

## The Incidence and Etiology of Anterior Cruciate Ligament Injuries in Patients under the Age of 18 in the State of Wisconsin

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### Abstract

**Background:** ACL injuries can have long-term effects on the musculoskeletal system, causing early osteoarthritis, and are of particular concern in children and adolescents as competitive sports participation increases.

**Purpose:** The objective of this paper was to determine the incidence and characteristics of Anterior Cruciate Ligament (ACL) reconstructions in children in the state of Wisconsin.

**Methods:** Wisconsin Hospital Association inpatient and ambulatory surgery data from January 2006 through December 2010 was used to identify the number of ACL reconstructions performed in pediatric patients younger than 18 years of age in the State of Wisconsin. Incidence rates were computed using US Census Bureau Population Estimates. A retrospective chart review was performed on pediatric patients younger than 18 years of age who underwent an ACL reconstruction at a single tertiary care pediatric center to abstract injury causation information.

**Results:** Between 2006 and 2010, 4059 ACL reconstructions occurred in pediatric patients younger than 18 years of age in Wisconsin. The incidence of ACL reconstructions averaged 56.7 per 100,000 children per year. The mean age over the five years of the study was 15.4-15.9 for both males and females. ACL reconstructions increased significantly by an average of 6% each year, with females 40% more likely than males to have had a reconstruction, and older children significantly more likely to have reconstruction than children 0-11 years old (12-13 years incidence rate ratio=20.1; 14-17 years incidence rate ratio=123.0). Among the chart reviewed cases, sixty-eight percent of ACL tears occurred during organized sporting activities and 68% were caused by a non-contact injury.

**Conclusion:** ACL tears increased significantly in Wisconsin children from 2006 to 2010. Interventions to prevent ACL injuries in children need to be developed and tested and better tracking of injuries is needed to increase understanding of risk.

**Keywords:** Anterior Cruciate Ligament (ACL); ACL tear; Immature anterior cruciate ligament tear; Knee injuries; Pre-adolescent; Sports injuries

### Introduction

What is known about this subject: There has been an increase in research effort directed at determining the frequency and cause of ACL injury over the past decade. However, few studies have reported on the incidence of ACL tears specifically in the pediatric population.

What this study adds: This study is the first of its kind to describe pediatric ACL reconstructions in an entire population and to also look at injury causation. In addition this is the first study to document an increase in ACL reconstructions in a geographical defined population.

The benefits of high school athletic participation have been documented by The National Federation of State High School Athletic

Associations [1]. Despite the many positive effects of sports participation, the risk of injury remains a significant problem for young athletes. There is increasing evidence that ACL injuries result in an increased risk for osteoarthritis later in life [2-5]. Shea et al. reported that knee injuries account for 13.2 percent of all sports injuries, of which a large majority is ACL tears [6]. Anterior Cruciate Ligament (ACL) tears in young athletes have increased in incidence over the past 20 years with literature reporting ACL tears in 250,000 to 300,000 individuals per year [5,7-9].

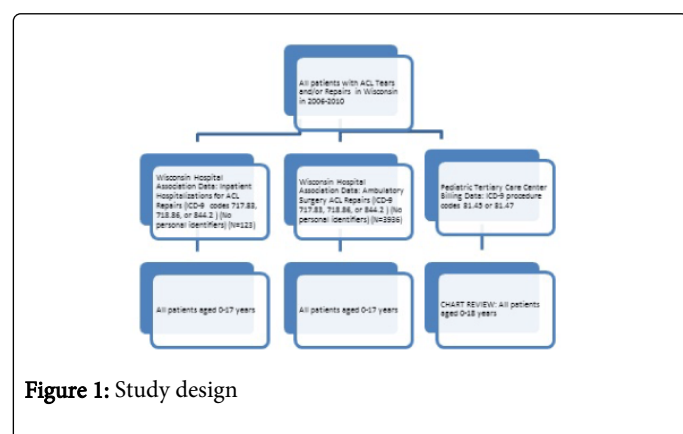
Research to determine the frequency and cause of ACL injury over the past decade has increased. At the time of this literature search there were three prior articles looking specifically at epidemiology of ACL tears and/or reconstructions [10-12]. The most recent article examined the population of New Zealand for knee injuries, including ACL tears, for a five year period. The authors found a rate of ACL reconstructions of 36.9 per 100,000 person-years [11]. These authors also examined the activity being performed at the time of the injury and showed that 65%

