



Sport specialization is associated with upper-extremity overuse injury in high school baseball players

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Background and hypothesis: Sport specialization is increasingly common in youth sports and is a risk factor for lower-extremity overuse injuries. However, limited data exist on whether specialization is associated with upper-extremity (UE) overuse injuries, specifically in youth baseball players. We hypothesized that specialization in baseball and being a pitcher would be associated with poorer arm health and UE overuse injury history in the previous year.

Methods: During the 2019 spring baseball season, 551 high school baseball athletes (aged 15.9 ± 1.3 years) from 3 states (Alabama, $n = 200$; California, $n = 188$; and Michigan, $n = 163$) completed an anonymous questionnaire. Athletes were recruited from 5 high schools in each state, with schools matched based on factors that influence specialization rates. The questionnaire consisted of (1) demographic characteristics, (2) baseball participation information (including sport specialization status), and (3) throwing-arm health and UE injury history in the previous 12 months. Throwing-arm health was assessed using the Youth Throwing Score (YTS), a validated and reliable outcome measure for youth baseball players. Multivariate regression analyses were used to examine the association between variables of interest and the YTS or UE overuse injury history, adjusting for covariates.

Results: After adjustment for covariates, highly specialized athletes were more likely to report a UE overuse injury in the previous year compared with low-specialization athletes (odds ratio [OR], 3.77; 95% confidence interval [CI], 1.39-10.2, $P = .009$). Both athletes who reported playing baseball for more than 8 months per year (OR, 2.03; 95% CI, 1.12-3.65; $P = .019$) and athletes who reported being a pitcher (OR, 2.11; 95% CI, 1.20-3.72; $P = .010$) were more likely to report a history of UE overuse injury. Highly specialized players reported lower (worse) YTS values compared with low-specialization players (least-squares mean estimate \pm standard error, 56.5 ± 1.1 vs. 53.3 ± 0.7 ; $P = .034$). Players who reported pitching as one of their positions scored worse on the YTS than non-pitchers (least-squares mean estimate \pm standard error, 51.6 ± 0.8 vs. 57.2 ± 0.6 ; $P < .001$).

Conclusion: Although baseball recommendations that discourage sport specialization are widely available for parents, athletes, and coaches, high rates of sport specialization were reported in our sample. We found that being highly specialized in baseball was associated with UE overuse injury history and worse throwing-arm health in high school baseball athletes. Continued education for baseball parents, athletes, and coaches is necessary to raise awareness of the risks associated with high specialization.

Level of evidence: Level III; Cross-Sectional Design; Epidemiology Study

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Baseball is the fourth most popular male high school sport in the United States, with roughly half a million annual participants.¹⁵ Despite the sport's continued popularity, the rate of shoulder and elbow injuries occurring in youth athletes has created growing concern among athletes, coaches, and sports medicine professionals. For example, the infamous "Tommy John" operation, also known as "elbow ulnar collateral ligament (UCL) reconstruction," was once reserved for veteran pitchers nearing the ends of their careers; however, 57% of all UCL reconstructions are now performed in adolescent pitchers.⁶ Other recent evidence suggests that the incidence of elbow injuries among youth baseball players significantly increased between 2006 and 2016.²⁶

One proposed explanation for the increase in youth baseball upper-extremity (UE) injuries has been the rise of year-round focus on a single sport, also known as sport specialization. As part of Major League Baseball Major League Baseball and USA Baseball's Pitch Smart guidelines, youth players are advised to avoid pitching and playing baseball year-round and to play other sports throughout the year.¹² These recommendations include taking at least 4 months off from baseball per year and avoiding specializing in baseball to allow for overall athletic development and to decrease the stress on the shoulder and elbow during the throwing motion.¹² However, the evidence linking year-round baseball with injury is mixed, with a recent systematic review concluding that recommendations regarding year-round pitching as a risk factor for injury cannot be supported or refuted based on existing research.¹⁶ Recently, a 3-point sport specialization scale was developed by Jayanthi et al¹⁰ using the definition of sport specialization as "year-round intensive training in a single sport at the exclusion of other sports."¹¹ Using this scale, a number of studies have reported high levels of specialization as a risk factor for overuse injuries—and lower-extremity overuse injuries in particular—in broad populations of youth athletes.^{2,10,14,22} However, to date, there has not been an examination of specialization as a potential risk factor for UE overuse injury in youth baseball now that a specific validated instrument for assessing specialization in youth sports exists.

