OPEN Research Article

Decline in Pediatric Anterior Cruciate Ligament Reconstructions Seen Over 20 Years in the American Board of Orthopaedic Surgeons Part II Oral Examination Database

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ABSTRACT

Introduction: Although increased treatment of pediatric anterior cruciate ligament (ACL) injury is well-documented, surrounding trends remain unknown. We evaluated national trends over 21 years using data from pediatric ACL reconstructions (ACLR) submitted to the American Board of Orthopaedic Surgeons (ABOS) Part II Oral Examination and compared fellowship training, geographic variation, and case volume trends.

Methods: The ABOS SCRIBE database was queried for ACLR in pediatric (<19) patients between 2000 and 2021. Data included geographic region, fellowship training, and patient demographics. ACLRs per capita was estimated using census data. Data were stratified by age and sex. Multiple linear regression assessed whether year, sex, and age/sex category predicted surgery number.

Results: From 2000 to 2021, ABOS Part II candidates reported 12,124 pediatric ACLR. Nearly 2/3 were in patients 16 years or older. Most were in the Midwest (22.8%) and South (22.2%). Each region decreased in ACLR. Overall, pediatric ACLR decreased 31.3% and contributing surgeons decreased 40.4%. Female ACLR increased 39.5% from 2009 to 2014, with 11.9% more than male patients in 2014. After 2014, sex differences and total ACLR decreased. 81.3% were reported by surgeons with sports medicine training and 6.0% with dual sports medicine and pediatric orthopaedics fellowships. Dual training increased in 2009 and declined after 2013. Surgeries in male patients compared with female patients (B = −6.777, 95% confidence interval, −9.534 to −4.279) and male patients 16 to 18 years compared with male patients younger than 16 years (B = −4.935, 95% confidence interval, −6.596 to −3.273) decreased.

Conclusion: Pediatric ACLR performed by ABOS Part II candidates decreased overall, but a concern for increased ACLR in female patients persists. More surgeries were done in the Midwest and South.

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JAAOS Glob Res Rev 2025;9: e24.00287

DOI: 10.5435/JAAOSGlobal-D-24-00287

Study Design: Cross-sectional Study Level of Evidence: III.

Over the past 2 decades, there has been a reported increase in the rate of pediatric and adolescent patients undergoing anterior cruciate ligament (ACL) reconstruction.[1-8] ACLR is now considered one of the most common arthroscopic procedures performed in youth patients, with the highest rate of surgeries performed in those aged 15 to 18 years.[8] Furthermore, it has been reported that the increase in pediatric ACLRs from 2004 to 2014 was greater than the increase in total pediatric orthopaedic surgeries over the same 10-year period.[7] This increased incidence of pediatric ACLRs has been noted both in the United States and internationally.[4,9,10]

Several trends regarding pediatric and adolescent ACLRs have been noted in the literature. First, with the exception of the 17- to 18-year age group, the incidence of ACLR in adolescent female patients is markedly higher than that of adolescent male patients.[1] These trends have been consistently reported, but it is unclear if they are representative of a true increase in ACL injuries, or the identification due to improved awareness and access to sports medicine professionals.

The field of orthopaedic surgery, specifically sports medicine, has become increasingly specialized.[6,11-13] After residency, more than 90% of orthopaedic residents complete a subspecialty fellowship and approximately 30% of pediatric orthopaedic fellowship graduates reported that they completed multiple fellowships.[14-16] Surgeon fellowship training and background may affect procedure choice for ACLRs.[17] Surgeons with sports medicine fellowship training and pediatric orthopaedics fellowship training are more likely to perform ACLR with meniscal surgery than surgeons with other fellowship backgrounds.[2,18] It has been noted that surgeons with sports medicine fellowship training are 46% more likely to repair meniscal injuries at the time of ACLR.[19]

Orthopaedic surgeons must complete a two-part certification process to become Board Certified by the American Board of Orthopaedic Surgeons (ABOS).[20] After the successful completion of an accredited orthopaedic residency program and the ABOS Part I (computer-based) Written Examination, the candidate is deemed ABOS *Board Eligible*. The candidate's clinical competence is then evaluated through the ABOS Part II Oral Examination. The surgeon is required to submit all surgical cases completed during a 6-month period through the ABOS SCRIBE system, and 12 are selected for presentation. After passing this Examination, the orthopaedic surgeon is deemed ABOS Board Certified for a 10-year period.[21]

