

The Association of Sport Specialization and Training Volume With Injury History in Youth Athletes

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Background: Recommendations exist to encourage safe youth participation in sport. These recommendations include not specializing in 1 sport, limiting participation to less than 8 months per year, and limiting participation to fewer hours per week than a child's age. However, limited evidence exists to support or refute these recommendations.

Hypothesis: High levels of specialization will be associated with a history of injuries and especially overuse injuries, independent of age, sex, or weekly sport training hours. Athletes who exceed current sport volume recommendations will be more likely to have a history of injuries and overuse injuries.

Study Design: Case-control study; Level of evidence, 3.

Methods: Youth athletes (n = 2011; 989 female and 1022 male; 12-18 years of age) completed a questionnaire regarding their specialization status, yearly and weekly sport participation volume, and injury history. Specialization was classified as low, moderate, or high using a previously utilized 3-point scale. Athletes were classified into groups based on either meeting or exceeding current volume recommendations (months per year and hours per week). Odds ratios (ORs) and 95% CIs were calculated to investigate associations of specialization and volume of participation with a history of sport-related injuries in the past year ($P \leq .05$).

Results: Highly specialized athletes were more likely to report a previous injury of any kind ($P < .001$; OR, 1.59; 95% CI, 1.26-2.02) or an overuse injury ($P = .011$; OR, 1.45; 95% CI, 1.07-1.99) in the previous year compared with athletes in the low specialization group. Athletes who played their primary sport more than 8 months of the year were more likely to report an upper extremity overuse injury ($P = .04$; OR, 1.68; 95% CI, 1.06-2.80) or a lower extremity overuse injury ($P = .001$; OR, 1.66; 95% CI, 1.22-2.30). Athletes who participated in their primary sport for more hours per week than their age (ie, a 16-year-old athlete who participated in his or her primary sport for more than 16 h/wk) were more likely to report an injury of any type ($P = .001$; OR, 1.34; 95% CI, 1.12-1.61) in the previous year.

Conclusion: High levels of specialization were associated with a history of injuries, independent of age, sex, and weekly organized sport volume. Athletes who exceeded volume recommendations were more likely to have a history of overuse injuries.

Clinical Relevance: Parents and youth athletes should be aware of the risks of specialization and excessive sport volume to maximize safe sport participation.

Keywords: specialization; overuse injury; youth sports; sport volume

Sport participation is often promoted and introduced early in children's lives as a way to maintain a healthy lifestyle, engage in social interaction, and for enjoyment. This has led to an estimated 60 million youths between 6 and 18 years of age in the United States participating in organized athletics.⁵ Despite the popularity and benefits of athletic participation, there is believed to be a concerning trend toward specialized training at earlier ages among youth athletes. Although no standardized definition exists, sport

specialization is commonly defined as "year-round intensive training in a single sport at the exclusion of other sports"^{13,17} and is associated with high-volume training that can result in psychological stress and overuse injuries.^{1,5,13} This trend is so concerning that various medical organizations have released position statements warning against sport specialization while at the same time calling for more research because of limited data supporting or refuting the various recommendations.^{2,3,5,9,11,21}

A sport specialization scale has recently been developed to better classify athletes along a continuum of specialization (low, moderate, high).^{12,13} Using this scale, being a highly specialized athlete has been established as a risk factor for injuries among youth athletes presenting

at a sports medicine clinic, independent of age, sex, and weekly hours of sport training.¹³ Recommendations exist to limit the volume (exposure) of participation in an attempt to reduce or prevent musculoskeletal injuries commonly blamed on sport specialization. These are general recommendations that focus on weekly and monthly training limitations. Training volume is thought to be important because year-round intense sport participation is a particularly concerning component of specialization. The 3 volume-related recommendations that are commonly cited in the literature are related to months per year and hours per week of organized sport participation. The recommendations state that children participating in organized sports should not play 1 sport more than 8 months per year, no more hours per week than their age (ie, a 13-year-old athlete should not participate in organized sports for more than 13 h/wk), and no more than 16 hours per week total.^{13,19,20} Anecdotally, the recommendation of 8 months per year seems to be the most well known but is based on data examining adolescent male baseball players and arm injuries, so it is unknown whether it is appropriate for other youth athlete populations or if this recommendation can be utilized for lower extremity injury prevention.¹⁹

There is a significant gap in the literature regarding the application of the sport specialization scale and current sport volume recommendations, particularly in young athletes. Previous research has examined sport specialization in a clinic-based setting, but no research to our knowledge has examined specialization and volume recommendations in a population-based setting among athletes participating in youth sport tournaments. Youth athletes (ages 12-14) are of particular interest because anecdotal evidence suggests that specialization is increasingly common in this age group and that they may be most susceptible to injuries due to their rapid growth.

