

High School Sport Specialization and Injury in Collegiate Club-Sport Athletes

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Context: Sport specialization during adolescence may affect future injury risk. This association has been demonstrated in some professional sport athletes.

Objective: To determine the association between adolescent sport specialization levels in high school and injuries sustained during collegiate club sports.

Design: Cross-sectional study.

Setting: Paper and online surveys.

Patients or Other Participants: Collegiate club-sport athletes.

Main Outcome Measures(s): An anonymous survey was administered from September 2019 to May 2020. The survey included sport specialization classification via a commonly used 3-point scale (*low, moderate, high*) for each high school year (9th–12th), high school sports participation, and collegiate club-sport injury history. The number of years (0–4) an individual was highly specialized in high school was calculated. Individuals who participated in the same sport in high school and college were compared with individuals who played a different sport in college than in high school. An injury related to sport club activities was classified as arising from a contact, noncontact, or overuse

mechanism required and the individual to seek medical treatment or diagnosis. Injuries were classified into overuse and acute mechanisms for the upper extremity, lower extremity (LE), and head/neck.

Results: Single-sport participation and the number of years highly specialized in high school sport were not associated with college club-sport injuries ($P > .1$). Individuals who played a different collegiate club sport than their high school sport were more likely to report an LE or head/neck acute injury compared with athletes who played the same collegiate and high school sport (LE = 20% versus 8%, $\chi^2 = 7.4$, $P = .006$; head/neck = 16% versus 3%, $\chi^2 = 19.4$, $P < .001$).

Conclusions: Adolescent sport specialization was not associated with reported injuries in collegiate club-sport athletes. Collegiate club-sport athletic trainers should be aware that incoming students exploring a new sport may be at risk for LE and head/neck acute injuries.

Key Words: injury risk, lower extremity injuries, upper extremity injuries

Key Points

- High school sport specialization was not significantly associated with injury risk in college-aged club athletes.
- Participating in a new club sport in college may increase the risk of acute lower extremity and head and neck injuries.

With the rise of the youth club-sport industry and the increased number of students participating in high school sports,^{1,2} healthy adolescent sport participation has been a growing area of research. Several authors^{2,3} have demonstrated that sport opportunities outside of interscholastic sports have been associated with sport specialization. *Sport specialization* is commonly defined as year-round sport participation to the exclusion of other sports⁴ and has been associated with an increased injury risk in adolescent athletes.⁵ Specifically, most researchers^{4–7} have demonstrated the association of sport specialization with overuse injuries, leading to the hypothesis that a high training volume with repetitive movements may be the mechanism for overuse injuries in specialized high school athletes. However, some investigators^{3,8,9} have found a link between sport specialization and acute injuries. Recently, authors^{10,11} have shown the association of sport specialization with movement patterns: specialized adolescent athletes had worse movement patterns than non-

specialized adolescent athletes. This finding was also observed in adults who participated in only 1 high school sport compared with adults who participated in ≥ 2 high school sports.¹² These results suggest an alternate or added hypothesis that sport specialization increases the injury risk because of its effects on movement quality. Both theories require serious consideration of the possibility that the effects of sport specialization during adolescence, and particularly high school sport specialization, may persist into young adulthood and beyond.

Two groups of investigators^{13,14} determined that professional athletes who were single-sport athletes in high school had an increase in major injuries during their professional careers as well as shorter professional sporting careers compared with professional athletes who were multisport athletes in high school. These findings may be explained by the previous hypothesis that sport specialization has a long-term effect on movement patterns that increase the risk of sport-related

injuries. An alternative explanation may be related to how prior injuries predispose an athlete to future injuries.¹⁵ Therefore, injuries sustained early in an athlete's sporting career because of sport specialization may have a compounding effect throughout his or her collegiate and professional careers. Even though previous authors^{16,17} noted that a proportion of collegiate athletes were highly specialized in high school, few have explored how sport specialization may affect the injury risk in collegiate athletes. Furthermore, even less is known about sport specialization and injuries in collegiate club-sport athletes.