Therefore, the purpose of this study was to examine the potential association between sport specialization and baseball participation characteristics with arm health and UE overuse injury history in a broad sample of high school baseball players from across the United States. We hypothesized that (1) high specialization in baseball, (2) participation in a baseball club team in addition to the high school team, (3) year-round baseball participation, (4) being a pitcher, and (5) pitching year-round would all be associated with poorer arm health and UE overuse injury history in the previous year.

Materials and methods

Participants

In this cross-sectional study, high school baseball athletes from 3 states (Alabama, $n = 200$; California, $n = 188$; and Michigan, $n = 163$) were recruited to complete an anonymous questionnaire during the 2019 spring baseball season. To participate, athletes were required to be participants on their high school's varsity, junior varsity, or freshman baseball team. Athletes were recruited in person at practices and provided informed assent before participating.

Athletes were recruited from 5 high schools in each state, with schools matched based on factors that have been shown to influence specialization rates (school size^{3,22} and socioeconomic status^{9,23}) or were theorized by us to potentially influence specialization rates (baseball team performance). School size was assessed using student enrollment, school socioeconomic status was assessed using the proportion of students eligible for free or reduced-price lunch, and baseball team performance was assessed by determining whether the school baseball team had made its local high school playoffs during the previous season. After matching, there were no differences in any of these 3 factors among the 3 states (Table I).

Questionnaire

Athletes were invited to complete a self-administered paper-and-pencil questionnaire that consisted of (1) demographic characteristics (age and grade), (2) baseball participation information from the previous year, and (3) throwing-arm health and UE injury history in the previous 12 months. Baseball participation information from the previous year included primary position, position(s) played, months per year and hours per week of baseball participation, sport specialization status, participation in a baseball club team in addition to the high school team, whether the athlete had regularly traveled overnight (at least once a month) for baseball competitions or showcases, and whether the athlete received private baseball coaching. Players who indicated that they pitched in the previous year were asked additional questions including the number of months and innings they pitched in the previous year and their average pitch count per game in the previous year. Incomplete surveys were included in the analysis if they included all major outcome variables of interest (specialization status, UE overuse injury history, and Youth Throwing Score [YTS]). The questionnaire was designed to be completed in 10 minutes and was written at a Flesch-Kincaid grade level of 4.1.

Sport specialization status was determined using a validated 3-point specialization scale that classifies athletes' level of specialization as either low, moderate, or high based on responses to 3 questions.^{10,21} Year-round baseball participation and year-round pitching were determined by whether the athlete played baseball for more than 8 months and whether the athlete pitched for more than 8 months in the previous year, respectively. Throwing-arm health was assessed using the YTS, a validated and reliable 14-item outcome measure for youth baseball players.¹ Responses to the YTS generate a score between 14 and 70, with higher scores indicating better arm health.¹

Table I Comparison of school-matching variables

Variable	Alabama (n = 5)	California (n = 5)	Michigan (n = 5)	P value
Student enrollment, median [IQR]	1338 [1317-1745]	2168 [1935-2418]	1834 [1685-2056]	.33
% of students eligible for free or reduced-price lunch, median [IQR]	36.0 [33.0-37.0]	32.3 [11.2-46.8]	40.0 [17.0-48.0]	.96
Baseball team made playoffs last year, n (%)	5 (100)	4 (80)	5 (100)	.34

IQR, interquartile range.

