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The impact of prior upper-extremity surgery on orthopedic injury and surgery in collegiate athletes

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Background: The influence of prior upper-extremity (UE) surgery on a collegiate athletic career is poorly understood. This study aimed to investigate the impact of prior UE surgery on participation, injury, and surgery rates in collegiate athletes.

Methods: Division I athletes who commenced collegiate athletics from 2003-2009 were retrospectively identified. Pre-participation evaluation forms were queried for the history of pre-collegiate UE surgery. Data on sport played, seasons played, injuries, days missed, and orthopedic imaging and surgical procedures were collected through athletic and medical records and compared with those of athletes without prior UE surgery. Subgroup analysis was performed for shoulder surgery, elbow surgery, and wrist and/or hand surgery.

Results: Between 2003 and 2009, 1145 athletes completed pre-participation evaluations. Of these athletes, 77 (6.7%) underwent at least 1 pre-collegiate UE surgical procedure. Prior UE surgery was most common in men's water polo (15.0%), baseball (14.9%), and football (12.6%). The UE surgery group had a higher rate of collegiate UE injury (hazard ratio, 4.127; $P < .01$) and missed more days per season because of UE injury (16.5 days vs. 6.7 days, $P = .03$) than controls. Athletes with prior shoulder surgery ($n = 20$) also experienced more UE injuries compared with controls (hazard ratio, 15,083; $P = .02$). They missed more days per season (77.5 days vs. 29.8 days, $P < .01$), underwent more magnetic resonance imaging scans (0.96 vs. 0.40, $P < .01$), and underwent more orthopedic surgical procedures per season (0.23 vs. 0.08, $P < .01$). The elbow subgroup and wrist and/or hand subgroup were comparable with controls on all measures.

Conclusions: Collegiate athletes with prior shoulder surgery missed more days and underwent more magnetic resonance imaging scans and surgical procedures in college, whereas those with prior

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elbow surgical procedures and wrist and/or hand surgical procedures were comparable with controls.
Level of evidence: Level II; Retrospective Design; Prognosis Study

Keywords: Upper extremity; shoulder; elbow; injury; collegiate; athlete; imaging; prevention

As youth athletic participation has increased over the past 3 decades so have the rates of adolescent sports-related injury. In 2002, it was estimated that over 30 million children and adolescents participated in organized sports, resulting in approximately 4.3 million trips to the emergency department for injuries related to sports and recreation.[4] In addition, early specialization and participation in year-round sports may predispose athletes to overuse injuries.[7]

Injuries to the upper extremity (UE) are common in youth, collegiate, and professional athletes, and these injuries may result in significant time loss and disability.[3,12,14] Mechanisms of injury depend on the sport played, with overuse injuries commonly affecting throwing sport athletes and fractures and dislocations affecting athletes in contact sports. The high school sports with the highest rates of UE injury include baseball, softball, wrestling, and football.[19] In a study of shoulder injuries in high school athletes, 7.9% of injuries required surgery.[24] At the collegiate level, UE injuries are also common, representing about 20% of all injuries in National Collegiate Athletic Association (NCAA) athletes.[12]

A significant proportion of the literature regarding athletic injuries has focused on lower-extremity injuries and surgical procedures in athletes, as these injuries represent a substantial contributor to athlete morbidity and days lost.[6,20,21,25] The impact of prior UE surgery on athletic performance and durability has been studied sparingly at the collegiate level. However, available literature from professional athletics has demonstrated a high rate of return to play after UE surgery and variable effects on career longevity and performance.[2,11,13,18,26] In 1 prospective study of professional baseball players who underwent surgery for elbow and shoulder injuries during their professional careers, athletes who underwent surgery were nearly 5 times more likely to experience a later injury or surgery than those who did not undergo surgery.[11] A study of 36 National Football League athletes who underwent open reduction–internal fixation of forearm fractures determined that there was a high rate of return to sport but that the career length was 1 season fewer and players played in 2 fewer games per season than matched controls.[26]

Despite the frequency of UE injuries and surgical procedures among youth athletes, the effect of a prior UE surgical procedure on injury, surgery, and longevity in a collegiate athlete's career is unknown. Identifying athletes with a risk of recurrent UE injury is an attractive target for coaches, athletic trainers, and recruiters. The goal of this study was to compare participation, injury, diagnostic imaging, and surgery rates in Division I college athletes at a single institution with and without a history of UE surgery. We hypothesized that athletes with a history of UE surgery would have more injuries and undergo more surgical procedures in college and would have shorter careers than athletes without prior UE surgery.