With the increased number of pediatric ACLRs, the purpose of this study was to evaluate national treatment trends over a 21-year period using ABOS Part II case list submissions of ACLRs in patients aged 18 years and younger. A secondary purpose was to describe treatment choice trends stratified by fellowship training, regional variation, and case volume. Overall, we hypothesize that there will be an increase in pediatric ACLRs performed by ABOS Part II candidates who will likely correlate with increases in dual pediatric orthopaedic and sports medicine fellowship training.

Methods

Study Design

This was a retrospective cross-sectional study of cases submitted by applicants to the ABOS Part II Oral Examination for all ACLRs performed in pediatric patients aged younger than 19 years between 2000 and 2021. This data set includes all case information of the ACLRs performed over the 6-month case collection period in preparation for the ABOS Part II of a candidate's orthopaedic board certification. The project was reviewed by the local Institutional Review Board and was determined to be exempt from review.

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Ms. Clark, Mr. Van Pelt, Dr. Wilson, Dr. Ellis—grant from the POSNA QSVI-SM Committee. Dr. Beck—ongoing financial relationship with OrthoPediatrics.

None of the following authors or any immediate family member has received anything of value from or has stock or stock options held in a commercial company or institution related directly or indirectly to the subject of this article: Ms. Clark, Ms. Sabatino, Mr. Lind, Mr. Van Pelt, Dr. Vandenberg, Dr. Beck, Dr. Pennock, Dr. Cruz, Dr. Ganley, Dr. Shea, Dr. Wilson, and Dr. Ellis.

Covariates

The Current Procedural Terminology (CPT) code 29888, defined as arthroscopically aided ACLR or augmentation, was used to identify eligible cases. Patient age, sex, and associated procedures in the form of CPT codes were collected for each eligible case and analyzed.

Self-reported fellowship training history, including the number and types of fellowships completed by each surgeon, chosen subspeciality examination taken by each surgeon, and geographic region where the surgeon practiced were included in the query. Fellowship types included adult reconstruction, foot and ankle, hand and upper extremity, oncology, pediatric orthopaedics, general orthopaedics, shoulder and elbow, spine, sports medicine, trauma, and other.

Each surgeon's total number of ACLRs performed during board collection was determined using applicants' CPT procedure codes and associated applicant numbers. Geographic variation was reported by region, which included Midwest, Northeast, Northwest, South, Southeast, Southwest, and Other. Each region had a set of predetermined states noted in Table 1. To calculate the ACLR performed per capita, pediatric (aged younger than 19 years) population statistics for each state and corresponding region were gathered from publicly available census data.[22] Yearly census data were combined into 2000 to 2002 and 2019 to 2021 groups for comparison. The number of surgeries performed in each region of the United States was obtained from the query data, and the census data were used to calculate the approximate volume of surgeries performed per capita (or per 100,000 people).

Analysis

Characteristics of the study population were first summarized as percentages for categorical variables and mean with SDs for continuous variables, and the aggregate data were reviewed for trends. Trends stratified by sex, with a focus on average age of maturity, were also reviewed. Previously literature reports that the average age of maturity in female patients is 14 years, and the average age in male patients is 16 years.[23,24] Therefore, to assess trends based on maturity, the data were separated into groups including female patients aged younger than 14 years and older than 14 years, as well as male patients aged younger than 16 years and older than 16 years. A multiple linear regression with 1,000 performances of bootstrapping was used to test if year of surgery, patient sex, and an interaction term between year of surgery and sex markedly predicted number of surgeries. Another multiple linear regression with 1,000 performances of bootstrapping was used to test whether year of surgery, the patient's age/sex category (male <16 versus males 16 to 18 versus females <14 versus females 14 to 18), and an interaction term between these two variables markedly predicted number of surgeries.