In 2012, there were an estimated 2 million collegiate club-sport athletes in the United States.¹⁸ As collegiate club-sport popularity grows, so does awareness of the need for health care professionals to understand the injury risks and patterns associated with this population.^{19–21} In particular, many campus recreational organizations employ athletic trainers (ATCs) to oversee the health and well-being of club-sport athletes. With improved knowledge about club-sport injury risks, ATs can better serve this large population and advocate for the need for ATs in these settings. Therefore, our purpose was to determine the association between adolescent sport participation behaviors and injuries sustained during collegiate club sports. We hypothesized that collegiate club-sport athletes who were specialized in high school would report more collegiate sports injuries than collegiate club-sport athletes who were not specialized in high school. Additionally, we hypothesized that collegiate club-sport athletes who were continuing participation in 1 of their high school sports would be more likely to report an injury compared with collegiate club-sport athletes who were exploring a new sport in the collegiate club setting.

METHODS

This study was approved by the Institutional Review Board of the University of Wisconsin–Madison. We used a cross-sectional design with paper and online anonymous surveys. The surveys were administered from September 2019 to May 2020. In the fall of 2019, the primary investigator (K.M.B.) emailed club-sport presidents and organizers at the University of Wisconsin–Madison to ask permission to present the study to their respective sport club teams. All club sports at the University of Wisconsin–Madison were contacted except for e-sports, water ski and wakeboard, and fishing. The primary investigator was then invited to present the study and distribute the survey to sport club teams during practices or team meetings. The surveys were completed during this time and returned to the primary investigator. In the spring of 2020, because of COVID-19 restrictions, the survey was moved online using Qualtrics. The survey link was forwarded to the club-sport presidents and organizers, who then emailed it to their respective team participants. All participants were students at the same university. Of the sports clubs contacted, 31 of 48 (65%) were represented in our data set. Represented sports were aikijujitsu, archery, baseball, men's and women's basketball, boxing, cheer, dance elite, fencing, field hockey, figure skating, gymnastics, men's and women's ice hockey, Irish dancing, men's and women's lacrosse,

women's rugby, women's soccer, softball, swim/dive, tennis, track, men's and women's volleyball, wrestling, taekwondo, triathlon, water polo, and men's and women's ultimate Frisbee. Because the survey was anonymous, the athletes were not required to sign a consent form. They were provided a written description of the study, and completing the survey was deemed consent.

Survey

The survey addressed the sport specialization classification for each high school year (9th–12th),¹⁷ high school sport(s) participation, and injuries sustained during the collegiate club-sport career. The original 3-point scale proposed by Jayanthi et al⁴ was adjusted based on research in which authors²² identified misclassification by single-sport athletes and others¹⁷ who used the scale retrospectively to assess high school sport specialization in National Collegiate Athletic Association Division I collegiate athletes. For each grade, athletes were classified in the 3-point scale based on the answers to 3 questions: (1) "In high school, did you consider one of your sports more important than your other sports and if you only played one sport, select 'yes'?" (2) "In high school, did you train more than 8 months a year in one sport?" (3) "In high school, did you quit a sport to focus more on a single sport OR have you only played a single sport?" Participants selected either *yes* (1 point) or *no* (0 points) for each question. Scores for each question were summed to determine the specialization category as *low* (0–1), *moderate* (2), or *high* (3) for the 9th, 10th, 11th, and 12th grades. Once an athlete selected *yes* to question 3, that question was marked as *yes* for subsequent high school grades.¹⁷ The number of years an individual was classified as highly specialized (range = 0–4 years) in high school was then calculated.

Multisport or single-sport participation was determined according to the number of sports an athlete identified participating in during his or her high school career. Those who selected 2 or more sports for the question "What sports did you participate in high school?" were categorized as *multisport athletes*. Conversely, athletes who selected only 1 sport for this question were categorized as *single-sport athletes*. Individuals who participated in the same sport in high school and college were considered athletes who continued their high school sport into college.

Previous Injury

The Figure is an example of the survey format for collecting injury data. An *injury* must have been related to collegiate club-sport activities and could be classified as arising from a overuse, contact, or noncontact mechanism (Figure, column 4) that required the individual to seek treatment or diagnosis from an AT or physician (Figure, column 5). Injuries labeled as resulting from overuse were analyzed as *overuse injuries* and injuries that occurred from either contact or noncontact were designated *acute injuries*. Therefore, for analysis, injuries were classified into overuse or acute injuries to the upper extremity (UE), lower extremity (LE), or head/neck. The marked mechanism of injury was reviewed by 2 authors (K.M.B. and D.R.B.) who are ATs to verify that the mechanism of injury aligned with any further injury description given by the participant.