Methods

Patient selection

Athletes who began NCAA Division I athletic participation from 2003-2009 at a single institution were eligible for the study. Sports archives and athletic training room records were used to identify athletes who participated in each of the 22 sports included in the study (12 women's and 10 men's sports). Before participating in collegiate athletics, all athletes underwent a pre-participation evaluation (PPE) by a licensed physician, at which time the history of surgical procedures, including orthopedic surgical procedures, was recorded. Athletes who began participation prior to the 2003 season were not included.

Data collection

Data on sport, seasons, and games played were obtained from the institution's sports archives for each athlete. Injury descriptions and days missed because of injury were obtained from the Sports Injury Monitoring System (SIMS; FlanTech, Iowa City, IA, USA). This system allows athletic trainers to record any sports injury if it results in restriction from participation or necessitates clinical management for more than 10 days. Days missed because of illness or other non-injury causes were excluded. Medical records and the Sports Injury Monitoring System were cross-referenced for diagnostic imaging and orthopedic surgical procedures performed during college. Redshirt athletes were included in the analysis for complete exposure. Redshirting is defined as participating in a college sport in up to 30% of competitions, with full practice capabilities. This practice allows an athlete to retain a year of eligibility in the NCAA.

PPE forms for entering athletes were queried to determine the history of orthopedic surgery and UE surgery prior to beginning participation in Division I athletics. Athletes with a history of shoulder surgery, elbow surgery, and wrist and/or hand surgery were identified for further subgroup analysis. The remaining athletes served as controls.

Table I Entering athletes from 2003 to 2009 from 22 sports at single institution

	No. of eligible athletes	Athletes with prior orthopedic surgery, %	Prior surgery type, %				College injury, %			
			Upper extremity	Shoulder	Elbow	Wrist and hand	Upper extremity	Shoulder	Elbow	Wrist and hand
Men's sports										
Baseball	67	20.9	14.9	4.5	9.0	1.5	28.4	7.5	9.0	10.4
Basketball	33	18.2	3.0	0.0	0.0	3.0	27.3	9.1	0.0	18.2
Cross-country	21	9.5	0.0	0.0	0.0	0.0	4.8	4.8	0.0	0.0
Football	174	21.3	12.6	4.6	2.3	5.7	24.1	12.1	2.3	9.8
Golf	21	9.5	4.8	0.0	0.0	4.8	14.3	0.0	0.0	14.3
Soccer	54	24.1	7.4	0.0	1.9	5.6	7.4	3.7	0.0	3.7
Tennis	35	17.1	11.4	5.7	2.9	0.0	42.9	5.7	2.9	34.3
Track and field	99	13.1	7.1	1.0	2.0	4.0	13.1	5.1	2.0	6.1
Volleyball	42	21.4	9.5	0.0	0.0	9.5	28.6	9.5	2.4	16.7
Water polo	40	17.5	15.0	2.5	5.0	7.5	35.0	22.5	2.5	10.0
Women's sports										
Basketball	23	8.7	4.3	0.0	4.3	0.0	26.1	8.7	0.0	17.4
Cross-country	29	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Golf	14	7.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gymnastics	35	54.3	11.4	5.7	5.7	0.0	31.4	14.3	11.4	5.7
Rowing	126	8.7	2.4	0.0	0.0	1.6	10.3	2.4	4.0	4.0
Soccer	60	30.0	5.0	0.0	0.0	3.3	8.3	3.3	0.0	5.0
Softball	32	9.4	3.1	0.0	0.0	0.0	37.5	18.8	18.8	0.0
Swimming and diving	56	10.7	7.1	1.8	3.6	1.8	35.7	17.9	10.7	7.1
Tennis	17	5.9	0.0	0.0	0.0	0.0	64.7	41.2	5.9	17.6
Track and field	91	11.0	0.0	0.0	0.0	0.0	4.4	2.2	1.1	1.1
Volleyball	35	22.9	5.7	5.7	0.0	0.0	51.4	25.7	2.9	22.9
Water polo	41	0.0	0.0	0.0	0.0	0.0	39.0	19.4	9.8	9.8
Total	1145	16.5	6.7	1.7	2.0	2.8	21.6	9.3	3.4	8.6