Therefore, the primary purpose of this study was to determine the association between sport specialization and injury history in adolescent athletes. We hypothesized that specialization would be associated with a history of injuries and especially overuse injuries in the previous year, independent of age, sex, or weekly sport training hours. A secondary purpose was to determine the association between sport volume recommendations and injury history. We hypothesized that athletes who exceed current sport volume recommendations would be more likely to have a history of injuries and overuse injuries.

METHODS

Participants

Adolescent athletes were recruited from summer athletic tournaments, competitions, and practices around the state

of Wisconsin. Eligible participants were 12 to 18 years old and active in organized sports during the previous 12 months. The Institutional Review Board at the University of Wisconsin–Madison approved this study and procedures. Parents and athletes were provided an information sheet describing the study before orally consenting to participate.

Questionnaire

Participants completed a short, anonymous paper questionnaire consisting of demographic information, sport participation, specialization classification, and injury history. Data regarding athlete training volume and history of sport-related injuries were restricted to the previous 12 months to minimize recall bias. Questionnaires were completed on site at each athletic event and took approximately 10 minutes to complete.

Sport specialization status was classified using a previously published 3-point scale¹³ to identify the degree of specialization along a continuum from low to high. This scale was calculated from a series of 3 questions that asked (1) if the athletes quit other sports to focus on their main sport, (2) if they viewed their primary sport as more important than other sports, and (3) if they trained or participated in their primary sport more than 8 months of the year. Scores were calculated by a “yes” response being 1 point and a “no” response being 0 points. Specialization was classified by scores 0-1 being low specialization, 2 being moderate specialization, and 3 being high specialization.

Athletes were asked to report the months per year that they participated in their primary sport and in organized sports in total. Additionally, athletes were asked to estimate their average hours per week of primary sport participation during their primary sport season, average total hours per week of organized sport participation, and average hours per week of unorganized sport participation (gymnasium class, playing with friends, etc). These responses were used to classify athletes as either meeting or exceeding the various sport volume recommendations. Athletes were considered to exceed the “more hours per week than age” recommendation if they reported participating in more primary sport hours per week than their numerical age. Athletic injury history was grouped according to the following body regions: head/neck, shoulder, elbow, wrist/hand, hip, upper leg, knee, lower leg, ankle, and foot. For each injury, participants were required to describe the injury, identify the mechanism, recall when the injury occurred, and estimate the number of days missed. The mechanism of injury was categorized as overuse injuries from repetitive practice or use, acute contact injuries from any direct blow, or acute noncontact injuries

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TABLE 1
Differences Between Levels of Specialization^a

Characteristic	Low (n = 507)	Moderate (n = 749)	High (n = 754)	P Value
Female sex, n (%)	227 (44.8)	355 (47.4)	406 (53.8)	.011 ^{b,c}
Male sex, n (%)	280 (55.2)	394 (52.6)	348 (46.2)	
Age, mean ± SD, y	13.5 ± 1.6	13.7 ± 1.7	13.8 ± 1.6	.011 ^c
Grade, mean ± SD	7.7 ± 1.7	7.9 ± 1.6	8.1 ± 1.5	<.001 ^{b,c,d}
Age starting organized sports, mean ± SD, y	6.8 ± 2.2	6.5 ± 2.0	6.3 ± 1.8	.002 ^{c,d}
Age starting primary sport, mean ± SD, y	7.7 ± 2.7	7.1 ± 2.6	7.0 ± 2.4	<.001 ^{c,d}
Time participating in organized sports, mean ± SD, y	6.8 ± 2.7	7.2 ± 2.4	7.5 ± 2.3	<.001 ^{b,c,d}
Time participating in primary sport, mean ± SD, y	5.8 ± 2.8	6.5 ± 2.7	6.9 ± 2.6	<.001 ^{b,c,d}
Time playing primary sport, median (IQR), mo/y	6.0 (4.0-9.0)	10.0 (6.0-12.0)	11.0 (9.0-12.0)	<.001 ^{b,c,d}
Time playing all sports, median (IQR), mo/y	11.0 (7.0-12.0)	12.0 (10.0-12.0)	12.0 (11.0-12.0)	<.001 ^{b,c,d}
Time playing primary sport, mean ± SD, h/wk	11.1 ± 5.8	12.3 ± 6.3	12.9 ± 6.1	<.001 ^{b,c,d}
Time playing all sports, mean ± SD, h/wk	14.4 ± 6.7	15.5 ± 6.9	15.7 ± 6.7	.011 ^{c,d}
Time playing unorganized sports, mean ± SD, h/wk	6.8 ± 5.2	7.2 ± 5.3	7.2 ± 5.2	.398
Missed time with friends, n (%)	295 (58.2)	544 (72.6)	627 (83.2)	<.001 ^{b,c,d}
Traveled out of state, n (%)	84 (16.6)	228 (30.4)	344 (45.6)	<.001 ^{b,c,d}

