicing joint movements, which causes a decrease in antagonistic coactivation, making the ACL the only joint stabilizer in these circumstances[93]. Other studies also show the synergy between the stabilizing function of the rotational laxity of the ACL and the antagonistic coactivation of the hamstrings[70].

5. ANATOMICAL CHANGES IN THE KNEE IN RELATION TO AGE AND GENDER:

The anatomical region with the highest number of injuries in children and adolescents is the knee, which suffers up to 60% of injuries in the sports environment[4]. Among knee injuries, ACL ruptures have a 10 times higher incidence than the rest of the injuries. The relationship between specific anatomical characteristics and the risk of ACL injury has been studied, as well as the relationship with changes in anatomical characteristics during the stages of growth and skeletal maturation. Kiapour Ata[51] in 2016 conducted a study in which he observed significant differences in both the size and orientation of the age-dependent ACL in both females and males in healthy knees. They presented preliminary results indicating that changes in ACL size in relation to length, cross section and area are significantly different in boys than in girls. Although it was observed that the ACL became more vertical in both the sagittal and coronal planes with similar patterns in boys and girls, the area of the ACL (cross section) increased more in boys during early school age and late adolescence while girls showed this modification only when they became adolescents[51]. This same author also studied modifications of femoral condyles in relation to age and sex: both bicondylar width and intercondylar notch increased continuously in boys after becoming adolescents, remaining constant in young adolescents; girls showed a higher medial femoral condyle curvature in late adolescents compared to boys of the same age and a more curved lateral femoral condyle compared to boys. They also found age-related anatomical modifications of the tibial plateau in both girls and boys. There was a difference in size, more pronounced in boys; slope, greater in girls; and depth, greater in boys, of the tibial plateau between girls and boys in the stages following skeletal maturation [2,6,9,28,37,47].

6. RISK FACTORS FOR ACL RUPTURE IN SKELETALLY IMMATURE PATIENTS:

Risk factors for ACL rupture in skeletally immature patients are divided into intrinsic and extrinsic factors.

The most studied, and therefore best known, intrinsic factors are those related to anatomy: increased pelvic tilt, increased femoral anteversion, increased Q-angle, increased tibial slope fall, increased foot pronation, scaphoid fall and decreased intercondylar notch[2,28,51]. Also very important as a risk factor is the female gender where ACL ruptures are 6 times more frequent compared to men[2]. In relation to this data, it is known that female patients are usually accompanied by data on hypermobility-hyperlaxity together with genu valgus and genu recurvatum[47].

In relation to hormonal factors, the relationship between the phase of the menstrual cycle and rupture of the ACL has been observed to be greater in the follicular phase where the concentration of estrogen is higher[2].

In relation to extrinsic factors, the most important are climatic conditions, footwear and its interaction with the playing field and court.

During the summer conditions of light rain followed by evaporation of the same, causes the surface to harden increasing ACL injuries in these conditions. It has also been studied how certain characteristics of footwear such as size, height and position of the lateral margin of the sole may increase ACL injuries[2,37].

7. RISK FACTORS FOR INJURY TO THE ANTERIOR CRUCIATE LIGAMENT IN RELATION TO ITS SIZE:

As previously mentioned, anatomical conditions are important in ACL injuries.

The size of the ACL may be a risk factor for injury in those cases where there is a decrease in the size of the ACL. Davis *et al* and Dienst *et al* have presented studies relating the size of the ACL to greater risk of injury in load situations[19,26].

Intercondylar notch is another factor to be taken into account. Narrow intercondileal notches are associated with risk of ACL injury. Narrow intercondileal notches cause increased loading on the ACL[4,57,98,100,112]. With the consequent risk of injury; the correlation between narrow intercondileal notches and small ACLs has also been observed, with the width of the intercondileal notch being connected to the area of the ACL cross-section in pediatric populations, being responsible for 24-26% of the variations in the ACL cross-section area[51]. Narrow intercondylar notches produce a mechanical impact on the ACL and may have a tearing effect on the ACL when subjected to repetitive and high-risk movements, reducing the structural properties of the ligament over time[51].