The columns represent percentages of athletes with prior orthopedic surgical procedures and collegiate upper-extremity injuries overall and by the affected joint.

Statistics

Statistical analyses were performed with GraphPad Prism 5 software (GraphPad Software, La Jolla, CA, USA). Two-tailed t tests and Mann-Whitney U tests were used to compare the surgery groups with controls for parametric and nonparametric distributions, respectively. Time-dependent analyses were completed using the Kaplan-Meier method, and curves were compared using the log-rank test. Dates of the entering PPE were used as the starting dates, and the last days of collegiate careers were censored if an athlete did not sustain a UE injury or undergo orthopedic surgery in college. Hazard ratios (HRs) were calculated when appropriate. Significance was predefined at $P < .05$.

Results

Demographic data

From 2003 to 2009, 1145 athletes at a single institution were identified and included in the study. There were 586 men and 559 women across 22 sports. Of the entering athletes, 16.4% had a history of any orthopedic surgery prior to NCAA participation (Table I). A history of UE surgery was noted in 77 athletes (6.7%), including 20 shoulder operations, 2 upper-arm operations, 23 elbow operations, 2 forearm operations, and 32 wrist and/or hand operations. Three subgroups were analyzed in addition to the UE group: shoulder (n = 20), elbow (n = 23), and wrist and/or hand (n = 32). Two athletes underwent more than 1 UE surgical procedure (shoulder and hand operations and elbow and hand operations) and were analyzed in both relevant groups. Sports with the highest proportion of athletes entering with prior UE surgery were men's water polo (15.0%), baseball (14.9%), football (12.6%), and tennis (11.4%) and women's gymnastics (11.4%). Prior UE surgery affected 18 female athletes (3.2%) and 59 male athletes (10.1%).

Participation, days missed because of injury, and career length

Athletes with a history of UE surgery missed an average of 16.5 days per season because of UE injury compared with 6.7 days for control athletes ($P = .031$) (Fig. 1). However, we found no significant difference in total days missed because of any injury between the 2 groups. Athletes with

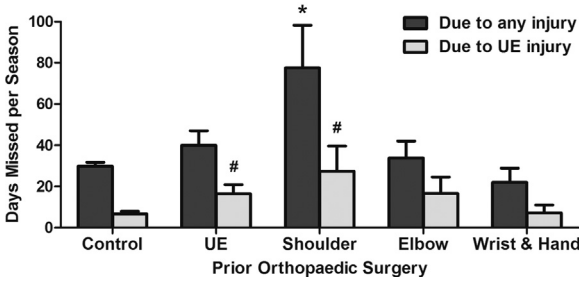

Figure 1 Days missed per season because of any injury (*black*) or upper-extremity (*UE*) injury (*gray*). *Error bars* represent standard deviations. *$P < .01$ vs. respective controls. #$P < .05$ vs. respective controls.

prior shoulder surgery missed more total days per season (77.5 days vs. 29.8 days, $P = .001$) and missed more days per season because of UE injury (27.4 days vs. 6.7 days, $P = .017$) than controls (Fig. 1). No differences in days missed were found between controls and athletes with a history of elbow surgery or wrist and/or hand surgery. Career length was not significantly affected by undergoing prior UE surgery.

Injury rate during college

Athletes with a history of UE surgery had increased rates of UE injury in college (HR, 4.127; $P < .001$) (Fig. 2, *A*). Furthermore, athletes with a history of shoulder surgery had a more prominent increase in the rate of UE injury compared with controls (HR, 15,083; $P = .019$) (Fig. 2, *A*).

