Sex Differences in Youth and Young Adult Sport Training Patterns, Specialization, and Return to Sport Durations

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Background: Young female athletes may have higher rates of overuse injuries and sport specialization than male athletes. The association of sports specialization and return to sport (RTS) timeframe is also unknown.

Hypothesis: Specialized female athletes will have more intense, year-round training patterns, more overuse injuries, and longer RTS times than male athletes.

Study Design: Cohort study.

Level of Evidence: Level 3.

Methods: Injured athletes aged 10 to 23 years presenting to a sports medicine clinic reported their degree of sport specialization and training patterns. Skeletal maturity was estimated using the Khamis-Roche method. Injury type and RTS timeframes were categorized from electronic medical records. Chi-square tests and logistic regression analysis assessed associations between variables.

Results: A total of 485 athletes (40.2% female) were enrolled. Higher degrees of sport specialization were associated strongly with overuse injuries ($P < 0.01$). After adjusting for specialization, female athletes were more likely to sustain an overuse injury (adjusted odds ratio, 1.49; $P = 0.04$). Female athletes participated in fewer total physical activity hours per week ($P < 0.01$), fewer free play hours per week ($P < 0.01$), and participated in their main sport for more months of the year than their male counterparts ($P = 0.02$). Female athletes were more likely to be at a higher developmental stage than male athletes ($P < 0.01$). RTS timeframes were increased in athletes with serious overuse injury; however, no association was found between degree of specialization and RTS time regardless of sex.

Conclusion: Female athletes are more likely to sustain overuse injuries with more organized, year-round, training and less free play compared with their male counterparts.

Clinical Relevance: Female sex may be an independent risk factor of overuse injury. Future strategies to mitigate these risks may include increased free play hours and limiting year-round training through seasonal rest.

Keywords: female athletes; sports specialization; youth sport

Youth participation in organized sport has numerous mental and physical health benefits, including lower depressive symptoms, lower perceived stress, greater self-esteem, greater cardiovascular fitness, and lower risks of developing metabolic syndrome later in life.[22] Beyond personal health benefits, sport participation teaches youth resiliency, leadership, and teamwork skills that can translate into successful careers.[22] In fact, 94% of female executives and 80% of Fortune 500 female executives have a background in sports.[11] Unfortunately, young female athletes are more likely than male athletes to drop out of sport (32% vs 22% in urban high schoolers),[33] and are more likely to sustain overuse injuries than their male counterparts (odds ratio [OR] 1.5; $P < 0.01$),[17] both of which restrict their time in sports.[17,28,29,31,34]

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Overuse injuries may be due to an athlete's training patterns. In recent years, there has been a trend in youth sports toward specialization in a single sport at an earlier age than in previous generations.[8] High degrees of sports specialization, or "the intentional and focused participation in a single sport for a majority of the year that restricts opportunities for engagement in other sports and activities,"[6] are associated with overuse injuries in young athletes.[4,15,17,20,28] Although specialization affects both male and female athletes, female athletes specialize more frequently in their sport.[5,28,30] A study of >1200 youth athletes found that only female athletes had an association between higher degrees of specialization and serious overuse injuries, that is, overuse injuries defined as taking >30 days to return to sport (RTS).[18] Thus, specialization may affect the risk profiles of young athletes differently based on their sex.

Due to the increase in overuse injury associated with specialization, many health organization guidelines have recommended against early specialization.[1] In previous literature, the age of 12 years is suggested as a proxy for prepubescence and defines early sports specialization[21]; yet there has not been a study that has exhibited an increased injury risk in athletes who specialize before the age of 12. In fact, a longitudinal study of 1208 youth athletes revealed that there was no association between injury risk and specializing before the age of 12 years.[17] In addition, a study of highly specialized Canadian youth athletes showed no significant difference in the rate of injuries between those who specialized before the age of 12 years and those who specialized later.[38] Since children enter puberty at different chronological ages, using a measure of skeletal maturation such as percent of predicted adult height (PPAH) may be a better indicator for injury risk than chronological age, as it can both individualize and standardize when athletes enter their adolescent growth spurts. For example, in a study of young elite soccer players, growth-related injuries occurred most frequently when athletes were 86 to 95 PPAH, which correlates to peak growth velocity.[24]

In addition to specialization, other training patterns are associated with injuries in youth athletes. Youth athletes who participate in more hours of training per week than their age,[17,30,35] and athletes who play their main sport for >8 months per year are more likely to sustain an overuse injury.[17,30] Youth athletes whose training ratio is greater than 2:1 of organized sport training hours to free play hours also have higher odds of sustaining an injury.[12,17] Competition play puts athletes at higher risk for injury than training.[16] Moreover, athletes have been shown to be at higher risk of injury when exposed to acute spikes in training loads relative to capacity.[13] Although these associations have been well demonstrated in the literature, sex-based subanalyses have been reported infrequently. Despite numerous studies related to sport specialization and injury risk, sex differences have unfortunately often not been included. Thus, a gap exists as to how the risk profiles of these training patterns may influence male and female athletes differently. In addition, to our knowledge, there has been no clinical study evaluating RTS timeframes following injury in young specialized athletes.

The purpose of this study was to: (1) evaluate sex differences in training patterns, including sport specialization, and (2) examine how these patterns pertain to overuse injuries in a clinical population of injured youth and college athletes. In addition, we will (3) evaluate the association between degree of sports specialization and RTS durations in a clinical population of injured male and female youth athletes.