Female sex in young adolescents is a risk factor for ACL injury, giving them a different anatomical profile[21]. One of the causes that may explain this fact may be related to a decrease in the inter-conditional space in the population of young adolescents compared to boys of the same age. Young adolescents also present steeper lateral tibial slopes and deeper tibial columns with the consequent greater risk of ACL injury[5,6,41,67,77,83,95,105].

As mentioned above, increased load on the ACL is associated with increased risk of ACL injury. The steep slopes of the posterior tibial plateau are related to this fact[8,9,34,42,43,68,75]. In activities involving weight loading, the posterior tibial slope causes a component of anterior shear force due to axial compression force[34].

The increase in the posterior tibial slope is found to be increased in adolescent girls[48] and may cause an increase in anterior tibial shear force[74] due to an acceleration of anterior tibial translation[75] with consequent damage to the ACL. Smaller tibial columns will stabilize less the femoral external rotation and femoral translation and may also cause an increase in ACL load[63].

Tibial depth has also been associated with risk of ACL injury in cases where there is less medial tibial depth by providing less resistance to anterior tibial translation[42,43].

8. RISK FACTORS RELATED TO THE MUSCULAR STATE:

There is no unanimity among the various authors on the correlation between an alteration at the muscular level and ACL injuries. Authors such as Zaínos *et al*[116] present a direct relationship between imbalances in the agonist-antagonist muscles of the knee together with muscle fatigue as with ACL injury. This author states that high levels of fatigue can lead to altered motor control leading to muscle imbalances, although there are not many studies that prove these claims. In the same vein, Orchard *et al*[91] indicate that excessive extensor force of the quadriceps muscles together with a decrease in the flexor force of the posterior femoral muscles are related to ACL injury. For Malinzak *et* *al*[71] motor control may be related to postures that put the ACL at risk in fact when a rapid lower limb maneuver will cause an angular change and an imbalance of the knee and hip; these modifications cause muscle adjustments that increase the risk of ACL injury. However, Garrido[33] and Benell *et al*[7] state that there is no relationship between knee muscle imbalances and ACL injury.

9. ASSOCIATED INJURIES IN ANTERIOR CRUCIATE LIGAMENT INJURY:

ACL injury may occur in isolation or be associated with injuries to other structures. In general, the structures most commonly associated with ACL injuries are:

Meniscal injuries: These may appear in conjunction with ACL injury in 30% to 60% of individuals. The external meniscus injury is the most frequent in acute ACL injuries and the internal meniscus injury in patients with chronic instabilities[7,24,111].

Chondral injuries: from bone edema to impacted fractures and even osteochondral fragments[36].

Capsuloligamentous lesions: usually appear when there are combined injury mechanisms.

Different authors have identified the appearance of associated lesions in relation to sex and age. Posterolateral contusion of the tibial plate tends to appear more frequently in women, while involvement in the external femoral condyle and soft tissue is more prevalent in men. Similarly, a higher rate of patellar tendon rupture has been observed in the adolescent population[29,30,79].

CONCLUSION

ACL rupture is a complex pathology with multiple approaches that should be based primarily on patient assessment and evaluation. In the absence of a solid evidence base and the lack of consensus in the literature on the approach and exploration of this injury in minors, these established guidelines aim to contribute to that decision-making process to assist the clinician in performing the most optimal treatment with the goal of benefiting the patient as much as possible. Following this expert consensus, surgical treatment is advised when the patient has a subjective sensation of instability accompanied by a pivot Shift ++ test, and may include an anterior drawer + test and Lachman + test. If these conditions are not present, the conservative approach should be chosen, as the anatomical and functional development of the children, together with a physiotherapy programme, can improve the evolution of the injury.

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The authors would like to the process of developing these screening and decision-making guidelines.

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PRIMARY SOURCES

1	Trenton Reyes, Darryn S. Willoughby. "Biochemical and Structural Alterations in Skeletal Muscle Following ACL Injury: A Narrative Review", International Journal of Kinesiology and Sports Science, 2020 Crossref	27 words — 1 %

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