^aIQR, interquartile range.

^bModerate level is significantly different than high level at Holm-adjusted $P < .05$.

^cLow level is significantly different than high level at Holm-adjusted $P < .05$.

^dLow level is significantly different than moderate level at Holm-adjusted $P < .05$.

caused without contact with a person or object. Each response was reviewed with each participant by an athletic trainer to ensure accuracy and correct classification of the responses.

Statistical Analysis

Data were summarized by means and SDs, frequencies and proportions (%), medians and interquartile ranges (IQRs), and odds ratios (ORs) and 95% CIs. Multivariable logistic regression analyses were utilized to examine associations between categorical variables (specialization category, exceeding or not exceeding volume recommendations) and the various injury categories, adjusting for differences in age and sex. Models for specialization were additionally controlled for hours per week in organized sports. Our primary analysis was the comparison of the odds of reporting any previous injury between levels of specialization. Our secondary analyses were comparisons of the odds of reporting any previous injury between meeting/exceeding volume recommendations and the comparison of specific injury types (overuse, concussion) or locations (upper extremity, lower extremity) between levels of specialization or meeting/exceeding volume recommendations. Similarly, multivariable regression analyses were used to examine relationships between the continuous variables (age, sport volume in hours and months, years of sport participation) and specialization category or injury history, adjusting for age and sex. Statistical significance was set at 2-sided a priori $P \leq .05$, and all analyses were performed in R statistical software (R Foundation for Statistical Computing).

To control for multiple testing, P values for multiple tests within a certain group were adjusted according to the Holm method. Post hoc pairwise comparisons of characteristic variables by the 3 specialization categories also utilized Holm-adjusted P values.

RESULTS

A total of 2011 participants (989 female; mean age, 13.7 ± 1.6 years) completed the questionnaires. Demographics by specialization category can be found in Table 1, and the frequency or primary sport distribution can be found in Table 2.

For the entire sample, age and sex influenced the distribution of specialization classification, with athletes classified as highly specialized more likely to be female (53.8%, $n = 406$) than male (46.2%, $n = 348$; $P = .011$) and specialization prevalence peaking at age 15 years (Figure 1). Therefore, age and sex were used as covariates for the remaining analyses. Compared with athletes in the low specialization category, highly specialized athletes started playing organized sports ($P = .002$) and their primary sport ($P < .001$) at a younger age and played their primary sport and organized sports in total for more months of the year ($P < .001$) and hours per week ($P < .001$ to $P = .011$).

Table 3 describes the demographics and questionnaire variables of respondents with and without a history of injuries over the past 12 months. Of the total sample, 295 (14.7%) participants reported a history of lower extremity overuse injuries, 118 (5.9%) participants reported a history of upper extremity overuse injuries, and 161 (8.0%) participants reported a history of concussions. The most common previously injured locations were the ankle ($n = 352$), wrist/hand ($n = 270$), head/neck ($n = 215$), and knee ($n = 201$). The most common previous overuse injury locations were the knee ($n = 91$), shoulder ($n = 73$), ankle ($n = 66$), and hip ($n = 58$). Compared with athletes without an injury history, athletes who reported a previous injury or overuse injury participated in their primary sport for more months of the year ($P < .001$ to $P = .004$) and participated in more hours per week for both their primary sport ($P < .001$ to $P = .036$) and organized sports in total ($P < .001$ to $P = .002$), even when controlled for age and sex.