UE overuse injuries were self-reported using separate questions for the shoulder and elbow. Specifically, for both the shoulder and elbow, participants were asked whether they had experienced an injury to that body part as a result of baseball participation in the past 12 months; the type of injury (muscle strain, joint sprain, tendinitis, fracture, bruise, or other); the mechanism of injury (overuse from playing or practicing too much or too often, direct contact with another player or object, or noncontact injury [ie, injury not caused by contact with another player or object]); whether they saw a doctor because of the injury; and how many days of baseball participation they missed as a result of the injury. For analysis, an UE overuse injury was defined as an overuse injury to either the throwing elbow or shoulder in the previous 12 months that caused the athlete to miss at least 1 day of baseball participation.

Statistical analysis

Data were summarized by means and standard deviations, medians and interquartile ranges, and frequencies and proportions (percentages). Continuous variables were assessed for normality by calculation of skewness and kurtosis values and visual inspection of histograms. All analyses were conducted both for the entire sample and for only players who reported pitching in the previous 12 months. Univariate parametric analyses (independent *t* test and 1-way analysis of variance) and nonparametric analyses (χ^2 and Mann-Whitney *U* tests) were used to examine differences and associations between variables of interest and athlete UE overuse injury history, as well as to examine differences in the YTS based on variables of interest. The type of univariate analysis used depended on variable type (categorical or continuous) and normality of the specified variables.

Multivariate logistic regression was used to examine the association between variables of interest and UE overuse injury history within the previous 12 months. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated for the variables of interest from the logistic regression model, adjusting for covariates. Multivariate linear regression was used to examine the association between variables of interest and the YTS. Least-squares mean estimates with standard errors were calculated for the variables of interest from the linear regression model, adjusting for covariates. All models were adjusted for geographic state, player age, and hours per week of baseball participation, in addition to covariates identified during univariate analysis with $P < .20$. Models involving only pitchers were also adjusted for innings pitched in the previous 12 months and average pitches thrown per game.

The multivariate linear regression model was assessed to determine whether it met the assumptions of linear regression using the Global Validation of Linear Models Assumptions package¹⁸ in R statistical software (R Foundation for Statistical Computing,

Vienna, Austria) and via visual inspection of quantile-quantile and residual plots. Comparisons of least-squares mean estimates of the YTS between levels of the variables of interest were conducted using post hoc pair-wise Tukey HSD (honestly significant difference) tests. Statistical significance was set a priori at a 2-sided P value of $P < .05$, and all analyses were performed in R statistical software. Bonferroni adjustments were made to account for the large number of univariate analyses, with the adjusted α value thresholds listed in footnotes to the relevant tables.

Results

Descriptive data regarding the study population are provided in Table II. In total, 551 athletes (aged 15.8 ± 1.3 years) took part in this study, with participants distributed roughly evenly among the 3 states. The most commonly reported primary position was pitcher ($n = 130$, 23.7%), with participants distributed evenly across the other 8 positions. However, the majority of participants ($n = 388$, 70.4%) reported pitching for a team in the previous year at least once. Just over half ($n = 285$, 51.7%) of all athletes were classified as highly specialized, and the majority of athletes reported participating in a club team ($n = 381$, 70.0%) or receiving private baseball coaching ($n = 318$, 58.2%).

Univariate comparisons between athletes who reported a history of UE overuse injury in the previous 12 months and those with no history of UE overuse injury are presented in Table III. Among all players, several factors were associated with a history of UE overuse injury in the previous 12 months: being highly specialized in baseball, playing baseball for more than 8 months in the previous year, and being a pitcher. Among pitchers only, being highly specialized in baseball was the only factor associated with a history of UE overuse injury. Differences in the YTS based on baseball participation characteristics are presented in Table IV. Being highly specialized (among all players and pitchers only) and being a pitcher were both associated with lower YTS values, indicating worse arm health.