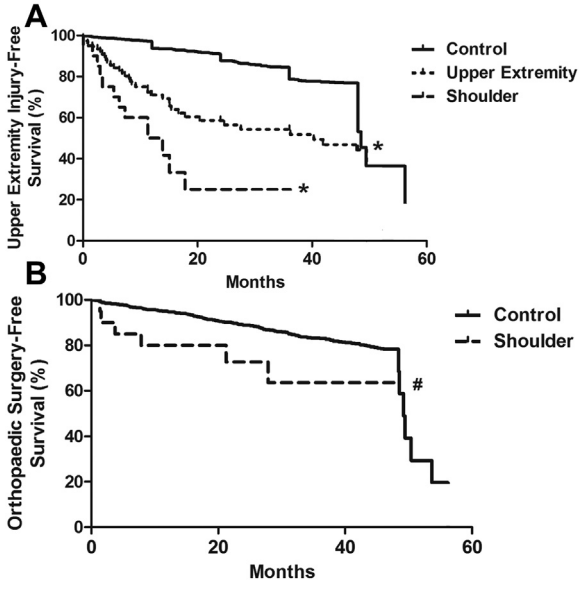

Figure 2 Kaplan-Meier survival analysis of athletes who sustained an upper-extremity injury (**A**) or underwent orthopedic surgery (**B**) during their collegiate careers. *$P < .001$ vs. respective controls. #$P < .05$ vs. respective controls.

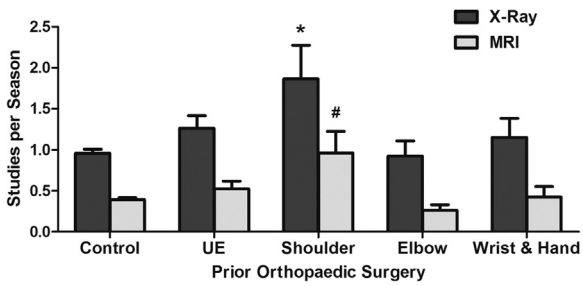

Figure 3 Imaging studies per season: radiographs (*black*) and magnetic resonance imaging (MRI) (*gray*). *Error bars* represent standard deviations. *$P < .05$ vs. respective controls. #$P < .01$ vs. respective controls. *UE*, upper extremity.

No increase in the injury rate occurred for athletes with a history of elbow surgery or wrist and/or hand surgery.

Imaging in college

Athletes with a history of shoulder surgery received more magnetic resonance imaging (MRI) scans per season (0.96 vs. 0.40, $P = .001$) and more radiographs per season (1.86 vs. 0.98, $P = .013$) than controls. The numbers of diagnostic imaging studies per season in athletes with prior UE surgery, elbow surgery, and wrist and/or hand surgery were not significantly different from controls (Fig. 3).

Surgery rate during college

Athletes with a history of shoulder surgery had an increased rate of orthopedic surgery in college (HR, 4.596; $P = .019$; Fig. 2, *B*) and underwent more orthopedic surgical procedures per season than controls (0.23 vs. 0.08, $P = .006$, Fig. 4). The rate of orthopedic surgical procedures per season for athletes with a history of UE surgery, elbow surgery, or wrist and/or hand surgery was not significantly different compared with the control group.

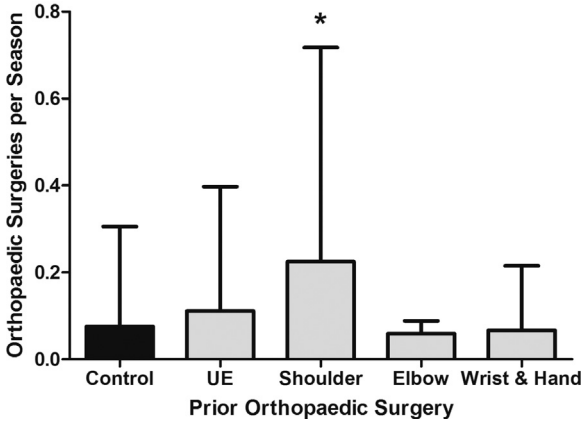

Figure 4 Orthopedic surgical procedures per season. *Error bars* represent standard deviations. *$P < .01$ vs. control. *UE*, upper extremity.