Have you ever injured <u>your</u> :	What was the injury?	What year/month did you sustain this injury?	How did the injury occur?	Did you have to see a doctor/athletic trainer as a result of your injury?	How many days of participation in your sport did you miss?
Head/Neck <input type="checkbox"/> YES <input type="checkbox"/> NO			<input type="checkbox"/> Overuse (result of repetitive practice or use) <input type="checkbox"/> Contact (direct blow from a teammate, opponent, or object) <input type="checkbox"/> Non-contact (injury not caused by contact with opponent or object) <input type="checkbox"/> Other (please describe): _____	<input type="checkbox"/> YES <input type="checkbox"/> NO	
Shoulder <input type="checkbox"/> YES <input type="checkbox"/> NO			<input type="checkbox"/> Overuse (result of repetitive practice or use) <input type="checkbox"/> Contact (direct blow from a teammate, opponent, or object) <input type="checkbox"/> Non-contact (injury not caused by contact with opponent or object) <input type="checkbox"/> Other (please describe): _____	<input type="checkbox"/> YES <input type="checkbox"/> NO	
Elbow <input type="checkbox"/> YES <input type="checkbox"/> NO			<input type="checkbox"/> Overuse (result of repetitive practice or use) <input type="checkbox"/> Contact (direct blow from a teammate, opponent, or object) <input type="checkbox"/> Non-contact (injury not caused by contact with opponent or object) <input type="checkbox"/> Other (please describe): _____	<input type="checkbox"/> YES <input type="checkbox"/> NO	

Figure. Example of the survey used to capture self-reported injuries.

Furthermore, athletes who wrote “concussion” in column 2 (Figure) of the head/neck injury section were classified as having sustained a concussion. An *LE injury* was considered an injury to the hip, upper leg, knee, lower leg, ankle, or foot (Figure, column 1). A *UE injury* was considered an injury to the shoulder, elbow, or wrist/hand (Figure, column 1). Back injuries were not included in this analysis because of the difficulty in classifying them as UE or LE without expanding the survey. Reported injuries could have occurred at any point during a participant’s collegiate club-sport career (Figure). Participants were then dichotomized as either having or not having reported a UE overuse, UE acute, LE overuse, LE acute, head/neck overuse, head/neck acute, or head/neck concussion injury during their club-sport career. This was done because few participants had >1 UE overuse, UE acute, LE overuse, LE acute, head/neck overuse, head/neck acute, or head/neck concussion injury (Table 1). No more than 2 people in each category reported multiple UE overuse, UE acute, or LE acute injuries (Table 1). Fifteen reported >2 LE overuse injuries (Table 1). Furthermore, no one reported >1 head/neck injury (Table 1).

Statistical Analysis

Data are presented as means and SDs for continuous variables and frequencies and percentages for categorical variables. Head/neck overuse injuries were not analyzed as only 2 injuries in the entire sample were reported (Table 1). We used a $2 \times 2 \chi^2$ analysis to compare reported UE overuse (*yes or no*), UE acute (*yes or no*), LE overuse (*yes or no*), LE acute (*yes or no*), head/neck acute (*yes or no*), and concussion (*yes or no*) injuries between males and females. A $2 \times 2 \chi^2$ analysis was used to compare reported UE overuse (*yes or no*), UE acute (*yes or no*), LE overuse (*yes or no*), LE acute (*yes or no*), head/neck acute (*yes or no*), and concussion (*yes or no*) injuries between multisport and single-sport high school athletes. The same $2 \times 2 \chi^2$ analysis was used to compare each injury variable between those continuing and those not continuing their high school sport into college. The number of years in high school classified as highly specialized was aggregated into 3 categories: 0, 1 to 2, and 3 to 4 years of high specialization. We did this to avoid violating the assumption that each expected cell count must be >5 for χ^2 analysis.²³ A $2 \times 3 \chi^2$ analysis was used to compare reported UE overuse (*yes or*

