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Clinical Relevance of Anterior Cruciate Ligament Tears in Skeletally Immature Patients: Incidence and Co-morbidities

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Introduction

Anterior cruciate ligament (ACL) tears account for 10% of sports injuries in children and adolescents.[1] ACL tears are often accompanied by various co-morbidities,[2-7] which affect surgical decision-making and prognosis.[8, 9] In this review, we discuss the incidence of ACL tears in skeletally immature patients highlighting their co-morbidities.

Incidence of ACL Tears

Incidence of ACL tears varies depending on the age of patients, sex, period of study, study population (general population vs. athlete), type of sports, competitive setting, and geographical region (Table 1). Over the past few decades, the frequency of ACL tears and subsequent reconstructions in the pediatric population has been on the rise, particularly among pre-adolescent and adolescent patients (Table 1).[10-23] One particular study utilized a nationwide database in the U.S. from 2007 to 2011 to reveal a 19% and 18% increase in the diagnosis of ACL tear and a 27% and 16% increase in ACL reconstruction in patients aged 10–14 years and 15–19 years, respectively.[10] However, the change in ACL reconstruction rate in patients aged 5–9 years was similar to that in observed adults although the diagnosis of ACL tears increased by 5%.[10] Another study using a claims and encounter database in the U.S. queried data from 2002 to 2014 and concluded that patients aged 13–17 years had the most significant increase in ACL reconstruction rate over the study period (females: 169.0 to 268.7 per 100,000 person-year; males: 146.8 to 211.7).15 However, the ACL reconstruction rate in patients aged $<$ 13 years was near-zero over the time-period studied.[15] Data from the administrative database of tertiary-care pediatric hospitals in the U.S. between 2004 and 2014 showed that 6.4-fold increase in ACL reconstructions relative to all orthopaedic surgeries in patients aged $<$ 10 years.11 Taken together, the diagnosis of ACL tears in young children is increasing, however, ACL reconstructions for them still seem to be performed mainly only in major children's hospitals, probably due to concerns regarding iatrogenic growth disturbance and deformity.

In a recent meta-analysis by Bram et al, they concluded that the rate of ACL injuries per 1,000 athlete-exposure was 0.069 (95% confidence interval [CI], 0.065–0.074), with a higher rate in females (relative risk, 1.40 [95% CI, 1.25–1.5]).[24] Additionally, they found girls' soccer (0.166 [95% CI, 0.146–0.189]) and boys' football (0.101 [95% CI, 0.092–0.111]) had the highest risk. ACL injuries were over 8 (95% CI, 6.46–11.30) and 6 (95% CI, 5.52–8.49) times more likely to happen in competition versus practice settings for females and males, respectively.[24]

Epidemiologic studies on ACL tears in skeletally immature patients prompted injury prevention programs in young athletes.[25-27] A recent study utilizing the New York statewide database showed the decline in ACL reconstruction rate performed on pediatric patients from 61.0 in 2014 to 51.8 by 2017.13 The authors suggested that the success of injury prevention strategies could be a factor of the recent drop in ACL reconstruction rate.[13]

Co-morbidities of ACL Tears

Incidences of acute lateral meniscal, medial meniscal, and chondral injuries in pediatric ACL tears were reported as 28–56%, 12–38%, and 0–26%, respectively (Table 2).[4-7,28-30] However, a delay in treatment increases the incidence and severity of meniscal and chondral injuries, especially of the medial meniscus (Table 2).[4-7,29] Older age and increased patient weight are also known as a risk factor of associated injuries.[2, 4,6,31-33] The most common associated meniscal tear pattern is a vertical tear.[7,30,34] The root tear, which compromises hoop stresses, was identified in 0.8-38% of the medial meniscus and 9% of the lateral meniscus in adolescent ACL tears.[35,34] Samora et al. found that the most common location and zone of tear were the posterior horn and red-white zone.[30] Due to the high incidence rate of ramp lesions (posterior meniscocapsular tear of the medial meniscus) found in almost 25% of pediatric ACL tears, along with the limited effectiveness of MRI and anterior arthroscopic approaches in detecting

Table 1. Incidence of ACL tears in the general pediatric population of the U.S. and other countries

