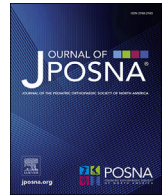




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Original Research

Trends in Complications Following Pediatric Anterior Cruciate Ligament Reconstruction as Reported to the American Board of Orthopaedic Surgery Part II Oral Examination Database



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ABSTRACT

Background: Pediatric anterior cruciate ligament reconstructions (ACLr) have increased dramatically in recent years. However, a comprehensive list of short-term complications related to this procedure has yet to be reported. This study aimed to report complication rates in pediatric ACLr using submissions to the American Board of Orthopaedic Surgery (ABOS) Part II Oral Examination. A secondary goal was to assess the relationship of complications with patient sex, geographic region of surgery, surgical volume, and surgeon fellowship training.

Methods: A query was submitted to the ABOS Part II Oral Examination Case List Database for all ACLr performed in patients younger than 19 years between 2000 and 2021. Surgeon fellowship training, geographic region of surgery, and patient demographics were included, along with medical, surgical, and anesthetic complications, reoperation, and readmission. Statistic comparisons used chi-square tests for categorical variables with significance set at $P < 0.05$.

Results: Surgical complications were the most common type of complication, present in 10.1% of pediatric ACLr. Stiffness (3.6%) and infection (1.5%) were the most prevalent surgical complications. Females had higher rates of overall complications than males (11.9% vs. 10.4%, $P = 0.010$). Females also had higher rates of surgical complications (10.7%–9.5%, $P = 0.019$) – specifically stiffness (5.0%–2.2%, $P < 0.001$). However, males had higher rates of infection (1.8% vs. 1.3%, $P = 0.047$). Geographic analyses showed higher infection rates in Hawaii and Alaska and lower surgical complication rates in the Northwest region. Procedures completed by surgeons with a fellowship training other than Sports Medicine and/or Pediatric Orthopaedics had lower rates of overall complications (8.9%, $P < 0.001$) and surgical complications (8.3%, $P < 0.001$).

Conclusion: This study establishes that female pediatric and adolescent patients are at an increased risk for complications following ACLr. Arthrofibrosis was more than twice as common in females than in males. Geographic region and fellowship training may be associated with complications in this population.

Study design: Cross-Sectional Study

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Key Concepts:

- (1) Complications following ACL reconstruction may be associated with geographic region and fellowship training.
- (2) Females present with more short-term complications following ACL reconstruction.
- (3) There was a higher reported infection rate overall for surgeons in their board collection period than infection rates in the literature, with males having an overall higher infection rate than females.
- (4) Arthrofibrosis is more than twice as common in females than males following ACL reconstruction.

Level of Evidence: III

Introduction

Anterior cruciate ligament reconstruction (ACLR) rates in pediatric patients have also dramatically increased in recent years [1–5]. The stark jump in ACLR rates in pediatric patients may come from various sources, including improvements in awareness and identification. However, the rise may result from the increase in year-round, high-demand sports or the growing emphasis on the importance of early intervention [6]. As rates of this injury have increased, surgical reconstruction of the pediatric ACL continues to be a key procedure for restoring joint function and preventing further injury to the knee in active young patients. As this procedure has become more common, new surgical techniques and rehabilitation protocols are becoming more specialized and ultimately contributing to improved success rates [7–10].

Despite reports of success in pediatric ACLR, complications from surgery continue to be concerning for patients and surgeons. These complications can manifest as harvest site symptoms, infection, growth disturbance, arthrofibrosis, and other surgical complications contributing to a higher likelihood of reinjury, reoperation, or long-term removal from sport [11–15]. A meta-analysis reported a combined physeal asymmetry (either leg length inequality or acquired malalignment) of 11.2% [15]. A majority of reported complications from pediatric ACLR have been in the form of case series or from retrospective reviews [4,15].

The purpose of this study is to utilize the American Board of Orthopaedic Surgery (ABOS) Part II Oral Examination Case List Database to elucidate the rates of short-term complications associated with pediatric ACLR. A secondary goal is to assess the relationship between complications and patient sex, geographic region of surgery, surgical volume, and surgeon fellowship training. The benefit of using the ABOS Part II Oral Examination is that it is a large, national database containing complications and detailed information about surgeon training from early in their careers.