Table 1. Self-Reported Injuries for Each Location and Injury Mechanism

Participants Variable	Injuries						
	Upper Extremity		Lower Extremity		Head or Neck		
	Overuse	Acute	Overuse	Acute	Overuse	Acute	Concussions
No. who reported an injury	20	22	51	42	2	22	16
No. of injuries reported	22	23	75	44	2	22	16
% Who reported ≥ 1 injury (n = 412)	5	5	13	10	<1	5	4

Table 2. Demographic Information for 412 Club-Sport Athletes

Variable	Value
Age, y, mean ± SD	20.1 ± 2.0
	No. (%)
Sex	
Male	167 (40.5)
Female	245 (59.5)
High school sport same as club sport?	
Yes	345 (83.7)
No	67 (16.3)
Club-sport participation	
Baseball	25 (6.1)
Basketball	39 (9.5)
Cheer/dance	11 (1.7)
Gymnastics	2 (0.5)
Ice hockey	26 (6.3)
Lacrosse	36 (8.7)
Soccer	18 (4.4)
Softball	17 (4.1)
Swim/dive	29 (7.0)
Tennis	13 (3.2)
Track	25 (6.1)
Volleyball	46 (11.2)
Wrestling	8 (1.9)
Other ^a	117 (28.4)

^a Aikijujitsu, archery, boxing, fencing, field hockey, figure skating, Irish dancing, women's rugby, taekwondo, triathlon, water polo, men's and women's ultimate Frisbee.

no), UE acute (*yes* or *no*), LE overuse (*yes* or *no*), LE acute (*yes* or *no*), head/neck acute (*yes* or *no*), and concussion (*yes* or *no*) injuries among the 3 categories of years a participant was classified as highly specialized. Statistical significance was set a priori at $P < .05$ and all analyses were performed using SPSS (version 26.0; IBM Corp).

RESULTS

Demographic information is provided in Table 2. Men's and women's volleyball contributed the largest number of athletes (Table 2), but representation of club sports in this population was heterogeneous. Approximately 47% of collegiate club athletes were classified as highly specialized during their high school careers (Table 3). Reported levels of sport specialization increased as the high school grade increased.

Table 4 provides the numbers of athletes who reported at least 1 UE overuse, LE overuse, UE acute, or LE acute injury during their collegiate club sports career as well as the χ^2 analysis for each sport participation variable. High school single-sport or multisport participation was not associated with any reported injury mechanism or limb in collegiate club-sport athletes (Table 4). Similarly, the number of years an athlete was classified as highly specialized in high school was not associated with any reported injury mechanism or limb in collegiate club-sport athletes. Athletes who played a new collegiate club sport were more likely to report an acute LE injury than athletes who were continuing 1 of their high school sports into college (20% versus 8%, $P = .006$).

The number of athletes who reported a head/neck acute injury or concussion during their collegiate club sports career as well as the χ^2 analysis for each sport participation variable are shown in Table 5. All concussion injuries

Table 3. High School Sport Specialization by Collegiate Club-Sport Athletes

Variable	No. (%)
Multisport high school athlete? (n = 412) ^a	
Yes	325 (78.9)
No	87 (21.1)
Sport specialization ^a	
9th grade (n = 398)	
Low	149 (37.4)
Moderate	135 (33.9)
High	114 (28.6)
10th grade (n = 398)	
Low	119 (29.9)
Moderate	140 (35.2)
High	139 (35.0)
11th grade (n = 401)	
Low	90 (22.4)
Moderate	135 (33.6)
High	176 (43.9)
12th grade (n = 399)	
Low	98 (24.6)
Moderate	127 (31.8)
High	174 (43.6)
No. highly specialized years in high school (n = 396) ^b	
0	210 (53.0)
1	17 (4.3)
2	35 (8.8)
3	29 (7.3)
4	105 (26.5)

^a Some participants missed or did not answer the question.

^b Only participants who provided sport specialization levels for each grade were included.

occurred from head/neck acute injuries. Head/neck acute injuries and concussion were not associated with either high school single-sport versus multisport participation or the number of years an athlete was classified as highly specialized. Athletes who played a new collegiate club sport were more likely to report a head/neck acute injury or a concussion compared with athletes who were continuing 1 of their high school sports into college (head/neck acute = 16% versus 3%, $P < .001$, and concussion = 13% versus 2%, respectively; $P < .001$).