Author (Year)	Incidence per 100,000 Person-years	Age (years)	Country/ State	Period	ACL Tear Definition
Dodwell[12] (2014)	17.6 in 1990 to 50.9 in 2009	3–20	New York	1990–2009	Reconstructions
Collins[14] (2014)	56.5 in 2006 to 62.8 in 2010	<18	Wisconsin	2006–2010	Reconstructions
Beck[16] (2017)	129 in females and 114 in males over the study period	6–18	U.S.	1994–2013	Tears
Herzog[15] (2017)*	Aged <13 years: 0 in both males and females over the study period Aged 13–17 years: 169.0 in 2002 to 268.7 in 2014 in females; 146.8 in 2002 to 211.7 in 2014 in males	<18†	U.S.	2002–2014	Reconstructions
Brodeur[13] (2022)	49.3 in 2009, 61.0 in 2014, and 51.8 in 2017	3–19	New York	2009–2017	Reconstructions
Gianotti[47] (2009)*	Aged 0–9 years: 0 in both males and females over the study period Aged 10–14 years: 10 in both males and females over the study period Aged 15–19 years: 100 in males and 70 in females over the study period	<20†	New Zealand	2000–2005	Reconstructions
Janssen[21] (2012)*	Aged 5–14 years: 5 in both males and females over the study period Aged 15–24 years: 70 in females and 180 in males over the study period	<25†	Australia	2003–2008	Reconstructions
Lopes[19] (2016)	Aged 0–10 years: 0 in both males and females over the study period Aged 11–20 years: 0.6 in 2008 to 1.2 in 2014 in females; 2.1 in 2008 to 4.0 in 2014 in males	<21†	Brazil	2008–2014	Reconstructions
Shaw[18] (2017)	2.74 in 2005/2006 to 6.79 in 2014/2015	5–14	Australia	2005–2015	Hospital-admitted injuries
Weitz[23] (2020)	17.7 in 1999 to 31.5 in 2011	<18	Finland	1997–2014	Hospital-admitted injuries
Longo[20] (2021)	0.16 in 2001 to 2.04 in 2015	<15	Italy	2001–2015	Reconstructions
Chung[22] (2022)*	10 in 2008 to 22 in 2016	<20	South Korea	2008–2016	Reconstructions

*The approximate incidence was inferred from a figure of the study. †Only data of the specified age group was used in this review.

Table 2. The rate of meniscal and chondral injuries of pediatric ACL tears

Author (Year)	Lateral Meniscus	Medial Meniscus	Cartilage	Time to Diagnosis	Age (years)
Millett[29] (2002)	47%	11%	0%	≤6 weeks	≤14
	36%	36%	0%	>6 weeks	
Lawrence[5] (2011)*	40%	15%	Lateral: 10% Medial: 15%	≤3 months	≤14
	45%	45%	Lateral: 45% Medial: 35%	>3 months	
Samora[30] (2011)	56%	29%	15%	<3 months	<17
Dumont[6] (2012)	56%	38%	Lateral tibia: 8% Medial tibia: 2%	≤5 months	<19
	57%	54%	Lateral tibia: 9% Medial tibia: 8%	> 5 months	
Anderson[7] (2015)	47%	24%	7%	≤3 months	<17
	67%	50%	28%	>3 months	
Newman[4] (2015)	42%	17%	Femur: 13% Tibia: 6%	≤3 months	≤19
	55%	40%	Femur: 39% Tibia: 19%	>3 months	
Dawkins[28] (2022)	49%	28%	NA	>3 months	≤18

*The approximate rate was inferred from a figure of the study. NA, not applicable.

these lesions, clinicians may opt to perform arthroscopic inspection through the intercondylar notch and thorough probing to accurately identify the lesion.[36,37]

Various ligaments around the knee are commonly injured during an ACL tear. The rate of concomitant medial collateral ligament (MCL) injuries is 2–37%.[4,29,38-41] In a study by Sankar et al., 12 of 180 adolescents with ACL tears (7%) had concomitant grade 2 or 3 MCL injuries, however, excellent functional outcomes were achieved at a mean follow-up of 5.3 years with use of a hinged brace to treat the MCL injury.[40] Lee et al. reported that older age and contact injuries were associated with concomitant MCL, lateral collateral ligament (LCL), and/or posterior cruciate ligament injuries.[39]

Additionally, concomitant PLC injuries are not uncommon, particularly in patients with a lateral meniscus tear or Segond fracture and in patients with older age.[38,41] Clinicians should remain vigilant regarding the possibility of such injuries. A retrospective review of MRI studies in adolescents with ACL tears identified a posterolateral corner (PLC) injury in 13% of the patients.[41] In another study evaluating the imaging of preadolescent and adolescent patients, MRI revealed PLC injuries in 52% of ACL tears, with 14% of patients having a complete tear of a structure of the PLC.[38]

Furthermore, the use of advanced, cross-sectional imaging may aid in assessing combined anterolateral ligament (ALL) injury because there is no specific physical examination for evaluating the integrity of ALL injury.[42] The rate of abnormality of ALL on MRI was reported as 60–76% in adolescent ACL tears.[43,44] Helito et al. reported that ALL injuries were associated with MCL, LCL, and iliotibial tract abnormalities and bone contusion on MRI.[43] However, due to the limited reliability in ALL detection with pediatric knee MRIs and due to the limited visualization of ALL on MRI in young children, careful history-taking and physical examination persist as an instrumental component of diagnosing patients with ALL injury.[45,46]

Conclusions

The incidence of ACL tears in skeletally immature patients is rising globally. As a significant proportion of patients have associated injuries and the incidence of these injuries increases without treatment, it is recommended that patients seek orthopaedic care as soon as possible.

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