TABLE 2
Responses for Selection of a Primary Sport

Sport	n (%)
Soccer	431 (21.4)
Basketball	404 (20.1)
Swimming/diving	231 (11.5)
Ice hockey	205 (10.2)
Volleyball	116 (5.8)
Track/cross-country	112 (5.6)
Lacrosse	111 (5.5)
Baseball	104 (5.2)
Football	94 (4.7)
Softball	73 (3.6)
Other	41 (2.0)
Cheer/dance	35 (1.7)
Gymnastics	34 (1.7)
Tennis	13 (0.7)
Wrestling	7 (0.3)

Age-, sex-, and weekly sport volume-adjusted ORs for the various specialization and volume classifications are presented in Table 4. Highly specialized athletes (reference: low specialization) were more likely to report a history of any injury, an overuse injury, or an upper extremity overuse injury. For our secondary analysis, athletes who exceeded the recommendation of playing 1 sport more than 8 months per year were more likely to report a history of any injury, an overuse injury of various types (any, upper extremity, lower extremity), or a concussion. Athletes who participated in more organized sport hours per week than their age (ie, a 16-year-old athlete who participated in his or her primary sport for more than 16 h/wk) were more likely to report a history of any injury or an overuse injury of any kind. Athletes who participated in more than 16 total hours of organized sport activity were more likely to report any previous injury or a previous overuse injury (any or lower extremity).

DISCUSSION

The most important finding of this study is that significant associations exist between sport specialization and injury history in a nonclinical population-based setting. Specifically, the odds of reporting a previous injury were 45% to 91% higher among highly specialized athletes compared with athletes in the low specialization category. The second most important finding of this study is that the odds of reporting a previous injury were 26% to 85% higher in youth athletes who exceeded sport volume recommendations of months per year and hours per week compared with athletes who met these recommendations. Finally, specialization prevalence appears to peak at approximately age 15 years, and female athletes are more likely to be classified as highly specialized than male athletes. This is the first report, to our knowledge, to observe these findings in a broad population-based sample of youth athletes participating in a wide variety of sports. The results of this study provide

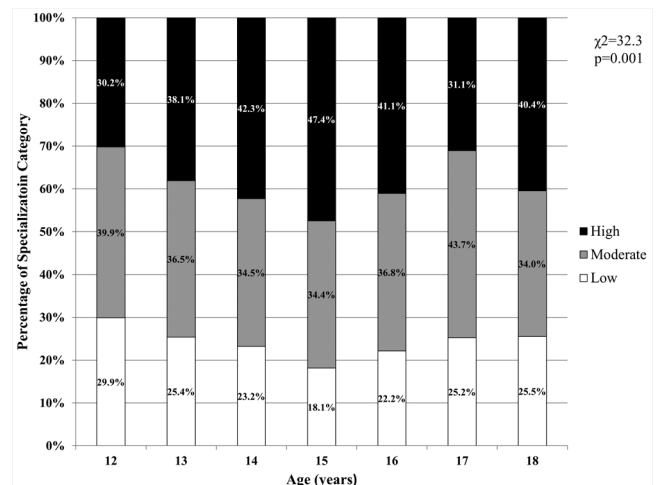


Figure 1. Distribution of specialization category by age.

further evidence of the relationship between early sport specialization, increased sport training volume, and injuries.

Sport Specialization

Specialization is associated with a history of injuries and overuse injuries, independent of age, sex, and weekly organized sport volume. Our results agree with previous research.¹³ Jayanthi et al¹³ observed that highly specialized athletes were more likely to report any injury (OR, 1.58) or an overuse injury (OR, 1.50) compared with athletes in the low specialization group. The reproduction of those findings in this study suggests a consistent association between specialization measured via the 3-point scale and an increased injury risk. It should be noted that Jayanthi et al¹³ adjusted for age and hours of training per week in sport in their analysis and recruited from patients reporting to a sports medicine clinic, while we additionally adjusted for sex and recruited from youth athletes currently participating at local sport events. Our study found significant sex differences between the various injury categories and levels of specialization, and therefore, we chose to additionally adjust for sex in our analyses. Additionally, Jayanthi et al¹³ found that highly specialized athletes were not at a higher risk for acute injuries. While our primary aim was to examine the association of specialization with overuse injuries, post hoc analyses revealed that the odds of reporting a previous acute injury of any kind (OR, 1.58; 95% CI, 1.24-2.00; $P < .001$), upper extremity acute injury (OR, 1.43; 95% CI, 1.09-1.88; $P = .011$), and lower extremity acute injury (OR, 1.41; 95% CI, 1.07-1.85; $P = .015$) were higher for highly specialized athletes compared with athletes in the low specialization category and were of similar magnitudes to our findings for overuse injuries. The contrast between this finding and previous research highlights the need for further prospective examination of the relationship of sport specialization with acute injuries.