Results

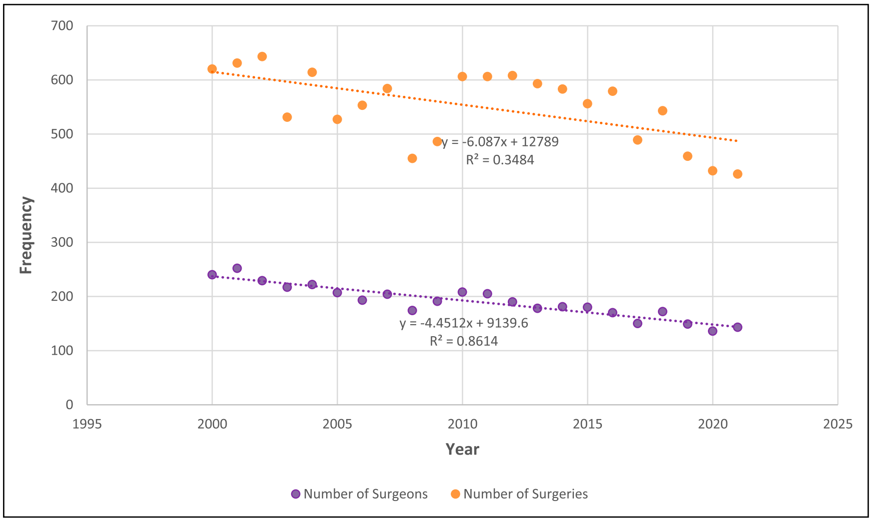
Between 2000 and 2021, ABOS Part II candidates reported a total of 12,124 pediatric ACLRs. The average age was 16.0 years (range 0 to 18) with 47.0% female patients. Almost two-thirds (8,201) of the surgeries in this series were done on patients who were 16 (2,846), 17 (3,151), or 18 (2,204) years old, and only 0.7% of surgeries were done in those younger than 10 years. Overall, there were a 31.3% decrease in the number of pediatric ACLRs ($R^2 = 0.3484$) and a 40.4% decrease in the number of surgeons performing these surgeries reported between 2000 and 2021 ($R^2 = 0.8614$) in this data set (Figure 1).

Table 1. Table Describing Which States are Included in Each Region Used to Determine Geographic Trends

Region	States Included
Midwest	Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin
Northeast	Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont
Northwest	Idaho, Montana, Oregon, Washington, Wyoming
South	Arkansas, Louisiana, Oklahoma, Texas
Southeast	Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, West Virginia
Southwest	Arizona, California, Colorado, Nevada, New Mexico, Utah

Alaska and Hawaii are excluded from the following regions.

Figure 1

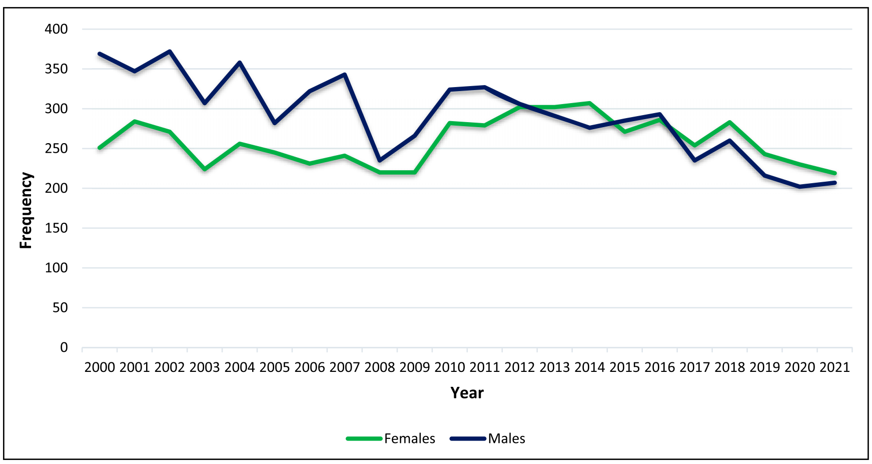


Graphical representation demonstrating the overall decrease in submitted pediatric anterior cruciate ligament (ACL) reconstructions performed in patients aged younger than 19 years and the number of surgeons performing pediatric ACL reconstructions between 2000 and 2021.