The results of the multivariate analyses are presented in Table V for UE overuse injury history and Table VI for the YTS. After adjustment for covariates, highly specialized athletes were roughly 4 times more likely to report a UE overuse injury in the previous year compared with low-specialization athletes both among all players (OR, 3.77; 95% CI, 1.39-10.2; $P = .009$) and among only pitchers (OR, 4.29; 95% CI, 1.22-15.1; $P = .024$). Both

Table II Participant demographic and sports participation characteristics

Variable	Data
Participants, n (%)	551 (100)
State, n (%)	
Alabama	200 (36.3)
California	188 (34.1)
Michigan	163 (29.6)
Age, mean (SD), yr	15.8 (1.3)
Grade, n (%)	
9th	174 (31.6)
10th	170 (30.8)
11th	93 (16.9)
12th	114 (20.7)
Primary position, n (%)	
Pitcher	130 (23.7)
Catcher	56 (10.2)
First base	37 (6.7)
Second base	54 (9.8)
Third base	52 (9.5)
Shortstop	47 (8.6)
Left field	49 (8.9)
Center field	59 (10.7)
Right field	65 (11.8)
Pitched for team in previous year, n (%)	388 (70.4)
Months per year of baseball participation, median [IQR]	11 [8-12]
Hours per week of baseball participation, mean (SD)	19.7 (7.6)
Specialization scale, n (%)	
Low	88 (16.0)
Moderate	178 (32.3)
High	285 (51.7)
Play baseball >8 mo per year, n (%)	385 (69.9)
Participate in club team, n (%)	381 (70.0)
Travel regularly for baseball, n (%)	222 (40.5)
Receive private baseball coaching, n (%)	318 (58.2)
YTS, mean (SD)	52.7 (10.7)

SD, standard deviation; IQR, interquartile range; YTS, Youth Throwing Score.

athletes who reported playing baseball for more than 8 months per year (OR, 2.03; 95% CI, 1.12-3.65; $P = .019$) and athletes who reported being a pitcher (OR, 2.11; 95% CI, 1.20-3.72; $P = .010$) were nearly twice as likely to report a history of UE overuse injury compared with athletes participating for fewer than 8 months and athletes not pitching, respectively. Highly specialized players reported lower YTS values compared with low-specialization players, even after adjustment for covariates. Among all players, those who reported pitching as one of their positions scored worse on the YTS compared with non-pitchers. When the sample was limited to pitchers, highly specialized pitchers had worse YTS values than low-specialization pitchers, but an interesting finding was that pitchers who pitched year-round scored better on the YTS than pitchers who did not pitch year-round.

Discussion

The most important finding of this study was that being highly specialized in baseball was associated with UE overuse injury history in the previous 12 months in high school baseball athletes. To our knowledge, our study is the first to examine the association between a direct measure of specialization and overuse injury in baseball. Previous research has established specialization as a risk factor for lower-extremity overuse injury,^{2,7,14,22} whereas studies specific to baseball have examined year-round baseball participation or geographic location as a proxy for specialization, with mixed results.^{5,16,28} Studies that examined year-round baseball participation as a risk factor for injury have found both positive¹⁷ and null^{4,27} results, as summarized in a recent systematic review.¹⁶ Furthermore, 2 studies have reported that players from warm-weather states are more likely to undergo UCL reconstruction, with the authors of both concluding that this result was likely a result of players from warm-weather states being able to participate in a higher volume of baseball activities and focus on baseball year-round.^{5,28} Even after adjusting for geography, we found that highly specialized athletes were roughly 4 times more likely to report a history of UE overuse injury compared with low-specialization athletes, both in the overall sample and when the sample was limited to pitchers.

Highly specialized players (among all players and among pitchers only) also reported significantly lower scores on the YTS compared with low-specialization players, even after adjustment for covariates. Similarly to the result found for UE overuse injury, players who reported pitching for a team in the previous year had lower YTS values than non-pitchers. Previous research has consistently identified pitching as a risk factor for UE injury, which is in agreement with the findings of this study.¹⁶ The YTS is a patient-reported outcome measure that evaluates UE health specifically in youth baseball players (aged 10-18 years).¹ Our finding of worse arm health in highly specialized players is consistent with the findings of previous research comparing the magnetic resonance imaging (MRI) results of uninjured youth baseball players. In 2 separate studies, Pennock et al^{19,20} reported that athletes who specialized in baseball and played year-round were more likely to have abnormal shoulder or elbow MRI findings. It is interesting to note that pitchers who reported pitching year-round scored significantly higher on the YTS than pitchers who did not pitch year-round. The reason for this association is unclear but may represent a survivor effect in which those pitchers who were healthy enough to continue to pitch throughout the year therefore reported higher scores. Furthermore, recovery following pitching is influenced by a number of individual factors such as nutrition, modality use, sleep, stress, and arm care routine; therefore, pitchers who are participating at a high level year-round may be more focused on maintaining their arm health.^{8,13,25}