TABLE 3
Comparisons Between Noninjured and Injured Participants^a

Variable	Any Injury Within 12 mo		P Value	Overuse Injury Within 12 mo		P Value
	No (n = 946)	Yes (n = 992)		No (n = 1585)	Yes (n = 377)	
Nonmodifiable						
Sex, n (%)			<.001			<.001
Male	534 (56.4)	450 (45.4)		864 (54.5)	140 (37.1)	
Female	412 (43.6)	542 (54.6)		721 (45.5)	237 (62.9)	
Age, mean ± SD, y	13.5 ± 1.6	13.9 ± 1.7	<.001	13.6 ± 1.6	14.1 ± 1.7	<.001
Time participating in primary sport, mean ± SD, y	6.3 ± 2.7	6.7 ± 2.7	.005	6.4 ± 2.7	6.6 ± 2.7	.740
Time participating in organized sports, mean ± SD, y	7.0 ± 2.4	7.5 ± 2.4	<.001	7.1 ± 2.4	7.5 ± 2.4	.036
Specialization						
3-point scale, n (%)			<.001			.040
Low	279 (29.5)	211 (21.3)		428 (27.0)	73 (19.4)	
Moderate	356 (37.6)	370 (37.3)		588 (37.1)	145 (38.5)	
High	311 (32.9)	411 (41.4)		569 (35.9)	159 (42.2)	
Playing 1 sport >8 mo, n (%)			<.001			.004
No	314 (33.2)	206 (20.8)		456 (28.8)	74 (19.6)	
Yes	632 (66.8)	786 (79.2)		1129 (71.2)	303 (80.4)	
Sport volume						
Primary sport, median (IQR), mo/y	9.0 (6.0-12.0)	10.0 (7.0-12.0)	<.001	9.0 (6.0-12.0)	10.0 (7.0-12.0)	.004
All sports, median (IQR), mo/y	12.0 (9.0-12.0)	12.0 (10.0-12.0)	<.001	12.0 (9.0-12.0)	12.0 (10.0-12.0)	.134
Primary sport, mean ± SD, h/wk	11.6 ± 6.0	12.8 ± 6.2	<.001	12.0 ± 6.1	13.0 ± 6.2	.036
All sports, mean ± SD, h/wk	14.5 ± 6.9	16.0 ± 6.7	<.001	15.0 ± 6.8	16.4 ± 6.7	.002
Unorganized sports, mean ± SD, h/wk	6.8 ± 5.2	7.4 ± 5.3	.002	7.0 ± 5.2	7.4 ± 5.3	.740
More time playing organized sports (h/wk) than age, n (%)			.002			.116
No	507 (53.6)	451 (45.5)		806 (50.9)	167 (44.3)	
Yes	439 (46.4)	541 (54.5)		779 (49.1)	210 (55.7)	
Organized sport:free play ratio >2:1, n (%)			.391			.740
No	428 (45.2)	430 (43.3)		709 (44.7)	163 (43.2)	
Yes	518 (54.8)	562 (56.7)		876 (55.3)	214 (56.8)	

^aBolded values indicate *P* < .05. IQR, interquartile range.

We observed that highly specialized athletes started playing their primary sport and organized sports at a younger age (reference: low specialization). Additionally, highly specialized athletes participated in both their primary sport and other organized sports for more months per year and hours per week than the low specialization group. Because the definition of specialization used to create the 3-point scale is “year-round intensive training in a single sport at the exclusion of other sports,” it is logical that highly specialized athletes would exhibit increased participation volume.¹³