DISCUSSION

Our findings did not support our hypothesis that high school sport specialization would be associated with reported injuries in collegiate club-sport athletes. A few factors may explain why sport specialization in high school was not associated with injuries in collegiate club-sport athletes. Though we were able to include many collegiate club sports in this study, it is important to recognize that these sports' playing styles, practices, season lengths, and competition levels vary widely. Therefore, it is possible that high school sport specialization is more detrimental for 1 sport than another. Post et al²⁴ reported that high school volleyball athletes who specialized were at an increased risk for overuse injuries compared with low-level specialized volleyball athletes, whereas the same relationship was not found in basketball or soccer high school athletes. Similarly, in a recent study of soccer players,²⁵ no link was evident between specialization and injury risk. Therefore, a sport-specific study in collegiate athletes may be beneficial to better understand the possible association of high school

Table 4. χ^2 Analysis of High School (HS) Sport Specialization by Overuse and Acute Injuries to the Upper Extremity (UE) and Lower Extremity (LE)^a

Variable	At Least 1 Injury											
	UE Overuse			LE Overuse			UE Acute			LE Acute		
	No. (%)		P Value	No. (%)		P Value	No. (%)		P Value	No. (%)		P Value
	Yes	No		Yes	No		Yes	No		Yes	No	
Sex			.177			.686			.629			.502
Male	11 (6)	156 (93)		22 (13)	145 (87)		10 (6)	157 (94)		15 (9)	152 (91)	
Female	9 (4)	236 (96)		29 (12)	216 (88)		12 (5)	233 (95)		27 (11)	218 (89)	
Same HS and club sport?			.462			.775			.364			.006
Yes	18 (5)	327 (95)		42 (13)	303 (87)		17 (5)	328 (95)		29 (8)	316 (92)	
No	2 (3)	65 (97)		9 (14)	58 (86)		5 (8)	62 (92)		13 (20)	54 (80)	
HS multisport athlete?			.663			.517			.849			.123
Yes	15 (5)	310 (95)		42 (13)	283 (87)		17 (5)	308 (95)		37 (11)	287 (89)	
No	5 (6)	82 (94)		9 (10)	78 (90)		5 (6)	82 (94)		5 (6)	82 (94)	
No. highly specialized years in HS			.533			.286			.876			.852
0	11 (5)	199 (95)		29 (14)	181 (86)		10 (5)	200 (95)		24 (11)	186 (89)	
1–2	4 (8)	48 (92)		3 (6)	49 (94)		3 (6)	49 (94)		5 (10)	47 (90)	
3–4	5 (4)	129 (96)		17 (13)	117 (87)		8 (6)	126 (94)		13 (10)	121 (90)	

^a Bold type indicates a difference ($P < .05$).

sport specialization with collegiate injuries and how this may vary among sports.

To the best of our knowledge, we are the first to report on the association of high school sport specialization and sport participation with collegiate club-sport injuries. Several groups^{13,14,16,26} have examined the association of injuries with early sport specialization in Division I and professional athletes. Unlike our results, all of these authors^{13,14,16,26} found an association with high school sport specialization and injuries in Division I and professional athletes. Confino et al¹⁴ and Rugg et al¹³ noted that single-sport athletes in high school had more publicly reported major injuries during their professional careers than professional athletes who were multisport athletes in high school. Buckley et al¹⁶ surveyed high school, collegiate, and professional athletes. Their goal was to cross-sectionally evaluate sport specialization habits in current high school, collegiate, and professional athletes and assess the association between reported injuries and sport specialization. Buckley et al¹⁶ found that current high school and collegiate players recalled more injuries that the athletes attributed to specializing in 1 sport compared with

current professional athletes. Lastly, Ahlquist et al²⁶ determined that Division I athletes who specialized in a single sport before age 14 were more likely to report multiple collegiate sport-related injuries than athletes who specialized at a later age. These studies support the hypothesis that sport specialization may affect injury risks throughout an individual's sporting career. Several reasons are possible for our different results. Given the demands of professional sports, the long-term training load is likely higher in professional athletes compared with club-sport athletes. It is equally likely that long-term training volume and repetitive motions are significantly higher in professional athletes than in our club-sport athletes. Anecdotally, club-sport athletes practice a few times a week, have a shorter competition season, and have fewer organized team events outside the regular season than Division I collegiate or professional athletes. Club-sport athletes' lower volume and training load compared with those of Division I and professional athletes may negate the possible negative effects of high school sport specialization. This is supported by previous literature indicating that training volume was a more important predictor of injury than early sport