Materials and methods

This study is a cross-sectional analysis of a national dataset of consecutive pediatric ACLR performed in patients less than 19 years of age between 2000 and 2021 by eligible candidates for the ABOS Part II Oral Examination. Eligible candidates must be actively practicing orthopaedic surgery in the United States for a minimum of 17 months at a single practice, passed the ABOS Part I Written (computer-based) Examination, and contribute six months of consecutive surgical cases into a large de-identified Health Insurance Portability and Accountability Act (HIPAA) compliant database. Due to the use of de-identified patient health information, an internal review board (IRB) exemption was obtained for this study.

The researchers requested a data query from the ABOS Part II Oral Examination case list database (Scribe by Web Data Solutions, Chicago, IL) to include all patients younger than 19 years old receiving an ACLR (based on Current Procedural Terminology (CPT) code: 29,888) between calendar year 2000 and 2021. Along with patient demographic data, this dataset included the contributing candidates' self-reported training history, type of fellowships, and chosen subspecialty examination for all ABOS Part II applicants. The resulting fellowship types were adult

reconstruction, foot and ankle, hand and upper extremity, oncology, pediatric orthopaedics, general orthopaedics, shoulder and elbow, spine, sports medicine, trauma, and "other." Patient information included age, sex, follow-up duration, and year of surgery.

Post-operative complications were self-reported by the contributing candidates. Complications are reported in 4 groups, defined as follows: (1) all reported complications, (2) surgical complications, (3) anesthesia and/or medical complications excluding infections, and (4) other categorical complications, including infections, deep venous thrombosis, and/or pulmonary embolism (DVT-PE). Patients with multiple complications are included in both complication groups for analysis.

The ABOS Part II Oral Examination database was updated in 2013, during which 24 additional data fields were added. Proportional adjustments were made for fields added in 2013 by adjusting the

Table 1.

Complications available for registration in ABOS 2001–2021 and the 2013 additions.

Original Complications Data Fields 2001–2021 (n = 9767)	Additional Complications Data Fields 2013–2021 (n = 5269)
Pulmonary embolism	Reoperation
Bone fracture	Readmission
Infection	Block anesthesia complication
Wound dehiscence	General anesthesia complication
Surgical unspecified	Anemia
Compartment syndrome	Arrhythmia
Nerve palsy injury	Deep venous thrombosis (DVT)
Wound healing delay/failure	Dermatologic complaint
Hemorrhage	GI bleeding/ulcer/gastritis
Implant failure	Renal failure
Surgical procedure intervention	Medication error reaction
Implant fracture	Respiratory failure
Tendon ligament injury	Urinary retention
Skin ulcer blister	Bone fracture
Vascular injury	Failure of tendon/ligament repair
Anesthetic	Implant failure/fracture/malfunction
	Graft-related problem
	Stiffness/Arthrofibrosis
	Hemarthrosis/Effusion
	Hematoma/Seroma
	Recurrent/persistent/uncontrolled pain
	Complex regional pain syndrome (CRPS)/reflex sympathetic dystrophy (RSD)
	Limb ischemia
	Loss of reduction

denominator of total cases for these complications only, and complications and their respective years of collection are listed in Table 1.

Reported regional variability divided national ABOS candidates into 7 groups as follows: 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

Table 2.

Surgery information from 12,124 pediatric and adolescent anterior cruciate ligament (ACL) reconstructions performed by the 4187 surgeons reporting surgeries in the ABOS Part 2 database between 2000 and 2021.

