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# Delayed reconstruction and high BMI z score increase the risk of meniscal tear in paediatric and adolescent anterior cruciate ligament injury

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## Abstract

**Purpose** The purpose of this study was to identify epidemiologic risk factors for secondary meniscal tears in paediatric and adolescent patients who sustain an anterior cruciate ligament (ACL) tear. The hypothesis was that delayed reconstruction and elevated BMI z score, increase the risk for secondary meniscal tears.

**Methods** A prospective, descriptive and analytical study of consecutively accrued children and adolescents with an ACL tear was performed. One hundred and sixty subjects (114 males and 46 females) were identified between 2006 and 2015 at one institution. The age range was between 7 and 19 years. Fifteen parameters were recorded and analysed: age at initial trauma, initial trauma circumstance, sex, BMI z score, affected side, type of sport, Tegner score, athletic level, time to MRI, time to first referral, time to surgery, age at surgery, attempted non-operative treatment, operative report and associated meniscal tear. These meniscal lesions could be diagnosed by an MRI and / or during surgery.

**Results** Out of the 160 cases, 143 were treated surgically and 17 cases non-operatively. Median corrected BMI z score was 0.5 (range - 1.8 to 4.7). 41.9% had one or more meniscal lesions. 55 patients were initially treated non-operatively, of which 39 patients were secondarily operated. There was a positive relationship between meniscal lesion and: BMI z score ( $p=0.0364$ ), attempted non-operative treatment ( $p=0.001$ ) and time to surgery ( $p=0.002$ ). The median time to ACL reconstruction was 229 days for patients with secondary meniscal lesions.

**Conclusions** Patients with ACL tears treated non-operatively developed secondary meniscal lesions requiring delayed surgical management. There was a positive correlation between BMI z score and secondary meniscal lesions. Thus, early ACL reconstruction is advocated in young athletes.

**Level of evidence** Retrospective comparative study, Level III.

**Keywords** Anterior cruciate ligament · Children · Adolescent · Meniscus · Epidemiology · Arthroscopy

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## Introduction

Historically, rupture of anterior cruciate ligament (ACL) is uncommon among the skeletally immature population. According to recent literature, the rate of paediatric ACL injuries has been rising steadily [3]. However, accurate data concerning the incidence of this injury is lacking due to the limitations of current epidemiological studies [12, 13]. In recent decades, the ACL has been among the most frequently studied musculoskeletal structures. ACL rupture is a devastating knee injury commonly related to sports activity [19]. In the United States, an estimated 1 billion dollars is spent annually on ACL reconstructions [18]. Recent literature suggests an increase in the incidence of ACL tears in the skeletally immature, related to increased participation in organized sports and high demand sports at an early age [2, 22]. Meanwhile, increased engagement in high school athletics over the past decade has resulted in 7.9 million participants during the 2015–2016 academic year in the US [38]. A new epidemiological study, conducted on a sample of high school athletic patients, demonstrated that the rate of ACL lesions was 20.5% [20]. Although ACL injuries in adults attract considerable interests in research, the management of ACL tears in children has received less attention [28].

Furthermore, there is no consensus in the literature on a single definitive treatment protocol for the skeletally immature patient [11]. There have been concerns that operative management would violate the growth plate, thus resulting in a low risk of growth disturbance and angular or rotational deformity of the limb [6, 34]. Consequently, many patients have been treated non-operatively by combining activity modification and bracing until skeletal maturity [3, 37]. Unfortunately, non-operative treatment has been associated with accumulated intra-articular injuries [22]. Participation in sports has undoubtedly numerous health benefits; yet interscholastic athletics incurs risk of acute injuries favoring long-term consequences [10]. Meniscal tears are one such injury and have been reported to have mean annual incidence rate of 66–70 per 100,000 people in the general population [14, 16, 30]. Beyond establishing broad trends, published epidemiologic data on meniscal injuries remain limited.