of the ACL injuries were sustained during sports or recreational activities. Another study reviewed the incidence of ACL reconstructions among all ages of patients cared for in the Kaiser Permanente HMO setting from 2001-2005 [10]. They found that females between 14 and 17 years of age had the highest incidence of ACL reconstructions with a total rate of 29.6 per 100,000 members [10]. Finally, Shea et al. analyzed an insurance data set to determine the incidence of soccer injuries among youths age 5 to 18 years between 1995 to 1999 [12]. A total of 6 million players were included and ACL injuries accounted for 6.7 percent of the total injuries and 30.8 percent of all knee injury claims.

The authors of this article are responsible for either treating or evaluating injury at their organization. The senior author had the opportunity to care for many young patients with ruptured ACLs due to sports participation and noted that the incidence of complete ACL ruptures in pediatric patients is not well documented. This lack of information about the frequency of this complex problem prompted an effort to find out how often this injury occurs to children in Wisconsin. Thus this study was performed to determine the incidence of ACL tears in the pediatric population of Wisconsin, along with reporting the cause of these injuries.

## Methods

This study is a retrospective review of all children and young adults younger than 18 years of age who underwent an ACL reconstruction from January 2006 through December 2010 in the state of Wisconsin. Inpatient and outpatient ACL reconstruction discharge data was obtained from the Wisconsin Hospital Association (WHA) Information Center. In addition, a retrospective chart review was performed with records from a single tertiary care pediatric center (Figure 1).



**Figure 1:** Study design

IRB approval was obtained for the study. The WHA dataset included inpatient and ambulatory surgery center discharges from all nonfederal acute care hospitals in Wisconsin. This data is derived from billing data, and thus does not contain the detail that is found in a medical chart and cannot be linked to other data. Each hospitalization or surgical visit was coded with one principal discharge diagnosis along with up to eight other diagnoses associated with the visit, a dedicated external cause of injury field (E-code), and one principal procedure and up to five secondary procedures.

ACL reconstructions were identified by the presence of primary or secondary discharge diagnosis codes with an International Classification of Diseases, 9th Revision (ICD-9) [13] codes of 717.83

(old disruption of anterior cruciate ligament), 718.86 (other joint derangement, not elsewhere classified), or 844.2 (sprain of cruciate ligament of knee) from January 2006 through December 2010.

In order to learn additional clinical details, a retrospective chart review from a pediatric tertiary care center in Wisconsin was also performed on a sample of cases. The electronic medical record, which includes scanned copies of all paper documentation, of all patients younger than 18 years of age who underwent an ACL reconstruction within the noted timeframe were also reviewed. ACL reconstructions were identified by ICD-9 [13] procedure codes of 81.45 (other repair of the cruciate ligaments) or 81.47 (other repair of the knee).

This chart review was completed by the primary author to gain additional injury causation data that could not be obtained from within the WHA dataset. A computerized data entry form was used to record age, date of injury, cause of injury, location of injury, surgery date, and any operative complications. A total of 68 charts were reviewed.

## Statistical Methods

The surgical reconstruction data from WHA was analyzed using SAS version 9.2 for data management, tabulations, and basic statistics [14]. Stata 12 (StataCorp, College Station, TX) was used for Poisson regression modeling [15]. The Poisson model examined the relationships between the rate of ACL repairs and year, gender, and age group (0-11, 12-13, and 14-17 years, and alternatively 0-13 and 14-17 years). Interaction terms were tested for year by gender, year by age group and gender by age group.