		n	%
Surgeon/Surgery Characteristics			
Surgeon specialty	Adult reconstruction	38	0.9
	Foot and ankle	27	0.6
	General orthopedics	2366	56.5
	Hand and upper extremity	10	0.2
	Pediatric orthopedics	253	6.0
	Shoulder	18	0.4
	Spine	4	0.1
	Sports medicine	1456	34.8
	Trauma	15	0.4
	Unspecified	1	0.0
Surgeon-specific fellowship training	Adult reconstruction	138	3.1
	Foot and ankle	69	1.6
	Hand and upper extremity	32	0.7
	Oncology	3	0.1
	Pediatric orthopedics	246	5.6
	Shoulder and elbow	65	1.5
	Spine	20	0.5
	Sports medicine	2574	58.4
	Trauma	61	1.4
	Unspecified	1	0.0
Surgeon fellowship classification	No fellowship training reported	1196	27.2
	Neither	1424	34.0
	Sports	2517	60.1
	Unspecified	1	0.0
Surgeon completed more than 5 surgeries	Pediatric orthopedics	189	4.5
	Both	57	1.4
	Yes	712	17.0
	Unspecified	1	0.0
Meniscectomy	Yes	363	3.0
	Unspecified	1	0.0
Meniscal repair	Yes	3642	30.0
	Unspecified	1	0.0
Geographic region	Midwest	2734	22.6
	Northeast	1859	15.3
	Northwest	786	6.5
	Other	130	1.1
	South	2662	22.0
	Southeast	1728	14.3
	Southwest	2225	18.4
	Unspecified	1	0.0
Patient characteristics			
Patient age mean (SD)		16.0 (1.7)	
Patient sex		Female	47.0

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), and Other (Hawaii and Alaska).

Characteristics of the contributing candidates and patients were first summarized as percentages for categorical variables and the aggregate data were reviewed for trends. The distribution of select complications was stratified by patient sex, geographic region of the surgery, surgeon fellowship training, and surgeon volume performed during the collection period, then statistically compared using chi-square tests and post-hoc analysis for categorical variables. Statistical significance was set at $P < 0.05$.

Results

A total of 12,124 pediatric ACLR were submitted to the ABOS Part II Oral Examination database from 4187 eligible surgeons. The median age of patients in this study was 16.0, ranging from 0 to 18 years, and 53.0%

Table 3.

Frequency of complications based on a sample of consecutive contributions from the ABOS Part II Oral Examination from 2000 to 2021.

Complication	n (%)
Any	1347 (11.1)
Medical	112 (0.9)
Surgical	1219 (10.1)
Anesthesia [†]	49 (0.4)
Anesthetic*	18 (0.3)
Block anesthesia*	23 (0.4)
General anesthesia*	8 (0.2)
Reoperation*	96 (1.8)
Readmission*	51 (1.0)
Selected complications	
<i>Medical</i>	
Medical unspecified	59 (0.5)
Dermatologic complaint*	19 (0.4)
Deep vein thrombosis*	11 (0.2)
<i>Surgical</i>	
Infection	186 (1.5)
Stiffness*	190 (3.6)
Implant failure/fracture	108 (0.9)
Wound healing issue	113 (0.9)
Graft-related problem*	90 (1.7)
Nerve palsy	84 (0.7)
Hemarthrosis*	54 (1.0)
Skin ulcer	47 (0.4)
Bone fracture	47 (0.4)
Fall*	31 (0.6)
Pain*	19 (0.4)
Failure of repair*	13 (0.2)
Hematoma*	8 (0.2)

* Data was only available for 6564 cases based on updates to the reporting platform in 2013.

[†] Before 2013, anesthesia complications were classified generally as “Anesthetic.” After 2013, surgeons were able to select either “Block” or “General” anesthesia complications.

Table 4.

Distribution of complications by patient sex.

Complication	Female n (%)	Male n (%)	P-value
Total population size	5701	6423	
Any complication	678 (11.9)	669 (10.4)	0.010
Anesthesia[†]	23 (0.4)	23 (0.4)	0.991
Anesthetic*	9 (0.3)	9 (0.2)	0.596
Block*	12 (0.4)	11 (0.4)	0.926
General*	2 (0.1)	6 (0.2)	0.138
Medical	49 (0.9)	63 (1.0)	0.486
Surgical	612 (10.7)	607 (9.5)	0.019
Infection	74 (1.3)	112 (1.8)	0.047
Stiffness*	134 (5.0)	56 (2.2)	<0.001
Implant failure/fracture	48 (0.8)	60 (0.9)	0.590
Wound healing issue	47 (0.8)	66 (1.0)	0.245
Graft-related problem*	48 (1.8)	42 (1.6)	0.677
Reoperation and readmission	2698	2571	
Reoperation*	56 (2.1)	40 (1.6)	0.158
Readmission*	26 (1.0)	25 (1.0)	0.974

* Data was only available for 5269 cases based on updates to the reporting platform in 2013.