ACL Trends by Sex

Overall, an average of 551 ACLRs were done each year between 2000 and 2021. Before 2012, more ACLRs in this data set were done on male patients than female patients (Figure 2). However, there was a 39.5% increase in pediatric ACLRs performed on female patients reported between 2009 and 2014. The increase in the incidence of females undergoing ACLR over the past 20 years persists despite an overall decrease in ACLRs in all patients within this data set. Although the results are approximate due to an adjustment not being made for the number of surgeries per sex, per year, or individually in the data set, male patients were found to have a stronger decrease in the number of surgeries across the years measured in the data set compared with female patients (B = −6.777, 95% confidence interval, −9.534 to −4.279). These effects are demonstrated by Table 2 and Figure 2. Similarly, although the results are approximate due to an adjustment not being made for the number of surgeries per sex, per year, or individually in the data set, it was determined that male patients of 16 to 18 years had a markedly decreasing trend in the number of surgeries across the years measured in the data set compared with male patients younger than

Figure 2



Graphical representation of the submitted pediatric anterior cruciate ligament (ACL) reconstructions performed in patients aged younger than 19 years between 2000 and 2021, separated by male and female.

Table 2. Table Demonstrating the Results of the Multiple Linear Regression of the Number of Surgeries With Surgery Year, Sex, and Their Interaction Term

Predictors	B (95% CI)
Male	110.753 (71.873 to 147.369)
Year	0.345 (−1.233 to 2.671)
Male × year	−6.777 (−9.534 to −4.279)

CI = confidence interval

16 years (B = −4.935, 95% confidence interval, −6.596 to −3.273). This same significant trend was not found; however, in female patients younger than 16 years and female patients 16 to 18 years. These effects are demonstrated by Table 3 and Figure 3.

ACL Trends by Maturity

Figure 3 demonstrates differences in ACLR performed in male and female patients separated into groups based on maturity. Mature female patients (aged ≥ 14 years old) experienced a 10.2% increase in ACLRs from 2000 to 2014. In this same period, mature male patients (aged ≥ 16 years old) experienced a 33.8% decrease in surgeries. The number of reported surgeries in both groups in the data set steadily declined after 2014.

Geographic Trends

ACLRs were most commonly done reported in the Midwest (22.8%) and South (22.2%) regions. The Southwest, Northeast, and Southeast regions comprised 18.6%, 15.5%, and 14.4% of surgeries, respectively. The Northwest region reported only 6.6% of surgeries. Figure 4, A demonstrates the geographic variation in the volume of submitted ACLRs per capita at the beginning of the study period, from 2000 to 2002, and Figure 4, B demonstrates the geographic variation at the end of the study period, from 2019 to 2021. Each region demonstrated a decrease in the number of ACLRs performed from the beginning of the study period (2000 to 2002) to the end of the study period (2019 to 2021). The proportion of surgeries performed in each region was relatively constant during both periods, as shown in Figure 5, A and B.

Fellowship Trends

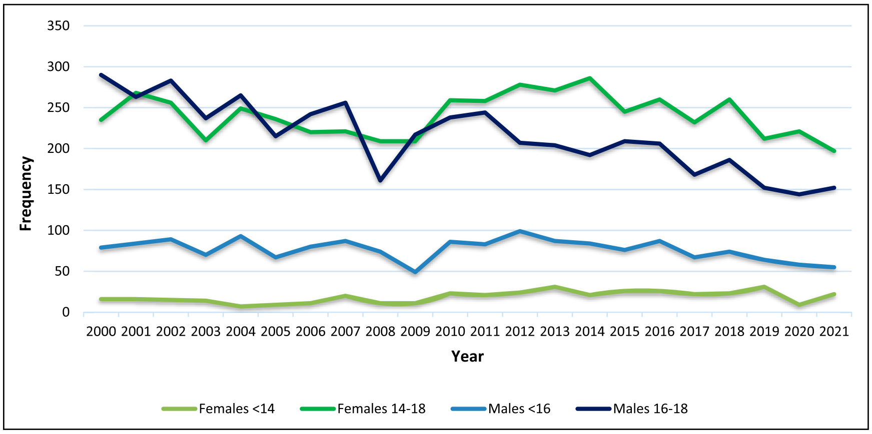
The 4,187 candidates participating in Part II Oral Examination of the ABOS performed an average of approximately three pediatric ACLR cases each. Approximately 83% reported performing between 1 and 4 cases during their 6-month case submission period from 2000 to 2021, with the remaining 17% of candidates performing more than 45% of all reported pediatric ACLRs. During the study period, surgeons who did not possess either sports medicine or pediatric orthopaedic fellowship training submitted about 24% of ACL procedures in patients aged younger than 19 years. Surgeons with sports medicine fellowship training performed 81.3% of procedures during the study period. 8.8% of procedures were done by surgeons with any combination of training that includes pediatric orthopaedics, but excludes sports medicine, and 6.0% of procedures were reported by surgeons dual trained in pediatric orthopaedics and sports medicine. 3.9% of surgeries were reported by surgeons with neither pediatric orthopaedics nor sports medicine fellowship training.

