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# Delay in diagnosis and management of adolescent anterior cruciate ligament injuries in patients with lower socioeconomic status

Reconstructive surgery for anterior cruciate ligament injuries in adolescents with lower socioeconomic status may have been delayed because their families had less capacity to seek multiple medical opinions and were less likely to be able to afford privately funded services such as physiotherapy and private advanced imaging.

## ABSTRACT

**Background:** Anterior cruciate ligament (ACL) injuries are common in physically active adolescents. Delayed treatment of these injuries is associated with increased intra-articular pathology. This study aimed to identify the patient factors associated with delayed ACL reconstruction in adolescents, the relationship between time to ACL reconstruction and frequency of intra-articular pathologies, and the barriers to timely access to treatment of ACL injuries in a publicly funded health care system.

**Methods:** A retrospective chart review was conducted for adolescents undergoing primary ACL reconstruction at a tertiary care pediatric hospital. Data on patient demographics, physiotherapy, income, and intraoperative status of cartilage were collected, and time from injury to orthopaedic referral, consult, and ACL reconstruction were calculated. Federal census data were used to determine the patients' socioeconomic status. A multivariate linear regression model was used to identify the association between time to ACL reconstruction and the patient's sex, age, family income, and distance to hospital. The model was run for each of the four time variables: injury to ACL reconstruction, injury to orthopaedic referral, referral to orthopaedic consultation, and consultation to ACL reconstruction. A logistic regression model was used to determine whether delayed reconstructive surgery led to higher likelihood of intra-articular pathology. Delayed time to ACL reconstruction was considered to be more than 180 days after injury.

**Results:** Eighty-three patients were identified. Mean time from injury to reconstruction was 286 days. Although no association was found between time to ACL reconstruction and frequency of medial or

lateral meniscal tear or articular cartilage damage, most patients had experienced delayed treatment and had meniscal or articular cartilage damage at the time of ACL reconstruction. Income was the only variable that had a significant effect on time to ACL reconstruction. For every \$10 000 increase in income, time to ACL reconstruction was reduced by 20.9% (43 days).

**Conclusions:** Most adolescent patients are having delayed ACL reconstruction, potentially contributing to increased frequency of intra-articular pathology. Increased income was associated with a significant decrease in time to ACL reconstruction. Further research is needed to determine why patient socioeconomic status was associated with differential access to ACL reconstruction within a publicly funded health care system.

## Background

Anterior cruciate ligament (ACL) rupture is a common sporting injury in physically active adolescents.<sup>1</sup> The incidence of this injury has been increasing over the last 20 years,<sup>2</sup> likely due to increased sporting involvement among adolescents and improved diagnostic techniques.<sup>3,4</sup> ACL rupture is frequently associated with

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*This article has been peer reviewed.*

articular cartilage damage and meniscal tears, which contribute to degenerative changes in the joint over time.<sup>5,6</sup> Historically, there was considerable concern that ACL reconstruction in skeletally immature patients could damage the physis and cause associated growth abnormalities.<sup>7</sup> However, more recent evidence has shown that ACL reconstruction can be done safely and effectively with techniques that protect the actively growing physis.<sup>8-10</sup> Surgical reconstruction for adolescent and pediatric ACL rupture is now considered standard care.<sup>11,12</sup>

In young, active patients, nonoperative management or planned delayed ACL reconstruction often results in recurrent episodes of instability due to a lack of adherence to activity modifications and bracing.<sup>13</sup> A delayed ACL rupture diagnosis similarly leads to recurrent episodes of instability due to a lack of knowledge that activity modification, bracing, or surgical reconstruction is needed. With each episode of instability, the patient is at risk of causing further damage to intra-articular structures, including the meniscus and articular cartilage.<sup>14</sup> Thus, delaying ACL reconstruction in adolescents leads to higher incidence and severity of medial meniscal tears<sup>5</sup> and irreparable chondral damage at the time of surgery.<sup>10,14</sup>

A family may elect to delay ACL reconstruction due to a variety of patient considerations. However, often the delay from injury to ACL reconstruction is related to a delay in diagnosis, access to specialist consultation, or access to operating room time. Patient factors, injury mechanism, and model of health care delivery can all contribute to the timing of diagnosis and definitive management after ACL rupture.<sup>15,16</sup> Socioeconomic status has also been found to be an important factor in the use of orthopaedic resources and access to treatments.<sup>17-19</sup> Specific patient factors that contribute to delayed ACL reconstruction and the consequences of this delay in a publicly funded health care system are poorly understood. The aim of this study was to identify patient factors associated with delayed ACL reconstruction in adolescents, understand

the relationship between time to ACL reconstruction and frequency of intra-articular pathologies, and describe barriers to timely access to care for ACL injuries in a publicly funded health care system. Identifying and clearly defining risk factors that contribute to late presentation and reconstruction of ACL ruptures in adolescents will aid in screening, detection, and improvement of patient outcomes.