[†] Before 2013, anesthesia complications were classified generally as “Anesthetic.” After 2013, surgeons were able to select either “Block” or “General” anesthesia complications.

were female. Patient follow-up duration ranged from 0 to 57 weeks post-operatively. A total of 1347 (11.1%) complications were reported, including 1219 (10.1%) surgical complications, 112 (0.9%) medical complications, and 18 (0.3%) anesthetic complications (Tables 2 and 3). The majority of surgeon contributors trained in a sports medicine

fellowship (60.1%); however, a majority declared a general orthopaedic specialty (56.5%). 17.0% performed more than 5 pediatric ACLR in a 6-month period and 30% reported performing a concomitant meniscus repair (Table 2).

Of the 5269 cases available for the analysis of reoperation and readmission, 96 (1.8%) reported reoperation and 51 (1.0%) reported readmission (Table 3). Medical Unspecified was the most commonly reported medical complication with 59 (0.5%) reported cases, compared to 19 (0.4%) reported dermatologic complaints and 11 (0.2%) reported cases of deep vein thrombosis. The most common surgical complications included stiffness (n = 190, 3.6%), infection (n = 186, 1.5%), implant failure/fracture (n = 108, 0.89%), wound healing issue (n = 113, 0.93%), graft-related problem (n = 90, 0.74%), and nerve palsy (n = 84, 0.69%).

Complications and sex

Females reported significantly more complications than males, with 678 (11.9%) female patients reporting a complication compared to 669 (10.7%) male patients ($P = 0.010$) (Table 4). Males demonstrated lower rates of surgical complications, specifically, with 607 (9.5%) male patients reporting a surgical complication compared to 612 (10.7%) female patients reporting a surgical complication ($P = 0.019$). Notably, arthrofibrosis/stiffness was more than twice as common in females than in males (5.0% vs. 2.2%, $P < 0.001$). Infection was higher in males (1.8% vs 1.3%, $P = 0.047$), while implant failure and graft-related problems were not different based on sex.

Complications and geographic region

Notably, the prevalence of complications varied significantly by geographic region ($P = 0.005$) (Table 5a). However, after post-hoc analysis, a specific region was not able to be identified as significant. The same applies to Anesthesia complications ($P = 0.043$), where a statistically significant relationship was detected but a specific region was not

Table 5a.

Distribution of complications by region.

Complication	Midwest n (%)	Northeast n (%)	Northwest n (%)	Other** n (%)	South n (%)	Southeast n (%)	Southwest n (%)	P-value
Total number of cases	2734	1859	786	130	2662	1718	258	
Any complication	311 (11.4)	203 (10.9)	67 (8.5)	24 (18.5)	314 (11.8)	167 (9.7)	261 (11.7)	0.005
Anesthesia[†]	17 (0.6)	7 (0.4)	2 (0.3)	1 (0.8)	4 (0.2)	12 (0.7)	6 (0.3)	0.043
Anesthetic	7 (0.4)	2 (0.2)	0 (0.0)	0 (0.0)	1 (0.1)	6 (0.6)	2 (0.2)	0.076
Block anesthesia*	10 (0.9)	3 (0.4)	2 (0.6)	1 (1.9)	2 (0.2)	4 (0.5)	1 (0.1)	0.059
General anesthesia*	0 (0.0)	2 (0.3)	0 (0.0)	0 (0.0)	1 (0.1)	2 (0.3)	3 (0.3)	0.481
Medical	29 (1.1)	15 (0.8)	10 (1.3)	0 (0.0)	25 (0.9)	11 (0.6)	22 (1.0)	0.575
Surgical	277 (10.1)	183 (9.8)	54 (6.9)	23 (17.7)	291 (10.9)	151 (8.7)	240 (10.8)	<0.001
Infection	44 (1.6)	27 (1.5)	4 (0.5)	8 (6.2)	55 (2.1)	15 (0.9)	33 (1.5)	<0.001
Stiffness*	49 (4.3)	20 (2.8)	7 (2.0)	2 (3.7)	47 (3.9)	28 (3.4)	38 (3.8)	0.438
Implant failure/fracture	30 (1.1)	16 (0.9)	9 (1.2)	2 (1.5)	24 (0.9)	15 (0.9)	12 (0.5)	0.462
Wound healing issue	36 (1.3)	14 (0.8)	9 (1.2)	0 (0.0)	25 (0.9)	11 (0.6)	18 (0.8)	0.195
Graft-related pproblem*	14 (1.2)	11 (1.5)	5 (1.4)	3 (5.6)	30 (2.5)	13 (1.6)	14 (1.4)	0.068
Reoperation and readmission	1160	717	350	54	1196	796	994	
Reoperation*	17 (1.5)	15 (2.1)	5 (1.4)	1 (1.9)	27 (2.3)	11 (1.4)	20 (2.0)	0.713
Readmission*	14 (1.2)	3 (0.4)	3 (0.9)	1 (1.9)	15 (1.3)	4 (0.5)	11 (1.1)	0.376