Table 5. χ^2 Analysis of High School (HS) Sport Specialization by Acute Head and Neck Injuries and Concussions^a

Variable	Head/Neck Acute Injury			Concussion		
	No. (%)		P Value	No. (%)		P Value
	Yes	No		Yes	No	
Sex			.629			.789
Male	10 (6)	157 (94)		7 (4)	160 (96)	
Female	12 (5)	233 (95)		9 (4)	236 (96)	
Same HS and club sport?			<.001			<.001
Yes	11 (3)	334 (97)		7 (2)	338 (98)	
No	11 (16)	56 (84)		9 (13)	58 (87)	
HS multisport athlete?			.377			.389
Yes	19 (6)	306 (94)		14 (4)	311 (96)	
No	3 (3)	84 (97)		2 (2)	85 (98)	
No. highly specialized years in HS			.320			.705
0	11 (5)	199 (95)		9 (4)	201 (96)	
1–2	1 (2)	51 (98)		1 (2)	51 (98)	
3–4	10 (6)	124 (94)		6 (5)	128 (95)	

^a Bold type indicates a difference ($P < .05$).

specialization. For example, Sugimoto et al²⁷ observed that increases in training volume were associated with the injury risk in adolescent females. However, Sugimoto et al²⁷ did not find that single-sport athletes were more associated with injury than multisport athletes as they had hypothesized. Post et al⁸ reported similar findings; however, McGuine et al⁷ demonstrated that sport specialization was a risk factor independent of training volume. Therefore, future authors should prospectively study training volume, sport specialization, and sport-related injuries in high school athletes as they transition to collegiate sports to better illuminate how these variables may affect collegiate athletes' sport injury risk.

To the best of our knowledge, we are the first to report that collegiate club athletes who did not play their club sport in high school were more likely to report an LE acute injury, head/neck acute injury, or concussion compared with club athletes who were continuing their high school sport in college. Most club athletes who were participating in a new sport were involved in club sports such as rugby (10 of 67, 15%), ultimate Frisbee (21 of 67, 31%), or martial arts (8 of 67, 12%). It is possible that these athletes' high school sport specialization affected their injury risk in club-sport activities; however, our investigation lacked sufficient power to analyze this factor in this specific subset of individuals. A number of authors^{10,12,28} demonstrated that adolescent multisport participation was associated with improved motor skills, movement patterns, endurance, and strength. When these athletes switch to a new sport, improvements (or lack of improvements) in these areas during adolescence may affect their risk of injury. Furthermore, switching sports after high school may protect an individual from overuse injuries but increase the risk for acute injuries. Evidence on the association of years of playing experience and sport-related injuries is limited and conflicting.^{29,30} It has been proposed that athletes starting to compete in a new sport lack a transitional period to prepare for the movements and loads necessary in competition.²⁹ Thus, a lack of knowledge of the given sport and insufficient physical preparedness for that sport may lead to an increased risk of injury. Our results support this hypothesis, though future research is needed to bolster this theory. Athletic trainers working with collegiate club-sport programs or organizers of club-sport programs may benefit from identifying athletes new to their respective club sport and providing extra lessons and training sessions in that sport to reduce the risk of acute injuries in this population.

Limitations

This study had several limitations. First, sport specialization was based on retrospective answers to questions regarding high school sport participation. Similarly, collegiate club-sport injuries were collected retrospectively; therefore, these data were subject to recall bias. However, we aimed to improve the accuracy of the injury data by restricting the analyses to injuries for which individuals could identify a specific mechanism of injury and that had been reported to a medical professional (AT or physician). The survey could have included more insight into training load and volume during athletes' high school athletic careers as well as the different sport organizations in which they participated (eg, Amateur Athletic Union, club

volleyball). However, we left these questions out to avoid burdening participants with too lengthy a survey. These results may not be generalizable beyond this specific university or geographic location. Future authors who track sport participation and specialization through high school and into college may provide a better understanding of how high school sport specialization affects the injury risk for college-aged athletes at all levels.