Table III Univariate comparison between players with and without history of UE overuse injury

	History of UE overuse injury		P value
	No	Yes	
All players (n = 551)	440	111	
State, n (%)			.116
Alabama	154 (77.0)	46 (23.0)	
California	147 (78.2)	41 (21.8)	
Michigan	139 (85.3)	24 (14.7)	
Age, mean (SD), yr	15.8 (1.3)	16.1 (1.2)	.017
Specialization, n (%)			<.001*
Low	82 (93.2)	6 (6.8)	
Moderate	144 (80.9)	34 (19.1)	
High	214 (75.1)	71 (24.9)	
Baseball >8 mo, n (%)			.003*
Yes	294 (76.4)	91 (23.6)	
No	146 (88.0)	20 (12.0)	
Months/year baseball, median [IQR]	11 [8-12]	12 [9-12]	.012
Hours/week playing baseball, mean (SD)	19.44 (7.6)	20.6 (7.5)	.158
Pitcher as one of positions, n (%)			.004*
Yes	297 (76.5)	91 (23.5)	
No	143 (87.7)	20 (12.3)	
Club team participation, n (%)			.786
Yes	303 (79.5)	78 (20.5)	
No	132 (81.0)	31 (19.0)	
Regular travel for competitions or showcases, n (%)			.052
Yes	168 (75.7)	54 (24.3)	
No	270 (82.8)	56 (17.2)	
Private baseball coaching, n (%)			.068
Yes	245 (77.0)	73 (23.0)	
No	191 (83.8)	37 (16.2)	
Pitchers only (n = 388)	297	91	
Age, mean (SD), yr	15.7 (1.3)	16.1 (1.2)	.012
Specialization, n (%)			.004*
Low	43 (93.5)	3 (6.5)	
Moderate	99 (79.2)	26 (20.8)	
High	155 (71.4)	62 (28.6)	
Pitch >8 mo, n (%)			.114
Yes	117 (72.2)	45 (27.8)	
No	180 (79.6)	46 (20.4)	
Months/year pitching, median [IQR]	8 [4-10]	8.5 [5-11]	.119
Hours/week playing baseball, mean (SD)	19.9 (7.6)	20.7 (7.6)	.377
Innings in previous year, median [IQR]	38 [15-70]	49 [25-80]	.090
Pitch count per game, median [IQR]	60 [45-70]	64 [50-80]	.016
Club team participation, n (%)			.821
Yes	218 (77.0)	65 (23.0)	
No	76 (75.2)	25 (24.8)	
Regular travel for competitions or showcases, n (%)			.067
Yes	127 (72.2)	49 (27.8)	
No	170 (80.6)	41 (19.4)	
Private baseball coaching, n (%)			.272
Yes	174 (74.4)	60 (25.6)	
No	122 (79.7)	31 (20.3)	

UE, upper extremity; SD, standard deviation; IQR, interquartile range.

* Significant after Bonferroni adjustment for 10 analyses in group ($P < .005$).