A better understanding of the epidemiological patterns of ACL injury is necessary to the development of prevention as well as treatment strategies. The ultimate goal of epidemiological studies is to improve the prevention of the disease or injury based on a better understanding of the “at-risk” patient. The purpose of this study was to identify risk factors for secondary meniscal injuries in ACL injured individuals less than 20 years of age. It was hypothesized that early ACL reconstruction in young athletes with high body mass index  $z$  score (BMI  $z$  score) is recommended to avoid secondary meniscal lesion.

## Materials and methods

This is a prospectively accrued consecutive, descriptive and analytical epidemiological study. The sample comprised 160 children and adolescents with an ACL tear (114 males and 46 females). The consultations were conducted between 2006 and 2015 within one institution. The age range was between 7 and 19 years. Diagnosis of ACL tear was made on the basis of history, physical examination (Lachman test and/or pivot shift test), and MR imaging. MRI was obtained for all participants at different intervals with a delay between 2 and 484 days from the initial trauma.

Fifteen parameters were recorded and analysed: age at initial trauma, initial mechanism of injury, sex, BMI, affected side, type of sport, Tegner score, athletic level, time to MRI, time to first referral, time to surgery, age at surgery, attempted non-operative treatment, operative report and associated meniscal tear. BMI was reported in standard deviations from the mean BMI, which varies with age and sex, and was expressed as BMI  $z$  score [35]. Boys younger than 14 years and girls younger than 12 were considered prepubescent. Boys older than 14 years and girls older than 12 were considered pubescent. For the purpose of this study, 12 types of sport were considered: rugby, soccer, downhill ski, basketball, gymnastics, handball, tennis, kick-boxing, motocross, cycling, judo and swimming. The injury occurred during practice or competition. The activity level was assigned a Tegner score ranging from 0 to 10, while the engagement level was classified as competitive or recreational.

The initial injury may be the result of contact or non-contact trauma. Contact trauma was defined as caused by a blow to the affected knee. Non-contact trauma was sustained without contact to the knee. A non-operative treatment was suggested to patients without meniscal tear, not partaking in competition and following parental agreement. The treatment was defined by a precise protocol of management by physiotherapy for 6 months. If the patient had several episodes of instability, the non-operative protocol was halted and reconstruction was scheduled. Associated meniscal tears may be primary or secondary. This lesion could be on the lateral or medial meniscus. A lesion was considered primary if it was discovered within 3 months of the initial trauma and secondary if observed later. These meniscal tears could be diagnosed either on MRI or during the reconstruction procedure. The presence of meniscal tears was ultimately confirmed during arthroscopic ACL reconstruction. The study was approved by Toulouse university hospital IRB (CHU Toulouse approval number no. 41-0713).

## Statistical analyses

The main hypothesis was that delayed reconstruction and high BMI  $z$  score increase the risk for secondary meniscal tears. Before doing any analyses, the power of the study for these hypotheses was assessed: 67 meniscal tears ( $N=21$  and  $N=46$  primary and secondary meniscal tears, respectively) among 160 children and adolescents provided a power greater than 80% to detect a standardized effect size  $\geq 0.5$  with a type-1 error rate of 5% ( $\alpha=0.05$ ) for the comparison of time to surgery and BMI  $z$  score [24]. Before analyses, verification of missing or aberrant or inconsistent data has been conducted. The characteristics of patients using the number of non-missing observation, mean with standard deviation (SD) or median with interquartile range (IQR) was described first, as appropriate, for continuous variables and number of non-missing observation with frequency (%) for categorical variables. Categorical endpoints were compared between groups using the  $\chi^2$ -test (or Fisher's exact test when necessary). Student's  $t$  test was used to compare the distribution of continuous endpoints (or Mann-Whitney's test when distribution departed from normality or when homoscedasticity was rejected) between 2 groups. ANOVA (or Kruskal-Wallis test) was used for comparisons between more than 2 groups. All reported  $p$  values were two-sided and the significance threshold was  $<0.05$ . Statistical analyses were performed using STATA software 14.1 (STATA Corp., College Station, TX, USA).