**Methods**

This was a retrospective case series. Following institutional review board approval, consecutive patients who had undergone ACL reconstruction at a

single tertiary care pediatric hospital were identified. Inclusion criteria were children and youth less than 18 years of age who had undergone ACL reconstruction between 2014 and 2018. Patients were excluded if they had undergone a revision ACL reconstruction during that period. Information collected included the patients' date of birth, sex, sport involvement, side of involvement, history of prior injury, and history of physical therapy prior to orthopaedic consult. Presence of articular cartilage damage or meniscal pathology was determined by review of the intra-operative surgical report. To assess socioeconomic status, federal census data were used to estimate mean after-tax individual income by postal code. Time variables recorded included date of injury, referral for orthopaedic consult, MRI, orthopaedic consult, and surgery.

Descriptive statistics were used to analyze differences between patients who had presented early after ACL injury and those with a delayed presentation. A multivariate linear regression model was used to determine the association between time to reconstructions (log transformed) and the patient's sex, age, family income, and distance to hospital. The model was run for each of the four time variables: injury to reconstruction, injury to orthopaedic referral (W0), referral to orthopaedic consult (W1), and consult to reconstruction (W2). A *P* value of < .0125 was considered significant to correct for the four independent models evaluated.

A logistic regression model was used to determine whether delayed reconstructive surgery led to a higher likelihood of intra-articular pathology. A *P* value of < .05 was considered significant. Delayed time to ACL reconstruction was defined as more than 180 days after injury. All analyses were conducted using SAS (version 9.4).

**Results**

Eighty-three patients were identified and had a mean age of 14.7 years (range 9–17) [Table 1]. Fifty-five patients were female (66.3%). Fifty-three patients (63.9%) had meniscal or articular cartilage damage at the time of ACL reconstruction. Twenty-one patients (25.3%) had medial meniscal tears; 36 (43.4%) had lateral meniscal tears. Forty-six patients (55.4%) had received physiotherapy prior to reconstruction, and 5 (6.0%) had not; history was missing for the remaining 32 (38.6%) patients. At the time of injury, 76 patients (91.6%) were playing sports: the most common sports included soccer (23, 27.7%), basketball (12, 14.4%), skiing (5, 6.0%), volleyball (4, 4.8%), running (3, 3.6%), and trampoline (3, 3.6%). Of the remaining patients, 6 were involved in non-sport activities at the time of injury, and for one patient, the mechanism of injury was unknown.

Mean time from injury to reconstruction was 286 days, injury to referral (W0) was 80

**Often the delay from injury to ACL reconstruction is related to a delay in diagnosis, access to specialist consultation, or access to operating room time.**

**TABLE 1. Demographics.**

Variable	Study cohort (N = 83)
Sex (no.)	
Female	55 (66.3%)
Male	28 (33.7%)
Mean age (years)	14.7
Side of involvement	
Right	43 (51.8%)
Left	40 (41.2%)
Mean after-tax individual income	\$40092 (SD 9590)

days, referral to consult (W1) was 30 days, and consult to reconstruction (W2) was 161 days [Table 2].

Fifty patients (60.2%) were treated more than 180 days after injury. There was no significant effect of patient sex, age, or distance from home address to hospital on time to reconstruction, but individual income did have a significant effect [Table 3]. For every \$10 000 increase in individual income, time to reconstruction was reduced by 20.9%. Using the median time to reconstruction of 223 days, this represents a decrease of 47 days for every \$10 000 incremental increase in income. When time from injury to reconstruction was divided into W0, W1, and W2, individual income showed a significant effect on time from injury to referral (W0) [Table 3], with a decrease of 43.8% for every \$10 000 incremental increase in individual income. No association was found between income and W1 or W2 [Table 3]. No association was found between time to ACL reconstruction and odds of medial or lateral meniscal tear or articular cartilage damage [Table 4].