**“Other” Region = Hawaii and Alaska.

* Data was only available for 5269 cases based on updates to the reporting platform in 2013.

[†] Before 2013, anesthesia complications were classified generally as “Anesthetic.” After 2013, surgeons were able to select either “Block” or “General” anesthesia complications.

Table 5b.

Post-Hoc analysis of complications by region.

Complication	Post-Hoc Adjusted P-value	Midwest Post-Hoc P-value	Northeast Post-Hoc P-value	Northwest Post-Hoc P-value	Other Post-Hoc P-value	South Post-Hoc P-value	Southeast Post-Hoc P-value	Southwest Post-Hoc P-value
Any complication	0.004	0.617	0.764	0.016	0.007	0.194	0.036	0.312
Anesthesia complication	0.004	0.046	0.842	0.494	0.484	0.021	0.036	0.271
Surgical complication	0.004	0.842	0.764	0.002	0.004	0.089	0.046	0.194
Infection	0.004	0.689	0.764	0.016	<0.001	0.012	0.016	0.842

Table 6a.

Distribution of complications by fellowship training.

Complication	Other [†] n (%)	Sports Medicine n (%)	Pediatric Orthopaedics n (%)	Dual [†] n (%)	P-value
Total number of surgeons	1424	2517	189	57	
Total number of cases	2903	7800	846	575	
Any complication	259 (8.9)	898 (11.5)	108 (12.8)	82 (14.3)	<0.001
Medical	20 (0.7)	81 (1.0)	4 (0.5)	7 (1.2)	0.152
Surgical	241 (8.3)	808 (10.4)	100 (11.8)	70 (12.2)	0.001
Infection	56 (1.9)	109 (1.4)	14 (1.7)	7 (1.2)	0.218
Stiffness*	15 (3.7)	142 (3.7)	15 (3.1)	18 (3.6)	0.915
Implant failure/fracture	32 (1.1)	63 (0.8)	8 (0.9)	5 (0.9)	0.549
Wound healing issue	24 (0.8)	78 (1.0)	9 (1.1)	2 (0.4)	0.388
Graft-related problem*	11 (2.7)	61 (1.6)	13 (2.6)	5 (1.0)	0.078
Reoperation and readmission	406	3863	499	501	
Reoperation*	12 (3.0)	68 (1.8)	8 (1.6)	8 (1.6)	0.351
Readmission*	5 (1.2)	38 (1.0)	3 (0.6)	5 (1.0)	0.799

* Data was only available for 5269 cases based on updates to the reporting platform in 2013.