Discussion

Given the frequency of UE injury and surgery in adolescent athletes, the goal of this study was to observe the effect of prior UE surgery on collegiate athletes' durability and subsequent injury and surgery in college. We found that those who underwent prior UE surgery had higher rates of collegiate UE injury and missed more days because of UE injury. This trend appeared to be driven by the subgroup of athletes with a history of shoulder surgery who, in addition to having more UE injuries, underwent more imaging studies and orthopedic surgical procedures than athletes without a history of UE surgery. Prior UE injury had no impact on career length.

At our institution, a history of UE surgery was present in 6.7% of all athletes and was most common in men's water polo, baseball, and football. In their study of high school sports, Rechel et al[21] reported that the highest rates of UE surgery were in wrestling, football, and baseball athletes. In our study, 15% of entering men's water polo players had a history of UE surgery. Although it is known that UE injuries are common in water polo,[5] orthopedic surgery rates in this group have not been well described. In addition, athletes participating at the highest levels of high school and club water polo prior to college may have increased rates of surgery compared with their recreational counterparts, and these athletes may be more heavily recruited to play at the collegiate level. Water polo athletes have largely been excluded from injury research, and given the growing popularity of the sport, this is an area for future study.

Injury to or surgery on a joint has been shown to increase the risk of reinjury to that joint. For example, in studies using PPEs to gather data on injury and surgery history, DuRant et al[9] and Rugg et al[25] have found that prior knee surgery was associated with subsequent knee injury. In a 2-institution study of collegiate football, athletes who were injured at least once were more likely to experience another injury in college than athletes without a history of injury, although the trend was not statistically significant in UE injuries.[29] In our study, athletes with a history of UE surgery missed more days because of UE injury in college. This trend was observed specifically in the subgroup of athletes with a history of shoulder surgery and was not evident in athletes with elbow surgery or wrist and/or hand surgery.

The shoulder is of particular interest when evaluating injury rates in athletes with a history of surgery, as prior studies have demonstrated significant injury recurrence following surgery.[10] In the RIO High School Injury Database, shoulder injuries made up 12% of recurrent injuries in high school athletes[27] and shoulder injuries represented 8.3% of all high school sports injuries that required surgery.[21] Wrestling, football, and baseball athletes had the highest rates of shoulder and hand surgical procedures. Authors using the same database demonstrated that dislocation or separation of the shoulder accounted for 53.4% of shoulder injuries requiring surgery.[1] The rate of return to sport is high after operative shoulder stabilization[17]; however, the rate of recurrent instability, defined as physician-documented reporting of a dislocation or subluxation event or a positive apprehension test, has been reported at 3% to 22%.[10,28] Risk factors for recurrent instability include young age, bony lesions, history of instability, use of fewer labral anchors, and ligamentous laxity.[8,10,28]

Athletes with a history of shoulder surgery in our study had increased rates of injury and surgery in college and, more specifically, had an increased rate of UE injury. The reasons for the increased rate of UE injury in this cohort is likely multifactorial. Although specific surgery type was not recorded, it is statistically likely that a significant portion of the athletes who underwent shoulder surgery prior to college received a shoulder stabilization procedure, given that dislocation or separation of the shoulder accounted for 53.4% of shoulder injuries requiring surgery in high school athletes.[1] The study population was young and active, which have been demonstrated as risk factors for recurrent instability after both nonoperatively and operatively treated shoulder instability.[8,10,23,28] Athletes with prior shoulder surgery may also have residual biomechanical deficits or decreased range of motion, which predispose to injury, or may have underlying anatomic variation contributing to their risk of injury; this has not been well studied. Nonmodifiable risk factors such as sport, sex, and position may also contribute to the increased days missed for these athletes. Finally, biomechanical deficits in athletes with recurrent instability likely played a role in increased injury rates in this cohort. Although there are numerous functional movement scoring systems for lower-extremity imbalance, scoring systems used to determine residual functional deficits in the UE are not in widespread use. During the PPE, basic physical examination maneuvers may be insufficient to evaluate subtle biomechanical deficits that place athletes at risk of injury recurrence.