Figure 6 demonstrates the number of ACLRs performed by ABOS Part II candidates over the study period, stratified by fellowship type. Every year, surgeons with Sports Medicine fellowship training consistently performed most of the procedures. The next most common fellowship overall was Pediatric Orthopaedics. Over time, this trend remained relatively stable. The "Other" category contains all fellowships and combinations of fellowships that do not include Sports Medicine, Pediatric Orthopaedics, or training in both. Dual fellowship training in Sports Medicine and Pediatric Orthopaedics is of particular interest. Figure 7 demonstrates the trend in dual-trained surgeons performing ACLRs over the study period. From 2000 to

Table 3. Table Demonstrating the Results of the Multiple Linear Regression of the Number of Surgeries With Surgery Year, Age/Sex Category, and Their Interaction Term

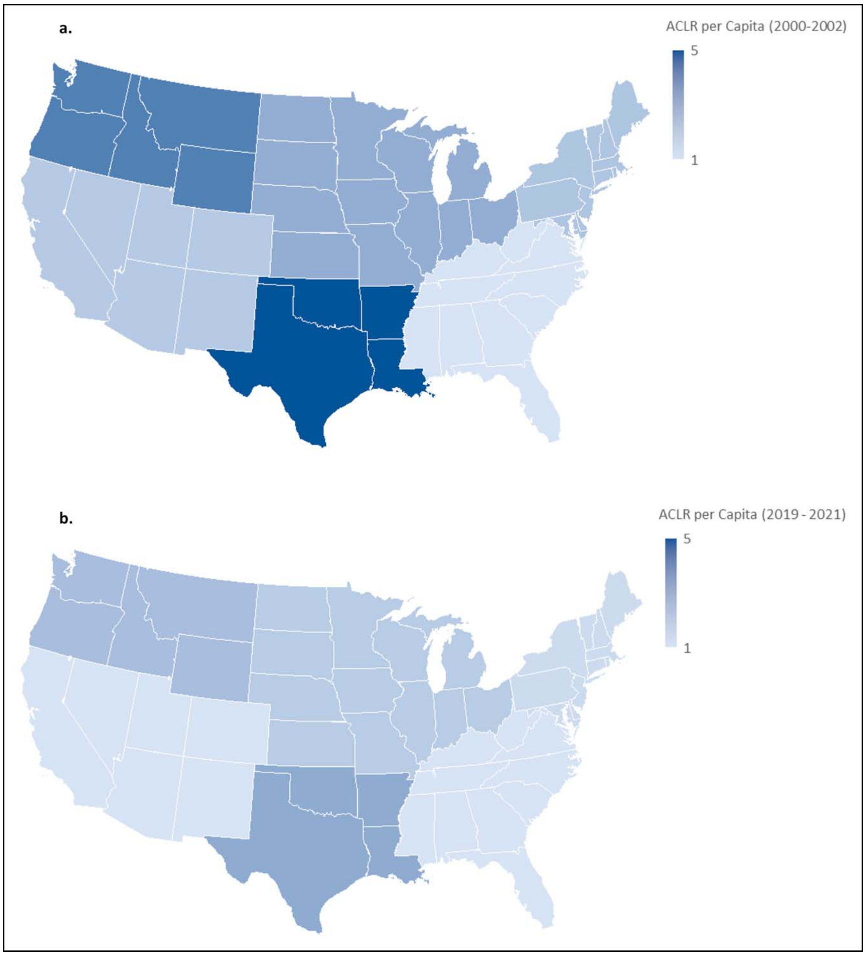
Predictors	B	Standard Error	95% CI
Males 16-18	194.883	11.1323	173.604 to 216.702
Males <16	Ref.	Ref.	Ref.
Year	−0.749	0.5993	−1.923 to 0.426
Males 16-18 × year	−4.935	0.8476	−6.596 to −3.273
Males <16 × year	Ref.	Ref.	Ref.