## Results

### Descriptive study

Mean age at initial trauma (IT) was 13.0 years  $\pm$  1.94 with 95% CI [12.06; 14] and concerned 114 (71.3%) of the children were boys. The median Tegner score was 8 (6–10). Concerning the circumstances of the initial trauma, 105 (65.6%) were caused by indirect mechanism and 55 (34.4%) by direct mechanism. Median BMI  $z$  score was 0.5 [IQR (–0.2 to 1.5)]. Lesions were found to have the same prevalence for both sides. Moreover, 100 (62.5%) children were engaged in competitive sports and 60 (37.5%) in recreational activities; rugby [ $N=45$  (28.1%)] was the most frequent activity carried out by the patients (Table 2). The median delay to MRI was 35.5 days [IQR (5–72)] and to the first referral was 76.5 days [IQR (44.5–138.5)]. The median delay of the ACL reconstruction was 188 days [IQR (132; 276)]. On 55 (34.4%) non-operative treatments originally prescribed, 39 (70.9%) of them were eventually operated on due to a lack of improvement. From the 105 (65.6%) children scheduled for surgery, 104 (99.0%) were operated as one patient refused the operation. The mean age of patients

operated was 13.81 years  $\pm$  1.97 with 95% CI [12.82; 14.8]. Of the 160 patients, 93 (58.1%) had an isolated lesion of the ACL, while 67 (41.9%) had an associated meniscal tear (Fig. 1). These meniscal lesions were divided into 21 primary lesions (13.1%) and 46 secondary lesions (28.8%). Primary meniscal lesions included 12 (7.5%) lateral lesions and 9 (5.6%) medial lesions. Among the secondary meniscal lesions 26 (16.3%) were lateral lesions, 18 (11.3%) medial lesions and 2 (1.3) medial and lateral lesions.

### Analytical study

An association was found between sex and age at initial trauma ( $p<0.0001$ ) and the Tegner score ( $p=0.0020$ ); this is detailed in the Table 1. An association between the distribution of mean age of the initial trauma and the type of sport ( $p=0.0058$ ). (Table 2). Higher BMI  $z$  score was significantly associated with meniscal tear ( $p=0.0364$ ) (Fig. 2). The presence of a secondary meniscal tear was correlated with longer ACL reconstruction delay related to isolated ACL reconstruction (229 days [IQR (162; 365)] versus 193 days [IQR (144; 250)];  $p=0.002$ ) (Fig. 3). Finally, non-operative treatment was associated with meniscal tear ( $p=0.001$ ) (Table 3).

## Discussion

The most important finding of the present study was the positive relationship between meniscal lesions and BMI  $z$  score ( $p=0.0364$ ), attempted non-operative treatment of ACL injuries ( $p=0.001$ ) and time to surgery ( $p=0.002$ ), respectively. An accurate description of meniscal tears is of utmost importance. The diagnosis of a meniscal tears ranges from the obvious injury to the obscure and is best established via MRI in addition to careful clinical examination [33]. The