Previous research has suggested that participating in multiple baseball teams simultaneously,^{4,27} participating in baseball showcases,^{4,17} and receiving private coaching²⁰

are potential risk factors for injury, with varying levels of evidence.¹⁶ Of these factors, participation in multiple baseball teams at the same time has been most consistently

Table IV Univariate differences in YTS based on baseball participation characteristics

	YTS, mean (SD)	P value
All players (n = 551)		
State		.25
Alabama	51.7 (10.4)	
California	53.4 (11.3)	
Michigan	53.0 (10.1)	
Specialization		.005*
Low	56.0 (8.2)	
Moderate	52.4 (11.5)	
High	51.8 (10.7)	
Baseball >8 mo		.31
Yes	52.4 (10.6)	
No	53.4 (10.7)	
Pitcher as one of positions		<.001*
Yes	50.9 (10.7)	
No	56.7 (9.3)	
Club team		.70
Yes	52.5 (10.6)	
No	52.9 (10.8)	
Regular travel		.42
Yes	52.2 (10.9)	
No	52.9 (10.5)	
Private baseball coaching		.98
Yes	52.6 (10.5)	
No	52.6 (11.0)	
Pitchers only (n = 388)		
Specialization		.003†
Low	55.9 (8.4)	
Moderate	50.2 (11.4)	
High	50.4 (10.6)	
Pitch >8 mo		.12
Yes	52.0 (10.3)	
No	50.3 (11.0)	
Club team		.60
Yes	50.8 (10.5)	
No	51.4 (11.5)	
Regular travel		.97
Yes	50.9 (10.8)	
No	51.0 (10.8)	
Private baseball coaching		.93
Yes	51.0 (10.1)	
No	50.9 (11.7)	

YTS, Youth Throwing Score; SD, standard deviation.

* Significant after Bonferroni adjustment for 7 analyses in group ($P < .007$).

† Significant after Bonferroni adjustment for 5 analyses in group ($P < .01$).

Table V Multivariate ORs for upper-extremity overuse injury history

	History of upper-extremity overuse injury, OR (95% CI)	P value
All players (n = 551)*		
Sport specialization scale		
Low	—	
Moderate	3.15 (1.15-8.60)	.025†
High	3.77 (1.39-10.2)	.009†
Baseball >8 mo		
Yes	2.03 (1.12-3.65)	.019†
No	—	
Pitcher as one of positions		
Yes	2.11 (1.20-3.72)	.010†
No	—	
Regular travel for baseball		
Yes	1.17 (0.71-1.91)	.541
No	—	
Private baseball coaching		
Yes	1.16 (0.72-1.88)	.542
No	—	
Pitchers only (n = 388)*,‡		
Specialization		
Low	—	
Moderate	2.94 (0.81-10.6)	.099
High	4.29 (1.22-15.1)	.024†
Pitch >8 mo		
Yes	1.16 (0.66-2.02)	.606
No	—	
Regular travel for competitions or showcases		
Yes	1.41 (0.79-2.52)	.247
No	—	
Private baseball coaching		
Yes	1.03 (0.59-1.78)	.924
No	—	

OR, odds ratio; CI, confidence interval.

* All models were adjusted for state, age, hours per week of baseball, and all other variables listed.

† Statistically significant at $P < .05$.

‡ The model for only pitchers was also adjusted for innings in the previous year and average pitch count per game.

associated with injury.^{4,16,27} However, we found that club team participation was not associated with UE overuse injury or the YTS in any of our univariate models, to the extent that it did not even qualify to be included in our multivariate models. The reason for this disparity may be differences in how this variable is measured. We asked participants whether they played baseball on a club team outside of school but did not ask whether that team

overlapped with their school team. Therefore, the association observed in previous research is likely because of the excessive volume and fatigue that occur with simultaneous participation in multiple teams and not because of some aspect of club teams themselves.

The evidence supporting both showcase participation and private coaching as risk factors for injury is mixed.^{4,16,17,20,24} We found that traveling overnight regularly (at least once a month) for baseball competitions or showcases was not associated with UE overuse injury or the YTS, after adjusting for covariates. Similarly to showcase participation, private coaching has been theorized to contribute to excessive baseball volume and potentially

Table VI Least-squares mean estimates for YTS based on multivariate linear regression

	YTS least-squares mean estimate (SE)	P value
All players (n = 551)*		
Sport specialization scale		
Low	56.5 (1.1)	.053 [†]
Moderate	53.4 (0.8)	.996 [‡]
High	53.3 (0.7)	.034 ^{§,¶}
Pitcher as one of positions		
Yes	51.6 (0.8)	<.001 [¶]
No	57.2 (0.6)	
Pitchers only (n = 388)*,		
Specialization		
Low	56.5 (1.7)	.005 ^{†,¶}
Moderate	50.3 (1.0)	.999 [‡]
High	50.4 (0.8)	.003 ^{§,¶}
Pitch >8 mo		
Yes	53.9 (1.1)	.023 [¶]
No	50.9 (0.8)	

YTS, Youth Throwing Score; SE, standard error.