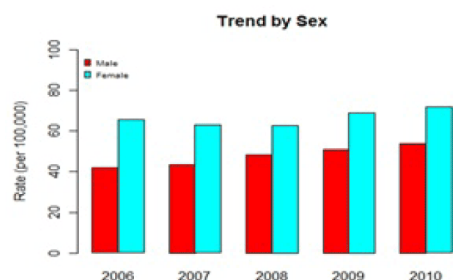
A secondary Poisson regression analysis was conducted to examine the effect of rurality of residence on number of ACL surgeries using the 2006 ZIP Code approximations of the Rural-Urban Commuting Area Codes (RUCA Codes) [16]. The RUCA Codes range from 1 (metropolitan core) to 10 (rural). The model also controlled for age and sex. Incidence Rate Ratios (IRR) and their 95% Confidence Intervals (CI) are reported.

Descriptive statistics were computed for the retrospective chart review data.

## Results

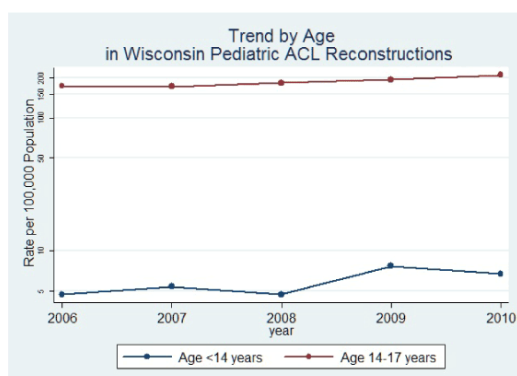
Between 2006 and 2010 in the state of Wisconsin, 4,059 ACL reconstructions were performed in pediatric patients younger than 18 years of age resulting in an average rate of 56.7 per 100,000 population. Of the total ACL reconstructions performed 3,936 were at an ambulatory surgery center and 123 were at an inpatient hospital. The incidence rates of pediatric ACL reconstructions in Wisconsin per 100,000 persons by year over this five year time span were 53.5 in 2006, 53.0 in 2007, 55.4 in 2008, 58.9 in 2009, and 62.8 in 2010. The mean age of pediatric ACL reconstruction over the five years of the study was 15.4-15.9 for both males and females.

External cause of injury codes (E-codes) were assessed for the 4059 ACL reconstructions and showed that 30% (1,210/4,059) of cases were attributed to overexertion/strenuous or repetitive movement, 25% (999/4,059) were coded as an accident not otherwise specified or not elsewhere classified, 22% (909/4,059) had no E-code, and 17% (682/4,059) were coded as sports-related. The annual incidence rates of pediatric ACL reconstructions by gender showed consistently higher statistically significant rates of ACL reconstructions in females compared to males (Figure 2).



**Figure 2:** Incidence rate per population of ACL reconstructions in Wisconsin's 0-17 year olds per year by gender

Regression analysis of the number of cases in children likely to have immature/open growth plates (<14 years of age) showed a significant 11% increase (95% CI; 3%-21%,  $p=0.009$ ) with each passing year (Figure 3).



**Figure 3:** Trend by Age in Wisconsin Pediatric Reconstructions

The Poisson regression model estimated a statistically significant average six percent increase in the rate of ACL reconstructions for all children from year to year during the study period (IRR=1.06; 95% CI 1.03-1.08). It also demonstrated that females were 40% more likely than males to have sustained an ACL tear and to have undergone reconstruction (IRR=1.40; 95% CI 1.32-1.49). Children 12-13 years of age were 20.1 times more likely to have an ACL reconstruction than children age 0-11 (IRR=20.1; 95% CI 15.3-26.5). Children 14-17 years old were 123.0 times more likely to have an ACL reconstruction surgery than children age 0-11 (IRR=123.0; 95% CI 96.4-156.9). The Poisson model examining rurality found a 6% increase in the expected number of ACL surgeries for each 1 category increase toward a more rural area (95% CI 4%-8%), while controlling for age and sex.