CONCLUSIONS

High school sport specialization was not associated with injuries reported by collegiate club-sport athletes. This may have been due to reduced sport volume and training load for collegiate club-sport athletes compared with higher-level athletes or the heterogeneity of the analyzed sports. Collegiate athletes who were playing a club sport different from any of their high school sports were more likely to report an LE acute injury, head/neck acute injury, or concussion compared with those who were continuing to participate in their high school sport. This may have resulted from a lack of experience in the new sport, leading to more injuries. Athletic trainers and other professionals who work with collegiate club-sport programs may benefit their athletes by identifying individuals who are starting a new sport at the collegiate level.

REFERENCES

1. High school sports participation increases for 29th consecutive year. National Federation of State High School Associations. Published September 11, 2018. Accessed August 5, 2021. <https://www.nfhs.org/articles/high-school-sports-participation-increases-for-29th-consecutive-year/>
2. Post EG, Bell DR, Trigsted SM, et al. Association of competition volume, club sports, and sport specialization with sex and lower extremity injury history in high school athletes. *Sports Health*. 2017;9(6):518–523. doi:10.1177/1941738117714160
3. Biese KM, McGuine TA, Kliethermes SA, et al. Sport specialization and sport participation opportunities and their association with injury history in female high school volleyball athletes. *Phys Ther Sport*. 2020;45:86–92. doi:10.1016/j.ptsp.2020.06.005
4. Jayanthi NA, LaBella CR, Fischer D, Pasulka J, Dugas LR. Sports-specialized intensive training and the risk of injury in young athletes: a clinical case-control study. *Am J Sports Med*. 2015;43(4):794–801. doi:10.1177/0363546514567298
5. Bell DR, Post EG, Biese K, Bay C, Valovich McLeod T. Sport specialization and risk of overuse injuries: a systematic review with meta-analysis. *Pediatrics*. 2018;142(3):e20180657. doi:10.1542/peds.2018-0657
6. Hall R, Barber Foss K, Hewett TE, Myer GD. Sport specialization's association with an increased risk of developing anterior knee pain in adolescent female athletes. *J Sport Rehabil*. 2015;24(1):31–35. doi:10.1123/jsr.2013-0101
7. McGuine TA, Post EG, Hetzel SJ, Brooks MA, Trigsted S, Bell DR. A prospective study on the effect of sport specialization on lower extremity injury rates in high school athletes. *Am J Sports Med*. 2017;45(12):2706–2712. doi:10.1177/0363546517710213
8. Post EG, Trigsted SM, Riekens JW, et al. The association of sport specialization and training volume with injury history in youth athletes. *Am J Sports Med*. 2017;45(6):1405–1412. doi:10.1177/0363546517690848
9. Bell DR, Lang PJ, Valovich McLeod TC, McCaffrey KA, Zaslow TL, McKay SD; PRISM Sport Specialization Interest Group. Sport specialization is associated with injury history in youth soccer