Sport Volume Recommendations

Recommended cutoffs for youth sport participation have been made based on research suggesting that playing 1 sport more than 8 months of the year, participating in more than 16 total hours of organized sport activity per week, and playing more hours of organized sports per week than the athlete’s age are risk factors for an injury.^{1,12,13,17,19,20} Olsen et al¹⁹ observed that adolescent pitchers who participated in competitive baseball for

more than 8 months were more likely to report an arm injury (OR, 5.05). In the current study, we were able to demonstrate that regardless of sport, the odds of reporting an injury were 62% to 90% higher among youth athletes who compete in 1 sport for more than 8 months of the year compared with athletes who did not exceed 8 months of participation in a single sport. Previous research has also established an apparent relationship between hours of organized sport exposure and the risk of injuries, with the risk of injuries peaking for athletes who participate for more than 16 total hours per week.²⁰ We observed that athletes who exceeded this guideline of hours per week were more likely to have sustained an injury of any kind, an overuse injury, or a lower extremity overuse injury in the previous year. Finally, Jayanthi et al¹³ reported that injured youth athletes have 1.59 times greater odds of playing more hours of organized sports per week than their age compared with uninjured athletes. We observed that youth athletes who participated in sport for more hours per week than their age were more likely to report sustaining an injury of any kind or an overuse

TABLE 4
Odds Ratios for Specialization Category, Volume Recommendations, and History of Various Injury Types^a

	History of Any Injury	History of Overuse Injuries	History of Upper Extremity Overuse Injuries	History of Lower Extremity Overuse Injuries	History of Concussions
Specialization					
Low	—	—	—	—	—
Moderate	1.32 (1.05-1.67) ^b	1.39 (1.02-1.90) ^b	1.46 (0.85-2.61)	1.39 (0.99-1.98)	0.81 (0.52-1.27)
High	1.59 (1.26-2.02) ^c	1.45 (1.07-1.99) ^b	1.91 (1.14-3.35) ^b	1.37 (0.98-1.95)	1.27 (0.85-1.94)
Volume recommendations					
Playing >8 mo					
No	—	—	—	—	—
Yes	1.85 (1.50-2.27) ^c	1.60 (1.21-2.14) ^d	1.68 (1.06-2.80) ^b	1.66 (1.22-2.30) ^d	1.61 (1.08-2.47) ^b
Organized sports >16 h/wk					
No	—	—	—	—	—
Yes	1.36 (1.13-1.64) ^d	1.38 (1.09-1.74) ^d	1.43 (0.98-2.09)	1.44 (1.12-1.86) ^d	1.21 (0.87-1.68)
More hours per week of organized sports than age					
No	—	—	—	—	—
Yes	1.34 (1.12-1.61) ^d	1.26 (1.01-1.59) ^b	1.41 (0.97-2.08)	1.30 (1.00-1.67)	1.29 (0.93-1.79)
Organized sport:free play ratio >2:1					
No	—	—	—	—	—
Yes	1.00 (0.83-1.20)	0.94 (0.74-1.18)	0.83 (0.57-1.21)	0.99 (0.77-1.28)	1.06 (0.76-1.48)

^aValues are reported as odds ratio (95% CI). Models for specialization were adjusted for age, sex, and hours per week in organized sports, while models for volume recommendations were adjusted for age and sex. For specialization, “low” serves as the reference category. For each of the volume recommendations, “no” serves as the reference category.

^b $P < .05$.

^c $P < .001$.

^d $P < .01$.

injury in the previous year. Our findings reinforce the use of these guidelines for limiting the risk of injuries in youth athletes.

Having fun is the most important factor for a child deciding to continue sport participation.^{8,22} It has therefore been suggested that there should be an increased focus on free play and unstructured physical activity in youth sports, especially at younger ages.¹⁸ Youth athletes who participate in a balanced ratio of organized sport to free play (<2:1 organized sport to free play) have been shown to be at a decreased risk of serious overuse injuries.¹³ Our results were not able to support this conclusion, but we did find that highly specialized athletes were more likely to miss time with friends as a result of participating in their sport, potentially decreasing the amount of fun that these athletes experience while playing their sport. We agree that a shift in focus among youth sport organizers and participants from organized sport activities to free play and unstructured sport activities could serve as a strategy to increase the chance of continued sport participation and decrease the risks of an injury.

Effect of Early Sport Specialization and Excessive Training Volume

There are an estimated 60 million youths between 6 and 18 years old participating in sport.⁵ In our sample, 37.5% (n = 754) of athletes were highly specialized, which agrees with previous research in high school athletes.¹ If these rates

are applied to the national population of youth sport participants, there are potentially over 20 million youth athletes who are highly specialized and therefore at an increased risk of sport-related injuries. Using the injury prevalence rates seen in this study for the different specialization categories, over 2 million potential injuries per year could be prevented by adhering to sport volume recommendations and prescribing appropriate rest periods for highly specialized athletes to bring them into the low specialization category.