The retrospective chart review data from the tertiary care center included 68 ACL reconstructions over the five year period. Mean age for the procedure was 15.3 and was consistent with the state data. Forty-six of the sixty-eight cases (67.6%) were participating in an organized sporting activity when the ACL tear occurred. The sports with the highest percent of injury were football 23.5%, basketball 20.6%, and soccer 11.8%. Just over two-thirds ( $n=46$ , 67.6%) of the cases also described their injury as non-contact and over one third ( $n=25$ , 36.8%) reported the injury occurred during competition. Fifty-

nine (86.8%) of the ACL reconstruction patients reported returning to sports, six (8.8%) were lost to follow-up, and three (4.4%) of the cases did not have a return to sports status documented.

## Discussion

This epidemiologic analysis of ACL reconstructions in the pediatric population in the state of Wisconsin showed that there was a significant increase in surgical rates over the five year time span studied. In the Poisson regression analysis, there was a statistically significant 6% annual increase in the rate of ACL repair in individuals under 18 years of age. In the 0-13 year old subgroup, there was an 11% annual increase. Females have a higher incidence of ACL tears compared to males. Football, soccer, and basketball were the activities with the highest frequency of ACL tears. Consistent with previously established research, the majority of ACL tears involved a non-contact mechanism of injury [1].

After eleven years of age, an increased incidence of ACL tears and/or reconstructions in both boys and girls has been identified, as reported by Soprano and the current study [5]. The increase in sports injuries in young athletes over the past few decades is thought to be related to many factors. Some factors reported in prior literature are increased participation rates in youth sports, sports specialization at a younger age, increased intensity of play, training year round or poor conditioning, participation on multiple teams and/or multiple sports in one season, and starting competition at a much younger age [3-5,7-9,17].

The adverse effects on the current and long-term health of young athletes and also the cost to society must be acknowledged. It is not just the surgical cost that needs to be considered, but also the indirect costs such as time away both from school for the patient and work for the parent or parents, or any other costs associated with the reconstruction such as pre- and post-surgery clinic visits, imaging, and physical therapy. If sports organizations, schools, and health professionals continue to leave this issue unaddressed, young athletes will remain at greater risk for lifelong inactivity due to the complications of ACL reconstruction. The data contained in this study can further public awareness through publicity, public debate, policy development, sports injury prevention programs, and possible improvements in sports and youth sports safety.

## Limitations

The Wisconsin Hospital Association data used to analyze ACL reconstruction rates over time are collected for administrative purposes. As such, the data does not contain the detail that is found in a medical chart. Identification of cases relied on ICD9 codes. Due to this it is possible the 0-11 year old range of ACL reconstructions may in fact include some congenital ACL tears, which are not sports related injuries. However, the information in this data set does not allow the authors to identify at what age the youngest sports related injury would have occurred and so all of these cases were analyzed. In addition, individual patients cannot be identified and it is possible that a single occurrence of an ACL injury might be over counted if it leads to multiple visits with the codes used to pull cases. ICD9 codes are not particularly good for identification of sports-related injuries. Thus the authors conducted a chart review on a sample of cases to provide the in-depth information lacking in the WHA data.

## Conclusion

There has been a significant increase in the rate of ACL reconstruction in patients under 18 annually in Wisconsin. Fortunately, successful techniques have been developed to address the skeletally immature patients and allow return to full activities. However, knowledge and awareness by parent's, coaches, youth sports league organizers, public health professionals and government officials is key to the future of ACL injury prevention. Identification of the best injury prevention techniques will be the next critical step to keeping young athletes healthy and active for a lifetime.

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