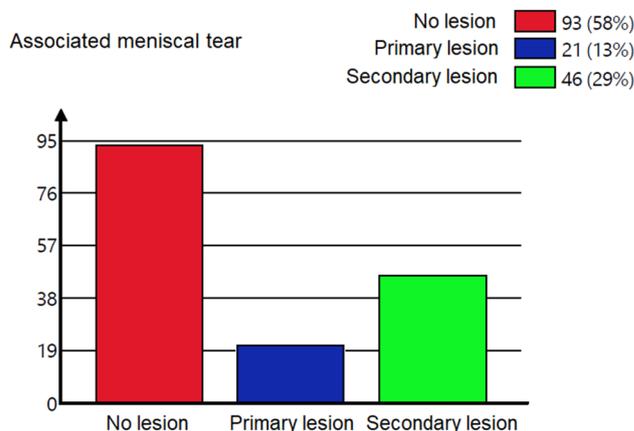


Fig. 1 ACL tear with or without meniscal tear

**Table 1** Association between the sex and age at initial trauma

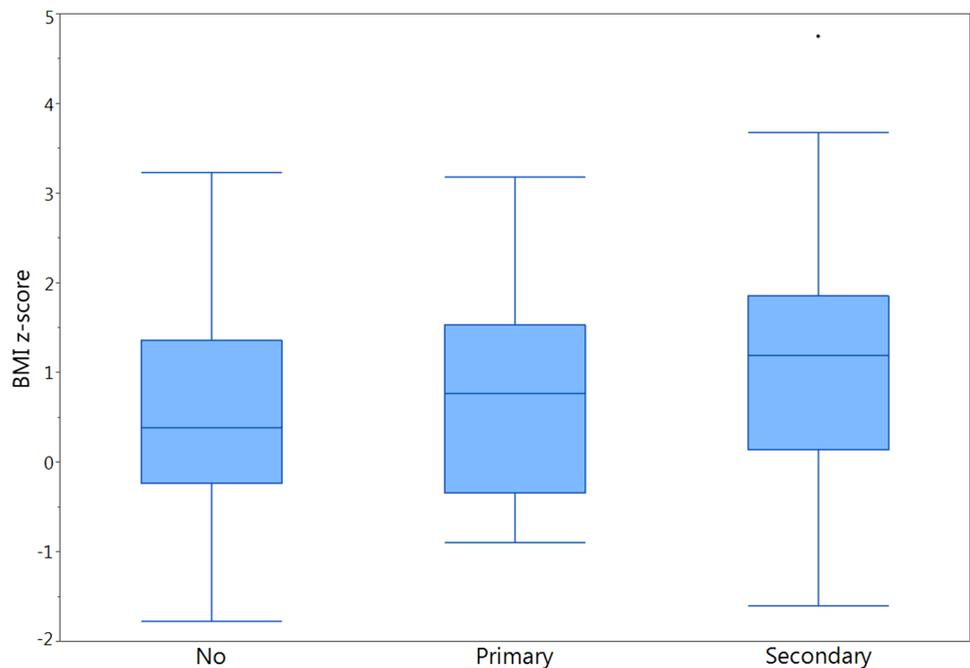
	Sex		<i>p</i> value	Total
	F	M		
	46 (28.8)	114 (71.3)		160 (100.0)
Age at initial trauma (years)	<i>n</i> (%)	<i>n</i> (%)	0.0001	<i>n</i> (%)
Prepubescent	12 (26.1)	77 (67.5)		89 (55.6)
Pubescent	34 (73.9)	37 (32.5)		71 (44.4)

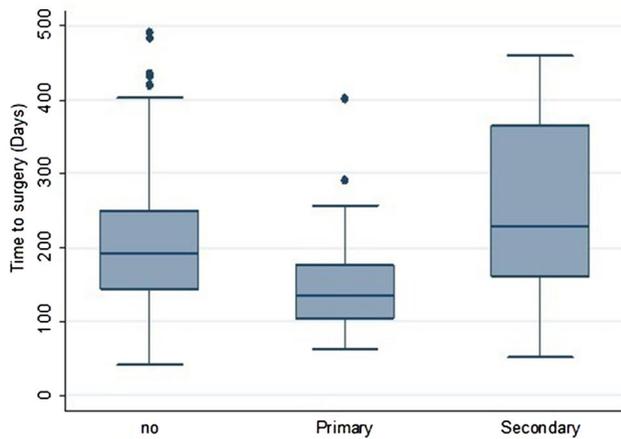
**Table 2** Association between type of sports and age at initial trauma (*p*=0.006)

Sports	Age at initial trauma (years)		
	Mean	Standard deviation	Number
Basketball	13.2	1.3	9
Cycling	13.5	1.6	3
Gymnastic	11.4	2.1	9
Handball	13.8	1.2	9
Judo	14.2	0.8	3
Kick-boxing	12.0	2.2	4
Motocross	14.9	2.6	4
Rugby	13.6	1.7	45
Downhill ski	12.3	1.8	22
Soccer	12.7	2.0	42
Swimming	10.8	4.5	2
Tennis	13.3	1.6	8

traditional description of a meniscal tear is that of a linear increased signal intensity within the meniscus. Meniscal tear can be classified according to orientation (vertical, horizontal, or complex); however, meniscal tears can be difficult to characterize using MRI alone and descriptions are often MRI sensitivity and observer-dependent [31]. Similar challenges may exist when attempting to characterize meniscal tears using clinical examination [27]. Often times, treatment decisions are made at the time of knee arthroscopy in an effort to integrate the knowledge of the pathoanatomy with the patients' presentations, expectations, and preferences for outcomes (including risk tolerance for complications). Thus the knowledge of the risk factors for meniscal lesion associated with ACL injuries is essential for pre-operative counseling and assisting with patient-centred decision-making.