[†] “Other” = Any fellowship or combination of fellowships that does not include Sports Medicine, Pediatric Orthopaedics, or both. “Dual” = Dual Sports Medicine and Pediatric Orthopaedics fellowship training.

able to be identified. Contrarily, the Northwest region had the lowest rate of surgical complications (6.9%, $P = 0.002$) after post-hoc analysis, while the Other (Hawaii and Alaska) region had significantly higher rates of

infection (6.2%; $P < 0.001$) (Table 5b). Hawaii and Alaska had nearly 3 times the rate of infection compared to the South, the next highest region (6.2% vs. 2.1%) (Table 5a). Reoperation and readmission were not different between regions.

Complications and fellowship training

Of the 4187 total surgeons, 2517 (60.1%) completed a Sports Medicine fellowship, 189 (4.51%) completed a Pediatric Orthopaedics fellowship, 57 (1.36%) completed “Dual” fellowship training in both Sports Medicine and Pediatric Orthopaedics, and 1424 (34.0%) completed any other fellowship that does not include Sports Medicine, Pediatric Orthopaedics, or training in both (Table 6a). After completing post-hoc analysis, surgeons who completed a fellowship other than Sports Medicine or Pediatric Orthopaedics had lower rates of overall complications (8.9%; $P < 0.001$) and – more specifically – surgical complications (8.3%; $P < 0.001$) (Table 6b).

Discussion

This study evaluated 12,124 pediatric and adolescent ACL reconstructions (ACLR) performed by 4187 surgeons as submitted to the ABOS Part II Oral Examination Case List database between 2000 and 2021. There were 1349 total complications reported, with surgical complications as the most common complication type (10.1%). The most common surgical complications were stiffness (3.6%), graft-related problems (1.7%), and infection (1.5%). Factors associated with higher complication rates include female sex, surgery performed outside of the continental US (Hawaii and Alaska), and fellowship training.

Sex and stiffness

The current study uniquely reports a large cohort of surgeon-reported complications, typically early in their career. Previous studies observing complications in pediatric ACLR have reported arthrofibrosis in 11.1% and 10.6% of female patients [14,16]. Although our study reports higher rates of stiffness in females, our reported rate of 5.0% is considerably lower than the previously mentioned rates. Previously reported results included complications data from ACLR at major tertiary care children's hospitals, whereas our dataset comes from ABOS Part II Oral Examination Case List submissions. However, in a 2019 study observing outcomes from ABOS Part II Oral Examination submissions, 1.1% of patients reported arthrofibrosis, which is lower than our reported 3.6% [11].

Table 6b.

Post-Hoc analysis of complications by fellowship training.

Complication	Post-Hoc Adjusted P-value	Other Post-Hoc P-value	Sports Medicine Post-Hoc P-value	Pediatric Orthopaedics Post-Hoc P-value	Dual Fellowship Post-Hoc P-value
Any complication	0.008	<0.001	0.057	0.110	0.012
Surgical complication	0.008	<0.001	0.134	0.072	0.089

With females shown to be 2 to 8 times more likely than males to suffer an ACL injury [17–19], complications following ACLR in females is an area of particular concern. The present study found that of the patients included in our analyses, females had a significantly higher rate of experiencing any complication (11.9% vs. 10.4%, $P = 0.010$). Specifically, females had higher rates of all surgical complications (10.6% vs. 9.5%, $P = 0.019$) and higher rates of stiffness than males (5.0% vs. 2.2%, $P < 0.001$). Other studies have reported similar trends regarding stiffness in females undergoing ACLR [20]. A 2023 systematic review found that the female sex was a risk factor for the treatment of arthrofibrosis requiring manipulation under anesthesia and lysis of adhesions following ACLR [21]. Our findings support previously reported conclusions that female sex is a risk factor for stiffness.

Sex and infection

A study observing infection rates in nearly 45,000 pediatric/adolescent ACLR had an overall infection rate of 0.52%, 0.58% in males, and 0.47% in females [12]. The present study noted similar trends, but found higher infection rates in all patients, with an overall infection rate of 1.53%, 1.8% in males, and 1.3% in females. Lower operation volume and longer duration of surgery are known risk factors for infection [22–24]. Surgeons submitting to the ABOS Part II Oral Examination are relatively early in their career and likely have lower operation volume and longer duration of surgery, which could explain the high infection rates reported in this study.