Figure 3



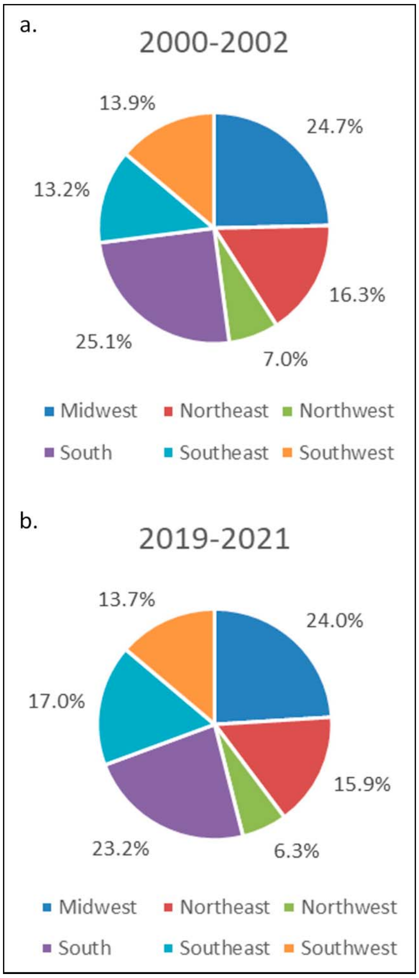
Graphical representation of the number of pediatric anterior cruciate ligament (ACL) reconstructions performed in male and female patients from 2000 to 2021, separated by sex and maturity or immaturity. Immature female patients are aged younger than 14 years, mature female patients are aged 14 to 18 years, immature male patients are aged younger than 16 years, and mature male patients are aged 16 to 18 years.

Figure 4



Diagrammatic representation of the geographic variation in the volume of submitted anterior cruciate ligament (ACL) procedures performed per capita in patients aged younger than 19 years in each region of the United States during the first 3 years of the study period (2000 to 2002; Figure 4, A.) and the past 3 years of the study period (2019 to 2021; Figure 4, B).

Figure 5



Graphical representation of the proportion of the total volume of submitted anterior cruciate ligament (ACL) procedures performed in patients aged younger than 19 years in each region of the United States during the first 3 years of the study period (2000 to 2002; Figure 5, A) and the past 3 years of the study period (2019 to 2021; Figure 5, B).

2009, dual fellowship training remained relatively stable. Between 2009 and 2013, however, there was a 13-fold increase in the number of procedures performed by dual trained surgeons. After its peak in 2013 and 2014, this number began to consistently decline, with a 98.8% decrease in the number of dual fellowship-trained surgeons performing ACLRs.