Patients with higher median BMI *z* score are at greater risk of secondary meniscal lesion, thus median BMI without meniscal lesion and with secondary lesion are, respectively,

**Fig. 2** Association between BMI *z* score and meniscal tear (*p*=0.0364)



**Fig. 3** Association between time to surgery and meniscal tear ( $p=0.001$ )

**Table 3** Association between non-operative treatment and meniscal tear ( $p=0.001$ )

Non-operative treatment	Associated meniscal tear			Total
	No	Primary	Secondary	
No				
N	58	21	26	105
%	55.2	20.0	24.8	100
Yes				
N	35	0	20	55
%	63.6	0.0	36.4	100

0.4 and 1.2 ( $p=0.0364$ ). The patients with higher BMI  $z$  score may not tolerate ACL deficiency. BMI varies in the paediatric population according to sex and age. To get an accurate assessment of the BMI in this population, it was necessary to calculate BMI  $z$  scores using a smoothing method. The BMI  $z$  score is a standard method allowing for comparison between difference in the observed BMI and the median of the reference population for age and sex, divided by the standard deviation of the reference population for the age and sex [35]. In the literature, a high BMI was associated with an increased risk of ACL injury in the paediatric population [21] and significant association have been demonstrated between the increase in BMI and meniscal surgery in both sexes, including obese in the adult population [9]. To our knowledge there is only one study that found a relationship between these two variables in the paediatric population [37].

In the current study, 65.6% of children received initial surgical treatment while 34.4% received first-line non-operative treatment. However, the total operation rate by the end of the follow-up was 89.4%. The majority of patients treated non-operatively were switched to surgical treatment

as they had persistent knee instability symptoms ( $p=0.001$ ). This suggests that non-operative treatment, which may be attempted in selected patients, bears a high failure rate.

Universal treatment algorithm for ACL ruptures in the paediatric population has yet to be determined and there is still a debate on the optimal management creating a therapeutic dilemma for the treating physician [2, 5]. General indications for surgery include the patient's inability to participate in the preferred sport, instability that affects daily activities, presence of an associated repairable meniscal tear or multiple knee lesions. Many athletes in the paediatric population and their parents refuse to limit sports activity. In these cases, non-operative treatment may result in additional episodes of instability, meniscal tear and early onset of osteoarthritis [1, 22, 26]. Therefore, the most recent literature supports early surgery for athletes in the paediatric population with ACL rupture and recurrent episodes of instability [1, 17, 22, 26, 32]. Ramski et al. [32] conducted a meta-analysis which examined studies comparing surgical to non-surgical treatment or early surgery to delayed surgery; they identified multiple trends favoring early reconstruction in this age group. In the studies reviewed, patients undergoing early ACL reconstruction were less likely to experience pathological laxity or instability, less likely to have a medial meniscus tear, and more likely to return to sports.

Concerning associated meniscal tears with ACL rupture, 58.1% of patients had isolated lesions, while 41.9% had associated meniscal tears. Secondary lesions were more frequent than primary lesions. Lateral meniscal lesions were more frequent in primary and secondary but this was not statistically significant.