The popularization of the “10,000 hours rule”⁷ as a strategy to gain expertise in a skill may be contributing to the large prevalence of early sport specialization cases because of the hope that specialized training may increase the chances of a college scholarship or professional contract. By enrolling in sport at an early age and focusing exclusively on that sport year round, a child is able to accumulate more hours of practice in that sport than a similar child who participates in a variety of sports throughout the year or plays 1 sport with adequate time off to rest. However, a recent meta-analysis concluded that only 18% of the variance in sport performance is explained by deliberate practice.¹⁴ Therefore, pursuing early specialization as a strategy for accumulating hours of deliberate practice to gain mastery of sport skills may not be beneficial, especially in light of the apparent risks of early specialization, such as psychological burnout and overuse injuries.^{10,13,15} In fact, athletes who progress to elite levels appear to sample multiple sports during early adolescence, specialize in 1 sport at a later age, and spend less time in deliberate

training in childhood compared with nonelite athletes.^{4,6,16} Therefore, a model of early diversification of sport activities with a focus on unstructured play may be the most beneficial strategy not only for improving athletic performance and decreasing negative outcomes but also for encouraging lifelong physical activity.^{2,5}

Limitations

Recall bias is a limitation of this study. Participants were asked to recall any previous sport-related injury in the previous 12 months and the number of months during the year and hours during the week that they participate in various sport activities. It is possible that participants who had suffered an overuse injury in the previous year may be more likely to recall higher levels of specialization or sport volume in the previous year, especially if they had been consulted by a health care provider regarding the cause of their overuse injury. However, we attempted to limit this bias by having each questionnaire reviewed individually with the participant by a certified athletic trainer to ensure accuracy and correct classification of the injury and sport volume responses. Younger athletes could have more difficulty accurately recalling these variables, but we thought that our approach was reasonable given the on-site nature of the data collection, large sample size, and critical importance of investigating these issues in a young population. The age of specialization or age that athletes quit all other sports was not determined, which may play a role in the risk of prospective injuries. Participants were from the same geographical area, and it is likely that sport specialization prevalence is affected by regional differences and socioeconomic status. Future research should prospectively track athletes from a wide variety of regions and background demographics to objectively quantify sport volume and the injury risk. Because of our study design, we had unequal numbers of participants from the various sports recruited, with a large portion of our sample consisting of team sports (soccer, basketball, ice hockey, volleyball). It is possible that our estimation of the prevalence of specialization would be different from samples that are recruited from different sports or with larger numbers of individual sport athletes (gymnastics, tennis, dance). It should be noted that the volume recommendations utilized in this study are general, and more sport-specific guidelines should be developed. However, general guidelines are easy to remember and communicate and are an effective starting point for reducing youth sport injuries. Additionally, we focused on team sports, which may limit the generalizability of these findings to individual sport athletes. Future research is needed to determine sport-specific training volume recommendations and guidelines to maximize youth sport safety.

Although we found associations between specialization, increased sport volume, and injuries, it is not possible to infer causality from these associations because of the cross-sectional nature of this study. While it is possible that specialization may lead to increased injuries, it is also possible that an athlete who suffers an overuse injury may specialize by quitting the sport that caused his or her injury or that an unknown third factor may be associated

with both specialization and injuries. It is also unclear whether the associations found in this study between volume and injury history represent true threshold effects or rather just increased opportunities for an injury. For example, the value of 16 hours per week was the highest volume category developed by Rose et al²⁰ that participants could select, so it is unclear whether 16 hours per week is a useful cut point that is associated with increased injuries or if it just represents an increased level of exposure presenting more opportunities for an injury. Future prospective studies should control for sport exposure levels and accurately track sport volume measures such as months per year and hours per week of sport participation to determine whether absolute sport volume cutoff values exist.

CONCLUSION

Among a broad sample of youth sport participants, high levels of specialization were associated with a history of injuries, independent of age, sex, and weekly organized sport volume. Athletes who exceeded current sport volume recommendations (participating no more than 8 months of organized sports per year, no more hours per week of organized sports than their age, no more than 16 total hours of organized sports per week) were more likely to report a history of injuries and overuse injuries in particular, with athletes who participated in 1 sport more than 8 months of the year having an increased rate of injuries across 5 different injury categories, including overuse injuries and concussions. There is a large population of youth sport participants at risk for injuries, with over a third of the youth athletes in this sample classified as highly specialized.

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