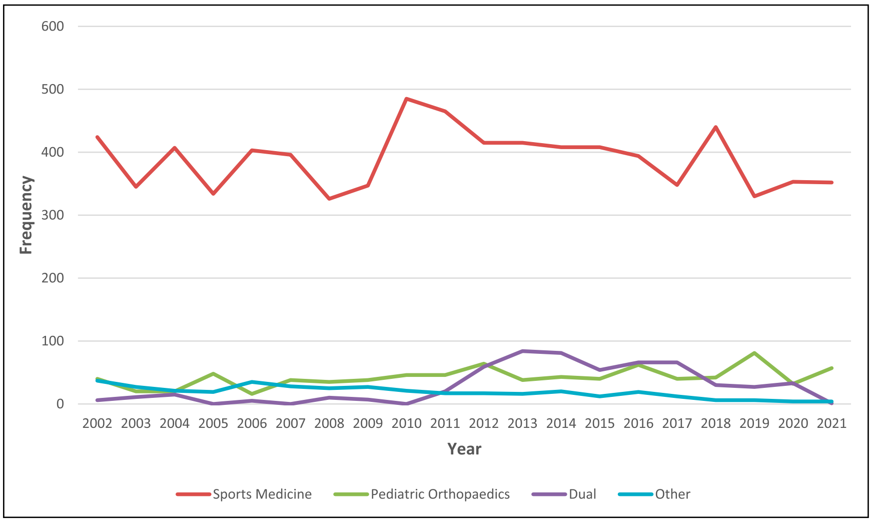
Discussion

In this study of pediatric ACLRs reported by ABOS Part II candidates, an overall decreasing trend in the number of surgeries was reported between 2000 and 2021. When focused on patients at the ages of maturity, there was a 10.2% increase in ACLRs reported in mature female patients between 2000 and 2014 compared with a 33.8% decrease in surgeries reported in mature male patients during the same timeframe. Both groups showed a steady decline after 2014. One of the original investigations on trends in pediatric ACLR noted an increase by as much as 67.8% between 1997 and 2006.[5] A 20-year study by Beck et al[1] between 1994 and 2013 noted a small increase in pediatric ACL (2.3% annual increase) with an incidence approximately 2 to 8 times higher in female than male patients. Only one other recent study noted a specific decline in 2014.[25]

We also identified a downward trend in the number of ABOS Part II candidates performing ACLRs beginning around the same time. This may suggest that the overall incidence in pediatric ACLR is not declining, but that ACLRs are more commonly being done by more experienced surgeons. However, it is important to note that this is not supported by the data set used for this study.

The COVID-19 pandemic could be responsible for the decrease in available surgeons to perform ACLRs after 2019. Fewer elective surgical procedures were done nationwide during this time, in efforts to control the spread of the virus and conserve hospital resources.[26] Some of the major changes after the pandemic have been an emphasis on remote learning and the withdrawal of 3rd- and 4th-year medical students from their in-hospital clerkships. The pandemic has also affected the orthopaedic sports medicine fellowship application process. COVID-19 has led fellowship programs to conduct interviews virtually rather than in person, which may affect the success of matching for applicants and programs.[27] The COVID-19 pandemic, however, does not explain the decrease in surgeons before its onset in the United States in early 2020. Our data noted this decrease in surgeons beginning in 2011. In 2011, a study was published that predicted an orthopaedic workforce shortage.[28] Another study noted a concern for a shortage in orthopaedic surgeons, and in medicine as a whole, which has been a prevalent concern since the 1990s.[29] Although the number of surgeons completing fellowship programs is roughly the same as the number of surgeons who are retiring, this shortage was predicted to be the result of an overwhelmingly increased patient demand for orthopaedic surgeons.[28] In 2014, a study noted that the number of available fellowship positions for orthopaedic subspecialties exceeded the number of orthopaedic surgery residents graduating from residency programs.[30] The issue of fewer surgeons being available to perform ACLRs in pediatric and adolescent patients may warrant additional study. Although the

Figure 6



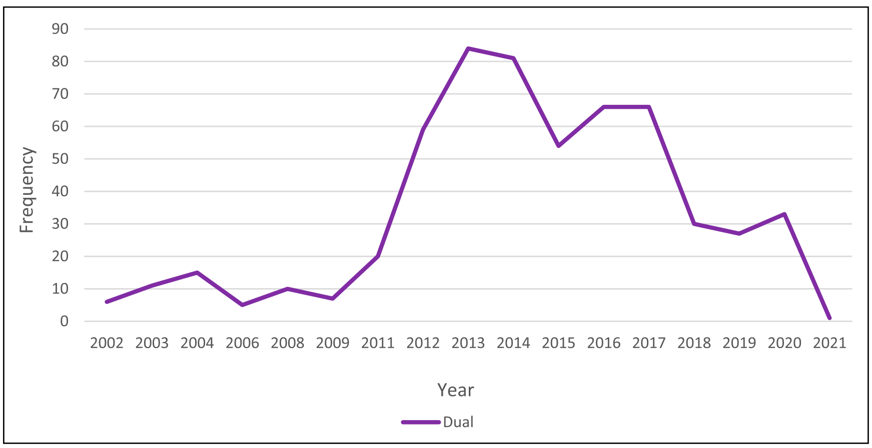
Graphical representation of the number of pediatric anterior cruciate ligament (ACL) reconstructions performed in patients aged younger than 19 years, stratified by surgeon fellowship training. The fellowships shown are Sports Medicine, Pediatric Orthopaedics, Dual Sports Medicine and Pediatric Orthopaedics, and Other.