Millett et al. in 2002 reported effect of time from injury to surgery in intra-articular lesions in a retrospective series of 39 children and teenagers. They found 11% of medial meniscal tears in the group that had undergone ACL reconstruction within 6 weeks after accident ( $n=17$ ), and 36% of medial meniscus lesion in the group with surgery performed after 6 weeks ( $n=22$ ) [26]. Dumont et al. [8] evaluated the incidence of meniscal and chondral injuries in patients undergoing early (< 150 days;  $n=241$ ) compared with delayed ACL reconstruction (> 150 days;  $n=129$ ) in paediatric population (< 19 years of age). Medial meniscal tears were significantly more common in the delayed treatment group, but the incidence of lateral meniscal tears was similar between groups. Guenther et al. [15] found that the incidence of a medial meniscal lesion increases even after 1 year of ACL rupture, and it is ACL reconstruction that can stop degradation of the meniscus even after 1 year of initial trauma. In the current study, there was a higher risk of secondary meniscal lesions if the delay of ACL reconstruction was more than 229 days ( $p=0.002$ ). Consequently, due to these findings it is recommended to do the ACL reconstruction within that time frame, following the initial trauma, to

prevent the increased risk of medial or lateral meniscal tear. Among 55 patients treated non-operatively, 35 (63.6%) did not have meniscal tears, while 20 (36.4%) had secondary meniscal tears. A significant association was found between non-operative treatment and secondary meniscal lesions ( $p=0.001$ ).

According to Lawrence et al. [22], children under 14 years who underwent surgical reconstruction of an acute ACL tear more than 12 weeks after the injury were noted to have a significant increase in irreparable medial meniscal tears and lateral compartment chondral injuries at the time of reconstruction. In a review of 1,252 patients from the Kaiser Permanente network, delay to surgery showed an odds ratio of meniscal tear of 1.81 at 6–12 months and an odds ratio of 2.19 if delayed for more than a year [4]. Anderson et al. [2] demonstrated that in patients younger than 17 years of age a delay in ACL reconstruction, history of any instability, and return to sports participation before reconstruction are associated with increased risk of meniscal and chondral injuries. Newman et al. [30] did a study to investigate factors that contribute to the prevalence and severity of concomitant chondral and meniscal injuries among patients aged 14–19 years versus those aged less than 14 years at the time of ACL reconstruction. There was a significant relationship between time to surgery and the development of an irreparable meniscal injury ( $p < 0.05$  for all) in both the younger and older groups. Time to surgery correlated with severity of chondral injury in the younger cohort ( $p = 0.0343$ ) but not in the older cohort. In the younger group, only a delay in surgery  $> 3$  months ( $p = 0.0027$ ) was significantly predictive of the presence of an injury that required additional operative procedures [29]. With each episode of knee instability, meniscal lesions may become more complex and the possibility of repairing them becomes harder [9]. After an ACL lesion, the older age, male sex and delayed surgery, increase the frequency and severity of meniscal and / or articular cartilage involvement [36]. Meniscal lesions have been shown to cause degenerative lesions [23, 25].

The limitations of this study are its relatively small sample size, the different types of meniscus injuries and the imprecise definition of meniscal lesions. Meniscal injuries were diagnosed using careful clinical examination and MRI. In cases where meniscal tear was suspected but could not be diagnosed preoperatively, the decision to perform knee arthroscopy was left up to the discretion of the treating surgeon.

That being said, the most recent concise and reliable classification system for meniscal tears is the International Society of Arthroscopy, Knee Surgery and Orthopedic Sports Medicine classification, which takes into account the following parameters: tear depth, tear pattern, tear length, tear location/ rim width, radial location, location according to the popliteal hiatus, and quality of the meniscal tissue [7].

The strengths of the study are the presence of 2 groups of patients, one treated surgically and the other non-operatively in the same study, which is not very common in the literature; the study of several parameters and the fact that it is both descriptive and analytical. Therefore this study confirms that the management of ACL injuries in children and adolescents can be tailored to the specific patient. Surgeons should be encouraged to select the appropriate time for ACL reconstruction in an effort to avoid secondary lesions [8]. Although many variables influence the timing of surgical intervention, this paper proved that in young patients, especially overweight ones, early stabilization may prevent further meniscal injury.

## Conclusion

Patients with ACL tears treated non-operatively developed secondary meniscal lesions requiring delayed surgical management. There was a positive correlation between BMI and secondary meniscal lesions. Thus, early ACL reconstruction is recommended in young athletes.

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## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical approval** Ethical approval was obtained from the Ethics Committee of CHU of Toulouse. All procedures performed were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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