In studies of professional sports, career longevity in athletes with a history of surgery has been shown to depend on the surgical procedure performed, sport, and position. Brophy et al[2] demonstrated that National Football League defensive linemen and receivers with a history of shoulder stabilization were less likely to play in the league and that offensive linemen were less likely to play in the league if they had previously undergone rotator cuff repair.[19] In contrast, in a case-control study of rotator cuff repair in Major League Baseball pitchers, career length was not significantly different for those who underwent operative treatment compared with controls.[16] The study populations for each study were different and account for the discrepancies in effect on career length seen between sport and position. In a study of professional athletes in 14 different sports who underwent a Bankart procedure for anterior shoulder instability, 66% of athletes were able to return to sport at the same level, 22% were able to return but at a lower level, and 12% were unable to return.[18] In our study,

career length in Division I athletics was not significantly affected by having a history of either UE surgery or shoulder surgery. Although our study did not include surgical procedure or position played as part of the analysis, given the findings in studies of professional football athletes, consideration of surgery type and player position may be valuable.

A previous study of athletes with a history of orthopedic surgery and, specifically, knee surgery demonstrated that these cohorts required more imaging studies during their college careers than control athletes with no surgery history.[25] Similarly, in our study, athletes with a history of shoulder surgery underwent more plain films and MRI scans during their college careers. Screening plain films are often included in the workup of shoulder pain in the athlete, as recommended by the American College of Radiology.[15] In this study, the increased rates of radiography and magnetic resonance imaging correlated with the elevated UE injury rates observed in athletes with a history of shoulder surgery. Because MRI scans have a substantial associated cost, the number of imaging studies required by athletes with a history of shoulder surgery may be a consideration for university programs considering recruitment and rehabilitation of these athletes.

Although this study is the first of its kind for UE injuries and surgery, it does have several limitations. PPE forms were used to identify athlete cohorts, and the surgical histories were based on athlete recall at the time of the visit with the physician. Thus, exact procedure descriptions were not available. It is also possible that surgical histories were not accurately reported and that recall bias affected the analysis. Furthermore, the control group in this study included all athletes who had not undergone UE surgery and therefore included those who had a history of orthopedic surgery in other anatomic areas. It is logical that a control group of athletes with no prior surgery would have had even lower rates of injury and surgery in college, but the goal of this study was to compare UE surgery athletes with average collegiate athletes, which included those with a history of other surgical procedures. In addition, redshirt athletes were included in this study to have complete data on athletes exposed to practice and competition. However, redshirt athletes were only able to participate in up to 30% of competitions, per NCAA guidelines. As injury rates increase in competition,[12,22] the inclusion of these athletes may have reduced the number of injuries observed in the study population. Redshirting is more common in certain sports (football, men's volleyball), which may also have introduced differences between sex and sport. Finally, prior UE surgery was a relatively rare occurrence, affecting only 3.2% of female athletes and 10.1% of male athletes; therefore, the sample sizes were small. We used a statistical method designed to compare sample sizes of small groups and were able to identify statistically significant trends, but future studies with larger samples would be beneficial. Despite these limitations, this study offers a new perspective on injury and surgery rates in college athletes with a history of UE surgery and may provide insight to individuals involved in recruitment of and injury prevention in elite collegiate athletes.

Conclusion

This study demonstrates that athletes with a history of UE surgery prior to collegiate athletics experienced more UE injuries and missed more days because of UE injury in college. This effect was likely because of the subset of athletes with a history of shoulder surgery, who had more pronounced increases in the rate of injury, days missed, MRI scans and radiographs, and rate of orthopedic surgery compared with control athletes. Conversely, injury rates in athletes with a history of elbow and hand surgery were similar to the injury rate in control athletes. Attention to symptom recurrence and residual functional deficits may be valuable for risk stratification of athletes with a history of shoulder surgery.

Disclaimer

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