While Anis et al. (2020) found that infection rates following primary total knee arthroplasties (TKA) were similar at high, medium, and low-volume hospitals, Brodeur et al. (2022) reported that low-volume facilities and low-volume surgeons had higher 1, 3, and 12-month rates of surgical site infection following TKA [25,26]. A retrospective study analyzing outcomes following open reduction and internal fixation (ORIF) of ankle fractures found that surgeons who completed fewer than 7 ORIF procedures per year had an increased risk of deep surgical site infection [27]. Given that the surgeons in this study are earlier in their careers, our reported infection rates may be influenced by their surgical volume.

Despite significantly lower rates of any complication occurring, we found a higher infection rate than previously noted in the literature [7]. Male patients, in particular, had higher rates of infection than female patients. Previous studies have also found an increased risk of infection in young male adults undergoing ACLR [12] and older adults undergoing any surgical procedure [28]. Male sex may also be a risk factor for colonization of *Staphylococcus aureus*, which could explain this finding [29–31]. Beyond sex, regional analyses indicated that the “Other” region (Hawaii and Alaska) had higher rates of infection, with 6.2% of cases reporting infection in this region compared to just 2.1% in the next highest region, the South. This area of interest requires further investigation into whether male patients should undergo different pre-operative cleansing; the relationship between ACLR post-operative infection, surgeon experience, and case volume; and the contributing factors to increased infection rates in Hawaii and Alaska.

Fellowship training

Our study found that surgeon fellowship training was related to an increase in various post-operative complications, a finding that is consistent with previous reports [11]. A 2013 study reported that of 1519 included meniscus repairs, 62.5% were performed by fellowship-trained surgeons or surgeons currently undergoing fellowship training. When adjusting for a variety of other factors, Sports Medicine fellowship-trained surgeons were 1.46 times more likely to repair meniscus injuries during ACLR than non-fellowship trained surgeons [32]. These findings support the tendency for surgeons with more training to take on more difficult, complex surgical procedures. Thus, our findings that fellowship training was associated with complication rates may be

explained by the complexity of procedures undertaken by surgeons with more fellowship training. Additionally, fellowship-trained surgeons may be more likely to report borderline stiffness as a complication compared to non-fellowship-trained surgeons. These procedures are often more involved than standard ACLR, and thereby may be associated with more frequent complications. Additional, more specific data on the type of procedures completed by these surgeons is necessary to elucidate the relationship between surgery complexity and complication rates, which may help contextualize complication rates in fellowship trained surgeons.

This study is not without limitations. First, the data used were collected from the ABOS Part II Oral Examination Case List submissions database, which is not comprehensive. Therefore, important aspects of patient care including operative notes, clinical observations, and patient reported outcomes were not available for analysis. This information, along with severity of injury and complexity of procedure, may have provided a more comprehensive understanding as to how surgeon and patient demographics relate to complications following ACLR. Complications from this database were also self-reported, which may introduce bias. Furthermore, the data is based on cases submitted to the ABOS Part II Oral Examination, which were performed by candidates during a 6-month board collection period, preventing the collection of medium-to long-term complications. Thus, there may be an underreporting of long-term complications like reoperation and readmission in this study. Finally, the nature of the present study and the limitations of the data set prevent the data from being broadly generalizable.

Conclusion

The present study established that female pediatric and adolescent patients had a higher rate of complications than male patients following ACLR. Females were more than twice as likely to develop arthrofibrosis than males. Males, however, are at an increased risk for post-operative infection. Geographic region and fellowship training may be associated with complication rates in this population. These findings provide insight into common complications which surgeons performing ACLR experience early in their career. Future studies could utilize data that contextualizes complication rates by the type and complexity of the procedure performed.

Consent for publication

The author(s) declare that no patient consent was necessary as no images or identifying information are included in the article.

Author Contributions

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Kevin G. Shea: Writing – review & editing, Writing – original draft, Methodology, Investigation, Data curation, Conceptualization. **Philip L. Wilson:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization. **Henry B. Ellis:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization.

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Declaration of competing interests

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