COVID-19 pandemic may have contributed to the trends observed in the past few years of our study, it does not explain the trends that appeared before and despite the pandemic's influence.

Awareness of ACL injury and prevention programs may have also contributed to the decline in pediatric ACLR being done because the literature regarding the cost-effectiveness of ACL prevention was published during this time.[31] The most effective of these prevention programs are neuromuscular training programs that focus on lower body strength and landing stabilization exercises in younger athletes.[32] The goals of these programs include restoring the knee to its proper function, overcoming psychological barriers to resuming activity, preventing additional injury, reducing the risk of osteoarthritis, and optimizing patients' long-term quality of life.[33] These programs have been associated with a 52% reduced risk of ACL injury in female athletes and 85% in male athletes.[34] For this reason, the growing popularity of ACL injury prevention programs may have contributed to the downward trend in the number of ACLRs noted in this study.

This study noted geographical trends in ACLRs, which few studies have previously investigated. The highest percentage of the reported surgeries were done

Figure 7



Graphical representation of the number of pediatric anterior cruciate ligament (ACL) reconstructions performed in patients aged younger than 19 years, stratified by surgeon dual fellowship training in Sports Medicine and Pediatric Orthopaedics.

in the Midwest and South regions, with a previous study also finding an increased incidence in the Midwest within our study period.[8] We also found that all regions experienced a decrease in ACLR per capita. However, the proportion of ACLR reported in each region remained relatively constant from the beginning (2000 to 2002) to the end (2019 to 2021) of the study period.

There were some notable findings in this study regarding trends in ACLRs performed by fellowship-trained surgeons. We found that 6.0% of reported procedures were reported by surgeons with dual pediatric and orthopaedics and sports medicine fellowship training. From 2002 to 2013, we found a substantial increase in the number of ACLR performed by dual trained surgeons. These findings are similar to those of previous literature, which suggest an increase in dual fellowship training among orthopaedic surgeons.[12,35] Our study, however, also found that there has been a decline in dual fellowship training recently, beginning after 2014. In addition, we found that surgeons who were fellowship-trained in sports medicine performed most of the reported surgeries (81.3%). This proportion remained relatively consistent throughout the study period.

There are limitations to this study. First, the data used were queried from the ABOS SCRIBE System and are contingent on the self-reporting of ABOS Part II Oral Examination candidates.[2] Therefore, the data are based solely on cases performed by fellows during a 6-month board collection period and are not generalizable to all surgeons, centers, or patients. Like any study that uses information from databases, this research relies on procedural codes, which limits the data to patients treated surgically and excludes patients managed nonsurgically or injuries that are undiagnosed.[3,8] The data used to assess maturity in this study were based on previously noted average ages in male and female patients; therefore, the results may not reflect true trends in ACLRs when considering radiographic skeletal maturity. These data lack important clinical information, including the mechanism of injury, details of the operation, complexity of the procedure, different techniques, radiographic skeletal maturity, and the postoperative rehabilitation protocol.[5] Furthermore, owing to sparse reporting of regional population data, geographic variation in ACLRs was reported as a proportion of the cohort and not the prevalence of each regional population as a whole. Finally, we have used ACLR procedures, as reported by candidate members to the ABOS, as a proxy measure for potential decreases in other areas, and these procedures may be poor predictors of the noted trends.

Conclusion

Although previous studies demonstrate an increase in ACLRs in the past few decades, the descriptive analysis of our datasets suggests that since 2014, there may be a decrease in pediatric ACL surgeries performed by ABOS Part II candidates. This may indicate the success of injury awareness and prevention programs, a decrease in available surgeons to perform ACL surgery, or an increased tendency for more experienced surgeons to perform ACLR. Despite the limitations of the study, our data were consistent with others—reflecting that the incidence of ACLR in female patients remains concerning. This study is also consistent with other studies which indicate an increase in dual pediatric orthopaedics and sports medicine fellowship training. Finally, geographic analysis demonstrates that surgeons who were ABOS Part II candidates in the Midwest and the South regions had the highest rate of reported ACLRs but are overall decreasing their per capita pediatric ACLR performed in those regions.

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