- athletes. *Athl Train Sports Health Care*. 2018;10(6):241–246. doi:10.3928/19425864-20180813-01
10. DiStefano LJ, Beltz EM, Root HJ, et al. Sport sampling is associated with improved landing technique in youth athletes. *Sports Health*. 2018;10(2):160–168. doi:10.1177/1941738117736056
 11. DiCesare CA, Montalvo A, Foss KDB, et al. Sport specialization and coordination differences in multisport adolescent female basketball, soccer, and volleyball athletes. *J Athl Train*. 2019;54(10):1105–1114. doi:10.4085/1062-6050-407-18
 12. Herman DC, Riveros D, Jacobs K, Harris A, Massengill C, Vincent HK. Previous high school participation in varsity sport and jump-landing biomechanics in adult recreational athletes. *J Athl Train*. 2019;54(10):1089–1094. doi:10.4085/1062-6050-412-18
 13. Rugg C, Kadoro A, Feeley BT, Pandya NK. The effects of playing multiple high school sports on National Basketball Association players' propensity for injury and athletic performance. *Am J Sports Med*. 2018;46(2):402–408. doi:10.1177/0363546517738736
 14. Confino J, Irvine JN, O'Connor M, Ahmad CS, Lynch TS. Early sports specialization is associated with upper extremity injuries in throwers and fewer games played in Major League Baseball. *Orthop J Sports Med*. 2019;7(7):2325967119861101. doi:10.1177/2325967119861101
 15. Clausen MB, Tang L, Zebis MK, et al. Self-reported previous knee injury and low knee function increase knee injury risk in adolescent female football. *Scand J Med Sci Sports*. 2016;26(8):919–926. doi:10.1111/sms.12521
 16. Buckley PS, Bishop M, Kane P, et al. Early single-sport specialization: a survey of 3090 high school, collegiate, and professional athletes. *Orthop J Sports Med*. 2017;5(7):2325967117703944. doi:10.1177/2325967117703944
 17. Post EG, Thein-Nissenbaum JM, Stiffler MR, et al. High school sport specialization patterns of current Division I athletes. *Sports Health*. 2017;9(2):148–153. doi:10.1177/1941738116675455
 18. Pennington B. Rise of college club teams creates a whole new level of success. *New York Times*. December 1, 2008. Accessed August 5, 2021. <https://www.nytimes.com/2008/12/02/sports/02club.html>
 19. Beidler E, Bretzin AC, Hanock C, Covassin T. Sport-related concussion: knowledge and reporting behaviors among collegiate club-sport athletes. *J Athl Train*. 2018;53(9):866–872. doi:10.4085/1062-6050-266-17
 20. Brezinski T, Martin J, Ambegaonkar JP. Prospective injury epidemiology in competitive collegiate club sports, quidditch, and ultimate frisbee. *Athl Train Sports Health Care*. 2020;13(3):111–116. doi:10.3928/19425864-20200107-01
 21. Warmath D, Winterstein AP. A social-marketing intervention and concussion-reporting beliefs. *J Athl Train*. 2020;55(10):1035–1045. doi:10.4085/1062-6050-242-19
 22. Miller M, Malekian S, Burgess J, LaBella C. Evaluating a commonly used tool for measuring sport specialization in young athletes. *J Athl Train*. 2019;54(10):1083–1088. doi:10.4085/1062-6050-379-18
 23. Portney LG, Watkins MP. *Foundations of Clinical Research: Applications to Practice*. 3rd rev ed. FA Davis; 2015.
 24. Post EG, Biese KM, Schaefer DA, et al. Sport-specific associations of specialization and sex with overuse injury in youth athletes. *Sports Health*. 2020;12(1):36–42. doi:10.1177/1941738119886855
 25. Frome D, Rychlik K, Fokas J, Chiampas G, Jayanthi N, LaBella C. Sports specialization is not associated with greater odds of previous injury in elite male youth soccer players. *Clin J Sport Med*. 2019;29(5):368–373. doi:10.1097/JSM.0000000000000643
 26. Ahlquist S, Cash BM, Hame SL. Associations of early sport specialization and high training volume with injury rates in National Collegiate Athletic Association Division I athletes. *Orthop J Sports Med*. 2020;8(3):2325967120906825. doi:10.1177/2325967120906825
 27. Sugimoto D, Jackson SS, Howell DR, Meehan WP III, Straccolini A. Association between training volume and lower extremity overuse injuries in young female athletes: implications for early sports specialization. *Phys Sportsmed*. 2019;47(2):199–204. doi:10.1080/00913847.2018.1546107
 28. Fransen J, Pion J, Vandendriessche J, et al. Differences in physical fitness and gross motor coordination in boys aged 6–12 years specializing in one versus sampling more than one sport. *J Sports Sci*. 2012;30(4):379–386. doi:10.1080/02640414.2011.642808
 29. Malone S, Roe M, Doran DA, Gabbett TJ, Collins KD. Protection against spikes in workload with aerobic fitness and playing experience: the role of the acute: chronic workload ratio on injury risk in elite Gaelic football. *Int J Sports Physiol Perform*. 2017;12(3):393–401. doi:10.1123/ijsp.2016-0090
 30. McCunn R, Fullagar HHK, Williams S, Halseth TJ, Sampson JA, Murray A. The influence of playing experience and position on injury risk in NCAA Division I college football players. *Int J Sports Physiol Perform*. 2017;12(10):1297–1304. doi:10.1123/ijsp.2016-0803

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