**Interpretation**

Most ACL reconstructions conducted at the publicly funded pediatric tertiary care hospital in this study were delayed. In 60.2% of patients, ACL reconstruction was performed more than 6 months after the initial injury. This type of delay was previously documented at another Canadian centre, where mean time from injury to ACL reconstruction was 342 days (range 42–1637).<sup>20</sup> This is similar to our mean of 286 days (range 51–1623). Times from injury to reconstruction at American medical centres are considerably shorter than those reported at Canadian medical centres. One US study reported a mean time to ACL reconstruction of 101 days;<sup>5</sup> other studies reported that 65% of patients were treated in less than 150 days,<sup>21</sup> and 59% were treated within 90 days.<sup>14</sup>

We were able to better understand the discrepancy in access to ACL reconstruction between Canada and the United States by analyzing the time from ACL injury to reconstruction in our study based on three separate time segments: injury to orthopaedic referral (W0), referral to orthopaedic consultation (W1), and consultation to ACL reconstruction (W2). The

**TABLE 2. Wait time variables.**

Variable	Mean	SD	Range
Injury to reconstruction	286 days	240.62	51–1623
Injury to referral (W0)	80 days	145.95	0–1030
Referral to consult (W1)	30 days	34.45	0–230
Consult to reconstruction (W2)	161 days	143.50	16–759

**TABLE 3. Effect of sex, age, income, and distance to hospital on time variables.**

Injury to reconstruction (total wait)					
Variable	Comparison	Time ratio	95% CI		P value
Sex	M > F	1.1207	0.8013	1.5674	0.5010
Age	per year	0.9938	0.9019	1.0950	0.8983
Individual after-tax income*	per 10 k	0.7914	0.6739	0.9292	0.0048
Distance	per 100 km	1.0329	0.9765	1.0926	0.2544
Injury to referral (W0)					
Variable	Comparison	Time ratio	95% CI		P value
Sex	M > F	0.6987	0.3266	1.4945	0.3475
Age	per year	0.9823	0.7984	1.2084	0.8627
Individual after-tax income	per 10 k	0.5619	0.3852	0.8197	0.0036
Distance	per 100 km	1.1592	1.0187	1.3190	0.0259
Referral to consult (W1)					
Variable	Comparison	Time ratio	95% CI		P value
Sex	M > F	0.7569	0.3965	1.4447	0.3912
Age	per year	1.0229	0.8669	1.2070	0.7848
Individual after-tax income	per 10 k	0.8022	0.5940	1.0833	0.1470
Distance	per 100 km	1.0901	0.9449	1.2576	0.2316
Consult to reconstruction (W2)					
Variable	Comparison	Time ratio	95% CI		P value
Sex	M > F	1.1025	0.7474	1.6264	0.6187
Age	per year	0.9950	0.8892	1.1134	0.9302
Individual after-tax income	per 10 k	0.8489	0.7047	1.0225	0.0836
Distance	per 100 km	1.0305	0.9655	1.0998	0.3610

\*Red text indicates significance (P < 0.0125).

**TABLE 4. Effect of time to anterior cruciate ligament reconstruction on odds of intra-articular damage.**

Variable	Odds ratio	95% CI		P value
Odds intra-articular damage: Total wait	0.698	0.368	1.325	0.271
Odds meniscal tear: Total wait	0.825	0.443	1.539	0.546
Odds articular cartilage tear: Total wait	0.462	0.211	1.013	0.054

longest mean wait times and standard deviations were recorded in W0 (80 [146] days) and W2 (161 [144] days) [Table 2]. The long W0 time may suggest a delay in presentation, in diagnosis by the initial health care provider, or in obtaining advanced imaging. The large standard deviation for this variable suggests that some patients were accessing health care resources better than others. The long W2 time may reflect a variation in management due to physiologic differences (swelling, stiffness, skeletal immaturity, concomitant injuries), availability of operating room time, scheduling conflicts due to the child's schooling, or lack of surgeon availability. The large standard deviation for this variable was likely related to differences in clinical patient factors. We did not identify any discrepancies in access to health resources based on socioeconomic status that would explain the variability in W2 among patients. Many of those delays can be attributed to insufficient funding or resources within the Canadian health care system. However, the discrepancies in access to health resources in W0 suggest there was systematic discrimination against patients with lower socioeconomic status.