* All models were adjusted for state, age, hours per week of baseball, and all other variables listed.

[†] Comparison between low- and moderate-specialization categories.

[‡] Comparison between moderate- and high-specialization categories.

[§] Comparison between low- and high-specialization categories.

^{||} The model for only pitchers was also adjusted for innings in previous year and average pitch count per game.

[¶] Statistically significant at $P < .05$.

injury, with 1 study reporting that Little League players who received private coaching were more likely to present with elbow MRI abnormalities during a preseason assessment.²⁰ However, receiving private coaching was not a risk factor for shoulder MRI abnormalities among Little League players in a separate single-season prospective study.²⁴ We found no association between private coaching and UE injury or the YTS after adjusting for covariates, which may be because of the differences in age between the 2 study populations (Little League vs. high school), highlighting the importance of physical maturation before intense investment in a sport. In addition, it is possible that having a private coach improves the player's pitching or hitting mechanics and, as a result, decreases the risk of injury. However, the fact that we observed no association (positive or negative) between private coaching and injury makes this difficult to determine.

Limitations

Several important limitations of this study should be noted. First, we are unable to determine causality between any of the factors examined in this study (specialization, pitching, and so on) and UE overuse injury or throwing-arm health. That is, we are unable to determine whether being highly specialized in baseball leads to an injury or worse arm

health or whether an injury or poor throwing-arm health causes an athlete to be unable to play other sports and thus focus on baseball. However, because of the lack of specialization research in baseball and the inclusion of athletes from a broad geographic area, we believed that a cross-sectional design was most feasible to establish the presence of an association between specialization and UE overuse injury in baseball. Furthermore, previous research has identified specialization as a factor that is consistently associated with lower-extremity overuse injury, and prospective studies have established specialization as an independent risk factor for overuse injury.

Another limitation is the fact that all injury data were self-reported by the participants in this study, creating the potential for recall bias. Participants may have misremembered previous injuries and reported them incorrectly, or participants who reported a previous overuse injury may have been counseled by medical providers regarding sport participation volume and therefore reported those variables differently. We attempted to control for this by also including a reliable and validated patient-reported outcome measure (the YTS) as one of our outcome measures to collect information regarding UE health in multiple ways. The consistency of our results across both outcome variables suggests that there is, indeed, a link between specialization or being a pitcher and throwing-arm injury among high school baseball players. However, even though the YTS is a validated and reliable patient-reported outcome measure, the minimal clinically important difference has not been established. Therefore, it is difficult to determine whether the differences we observed in the YTS were actually clinically meaningful or merely statistically significant.

Finally, separating our sample into just the pitchers and then comparing among 3 levels of specialization (low, moderate, or high) and 2 levels of injury history (yes or no) resulted in some groups becoming quite small. For example, only 3 participants were low-specialization pitchers with an UE injury in the previous year. This may have resulted in an overfitting of our multivariate regression models, limiting our ability to identify true relationships between our variables.

Conclusion

Although baseball recommendations that discourage sport specialization are widely available for parents, athletes, and coaches, high rates of sport specialization were reported in our sample. This study provides some of the first data on injury and specialization in youth baseball, and we found that being highly specialized in baseball was associated with UE overuse injury history and worse throwing-arm health in high school baseball athletes. Highly specialized athletes were roughly 4 times more likely to report a history of UE overuse

injury compared with low-specialization athletes, both in the overall sample and when the sample was limited to pitchers. Continued education for baseball parents, athletes, and coaches is necessary to raise awareness of the risks associated with high specialization.

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