Our analysis showed that an increase in individual income was associated with a significant decrease in time from injury to ACL reconstruction. When neighborhood-level individual income was used to reflect patient socioeconomic status, every \$10 000 increase in income was associated with a 20.9% reduction in time to ACL reconstruction. However, socioeconomic status affected only the W0 time variable: for every \$10 000 incremental increase in individual income, time from injury to referral decreased by 43.8%. Delay in referral to a specialist was often related to missed diagnosis of ACL tear after initial injury, failure to present to a medical practitioner, or reduced access to advanced imaging modalities. We hypothesize that the effect of income on time to orthopaedic referral was due to reduced access to musculoskeletal specialists (e.g., sports medicine clinics), health care resources, privately funded physiotherapy, or private MRI. In a publicly funded system that is often functioning at or above capacity, patient advocacy from the family and medical practitioner is often necessary to obtain appropriate care in a timely fashion. Our

findings suggest that children and adolescents from families with lower socioeconomic status may have less support or capacity to seek multiple medical opinions, private physiotherapy, or private advanced imaging, which can contribute to a delay in diagnosis and an increase in W0. These patients are also less likely to have parental support or capacity for multiple outpatient visits, which require time off work, or the insurance and/or money necessary to pay for privately funded services.

**Our analysis showed that an increase in individual income was associated with a significant decrease in time from injury to ACL reconstruction.**

Discrepancy in access to health care based on socioeconomic status has also been found in American adolescent patients with ACL injuries. Patel and colleagues found that children in the United States who had no private health insurance coverage and relied on government health care had delayed ACL reconstructive surgery compared to children with private coverage.<sup>15</sup> Individual income was also a significant and independent predictor of ACL reconstruction timing, with patients with lower socioeconomic status experiencing delays in treatment. In contrast to our study, Patel and colleagues found an association between socioeconomic status and time from initial orthopaedic evaluation to surgical reconstruction. The authors speculated that this was due to reduced access to care, familial resources, and social support.<sup>15</sup> In our publicly funded health care system, all patients have equal access to specialist consultation (time to consultation from referral) and surgical reconstruction (time to reconstruction from consultation) independent of socioeconomic status; however, further work is needed to address discrepancies in access to resources for early diagnosis of injuries.

By understanding the timing of delay in management of adolescent ACL injuries and

the patients at risk of experiencing those delays, attention can be focused on initiatives to address those gaps in care. Improving W0 for all patients could be achieved without significant increased cost of care or health care resources. Education on ACL injuries in adolescents that is aimed at parents, coaches, and primary care health practitioners would likely improve W0 by reducing the time to diagnosis and improving the quality of orthopaedic referrals, which could lead to an additional decrease in W1. Educational initiatives for primary care physicians would help them recognize the importance of accurate and timely diagnosis of adolescent acute knee injuries. This would result in an increase in appropriate referral for advanced imaging and specialist care after an initial patient presentation. Likely, these initiatives would have the greatest effect if they were implemented during medical training and provided easily accessible resources for knowledge acquisition and skill development (physical examination). There is a discontinuity between the amount of time spent on musculoskeletal teaching during medical training and the volume of musculoskeletal pathology seen in a typical primary care practice. Although a large proportion of visits to primary care providers involve musculoskeletal issues, many physicians feel this is not adequately addressed in their medical undergraduate training.<sup>22</sup> A summary of current recommendations for the diagnosis of adolescent ACL injuries for primary care providers is provided in Table 5.<sup>23-26</sup>

Several studies have shown an association between increasing time from injury to reconstruction and frequency and severity of intra-articular pathology.<sup>5,12,14,19-21,27</sup> A systematic review and meta-analysis of ACL reconstruction and associated medial meniscal and articular cartilage damage in children and adolescents that was conducted in 2018 showed a significant reduced risk of concomitant medial meniscal injury in patients with early ACL reconstruction (26%) compared to those with delayed ACL reconstruction (47%). There was also a reduced risk of chondral damage in the early versus late ACL reconstruction groups.<sup>11</sup> We did not find an association between time to ACL reconstruction and odds of intra-articular pathology. However, treatment of most of our

**TABLE 5.** Adolescent anterior cruciate ligament injury diagnosis recommendations for primary care providers.

Provide injury prevention education to highly active adolescents, their parents, and coaches	Certain injury prevention programs have been well established in the pediatric population, including FIFA 11+. <sup>23</sup> These programs should target athlete biomechanics, using strength, plyometric, and sports-specific agility exercises. <sup>24</sup>
Acute knee injury diagnosis	History: <ul style="list-style-type: none"> <li>• Twisting or contact acute knee injury obtained during high-risk sports (skiing or cutting sports such as soccer, football, volleyball, etc.).</li> <li>• Recurrent episodes of instability/giving way with activity.</li> <li>• Acute period of knee swelling with stiffness and possible difficulty weight-bearing.</li> </ul> Physical examination: <ul style="list-style-type: none"> <li>• Large effusion/hemarthrosis within 24 hours.</li> <li>• Decreased range of motion—loss of terminal extension suggestive of large meniscus tear.</li> <li>• Ligamentous laxity—Lachman, pivot shift,<sup>25</sup> and anterior drawer test.</li> </ul>
Imaging	Begin with plain knee radiographs (findings suggestive of ACL tear include presence of hemarthrosis, Segond fracture). These will also assist in ruling out other intra-articular pathology/fractures. An MRI should be obtained in all adolescent patients presenting with an acute hemarthrosis or recurrent episodes of instability. <sup>26</sup>
Referral to specialist	Urgent referral to a musculoskeletal specialist should be made for all adolescent patients with an acute hemarthrosis or loss of terminal extension after an acute knee injury, recurrent episodes of instability/giving way, or concern of ligamentous knee injury.

patients was delayed (60.0% to 87.0% depending on the definition of *delayed*),<sup>5,21,28</sup> and the frequency of meniscal tears and articular cartilage damage was reflective of this finding: 53 patients (63.9%) had meniscal or articular cartilage damage at the time of ACL reconstruction. This is further support for what has already been established in the literature: delayed reconstruction leads to increased intra-articular pathology, likely due to ongoing instability. It is important to advocate for more medical resources for adolescent acute knee injuries to try to reduce the time to ACL reconstruction for all patients and prevent irreversible intra-articular damage when access to resources is delayed.

### Limitations and future directions

Due to the retrospective nature of our study and gaps in our data, we were unable to identify a relationship between access to private health care services and time to ACL reconstruction. We hypothesized that history of access to physiotherapy could be used as a surrogate for socioeconomic status and overall family support. More than half the patients (55%) in this study had access to a physiotherapist prior to surgical

reconstruction. However, no association was found between access to physiotherapy and time to ACL reconstruction. This possibly is related to the inherent challenges of retrospective data collection, as no history on access to physiotherapy was available for 39% of patients. We similarly hypothesized that access to private MRI would reduce time to ACL diagnosis and reconstruction. However, due to incomplete MRI data, we were unable to investigate this further. This is an area that will be assessed in future prospective studies.

Geographic-based census data were used to estimate patient socioeconomic status, which contributed to an ecological fallacy. A number of studies have used census data to predict socioeconomic status.<sup>12,15,18,29</sup> However, it is possible that incomes estimated using this method were not always reflective of patient socioeconomic status. The estimates are based on average income for a given geographic region. It is possible that some of the delay in treatment of ACL injuries could be related to challenges in accessing health care resources in a given geographic region. However, distance to the tertiary care hospital in our study was not associated

with a delay in diagnosis and definitive management of ACL injuries. Any interaction between geographic location and access to health care is likely a complex interaction among availability of local resources, proximity to higher level care, and family socioeconomic status.

Future research is needed to provide more insight on the discrepancy between income and surgical wait time. A prospective cohort would provide more accurate information on income levels, as well as any other patient factors (such as ethnicity) related to delayed injury presentation and reconstruction. Additionally, communicating with primary health care providers about possible gaps in education on musculoskeletal injuries in pediatric populations may help identify where to target educational resources.

### Conclusions

At a pediatric tertiary care hospital in a public health care system, most adolescent patients experienced delays in ACL reconstruction, which contributed to a high rate of intra-articular pathology. Increase in parental income was associated with a significant decrease in time to orthopaedic referral, which suggests there was differential access to health care resources based on patient socioeconomic status. Further research is needed to determine the specific factors that caused this discrepancy in access to health care within a publicly funded system. ■

### Competing interests

Dr Leveille received a clinical research stimulus award from the BC Children's Hospital Research Institute to help cover research-related costs. None of the authors received financial support for the completion of this project.

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