METHODS

Participant Recruitment

Injured youth athletes who presented to an academic hospital-based sports medicine clinic were recruited for participation. Study approval was obtained from the institutional review board. Athletes were offered participation if they met the following inclusion criteria: (1) were 10 to 23 years of age, (2) participated in organized sport, and (3) sustained their injury during their organized sport. Athletes were excluded if (1) they were non-English speaking and/or (2) their sport-related injury was deemed likely to require surgery by a sports physician at their initial clinic visit, which would preclude return to play during the 6-month study period. Signed consent was obtained from participants who were ≥18 years; signed assent and signed parental/guardian consent was obtained from athletes who were 10 to 17 years old. Recruitment was incentivized with a US $20 dollar gift card awarded to participants who completed all follow-up surveys to the study completion at 6 months, or who completed at least 1 additional interim survey after they returned to sport, if return occurred before the study completion. Study tracking began after participants consented.

Surveys

All participants completed a baseline survey via RedCap, which assessed patient self-reported biological sex, parental height, organized sport and free play participation hours, and current ability to participate in practice and competition. Follow-up surveys, which assessed when participants were able to return to practice and competition, were emailed to participants at 1, 3, and 6 months from the time the baseline survey was completed.

Skeletal Maturation

At the time of enrollment, the participant's height and mass were measured in clinic. The participant and/or an accompanying family member was asked to provide the height of the athlete's biological father and mother so that predicted adult height could be calculated using the Khamis-Roche method as described by Towlson et al.[37] The athlete's height at the time of enrollment was used to calculate their PPAH. Athletes that were 85 to 96 PPAH were categorized as being in their peak height velocity (PHV). Athletes <85 PPAH were categorized as being in their pre-PHV. Athletes >96 PPAH were categorized as post-PHV. Athletes who were ≥18 years old were automatically grouped into the post-PHV group (and listed as a PPAH of 100%), as the Khamis-Roche scale is not validated for this age group.

Injury Type

Injuries were classified by physician documentation in the electronic medical record (EMR). A standardized coding system was used to classify injuries as acute, overuse, or serious overuse as per previous studies.[17,20] Acute injuries were defined as traumatic injuries such as ankle sprains and concussions, whereas overuse injuries were defined as gradual onset injuries such as patellofemoral pain and calcaneal apophysitis. Serious overuse injuries were defined as nontraumatic injuries that typically require >30 days to RTS, such as stress fractures, osteochondritis dissecans, spondylolysis, hip impingement, and elbow ligament injuries.[20]

Return to Sport

Athlete-reported RTS was assessed via 1-, 3-, and 6-month follow-up surveys where athletes were asked for the number of weeks the athlete "had to completely miss training or competition due to this injury/pain from its onset." Retrospective EMR review was also used to determine RTS timeframes. Return to modified sport (RTMS) and return to full sport (RTFS) were defined as the duration between the date on which the athlete stopped participation in their main sport due to injury and the date on which they were cleared to return to modified play (practice or restricted sport) or full play (competition-level play) per their treating physician. RTMS and RTFS were categorized as <10 days, 10 to 30 days, and >30 days. Participants with an unclear RTMS or RTFS status after retrospective EMR review were not included in final analysis for RTS data.

Acute to Chronic Workload Ratio

Acute-to-chronic workload ratio (ACWR) was defined as the athlete's total training and competition hours in the 1 week before their injury divided by the athlete's weekly average training and competition hours in the 4 weeks before their injury (coupled ACWR).[14]

Time to Presentation

EMR-based time to presentation (TTP-EMR) was defined as the number of weeks from the date on which the injury was sustained until the date the athlete presented to a sports medicine clinic by EMR review. This time period was categorized as ≤1 week, between 1 and 4 weeks, and >4 weeks.

Statistical Analyses

The sample size was fixed based on enrollment into the study. Any missing data were quantified by reporting denominators. Descriptive statistics for continuous variables (ie, training outcomes) included means and standard deviations. Spearman rank correlation was used to assess free play hours versus age. Categorical variables were summarized using frequency counts and percentages. These statistics were calculated for male versus female injured athletes. Baseline continuous characteristics were compared between male and female athletes using a standard linear model for 2 independent groups implemented with the SAS MIXED procedure. Baseline categorical characteristics were compared between male and female athletes with a chi-square test. CIs (95%) were calculated for injury prevalence by RTMS and RTFS. Univariable and multivariable logistic regression were performed to identify risk factors and potential confounding variables (ie, sex, age, and sport specialization) associated with injury type (outcomes: overuse injuries relative to acute injuries and serious overuse injuries relative to overuse injuries). Statistical significance was defined as a 2-sided *P* value of <0.05.

RESULTS

Sex Differences in Training Patterns

Baseline survey data was collected from 485 injured athletes (40.2% female; Table 1); 68% of all participants played only a single sport or indicated a main sport. Of these athletes, tennis (30.42%), soccer (18.37%), and lacrosse (9.94%) were the most prevalent sport types (Table 4). There were no differences in mean age between male and female athletes (16 years old; P = 0.57) (Table 1). There was no significant difference in the distribution of specialization status between male and female athletes (P = 0.15); however, female athletes were more likely than male athletes to train for >8 months of the year in their main sport (P = 0.02) and, on average, trained for more months of the year than male athletes ($P < 0.01$). Male athletes participated, on average, in more hours of total physical activity per week than their female counterparts [male athletes, mean 21.0 (SD = 10.6); female athletes, mean 18.1 (SD = 9.8); $P < 0.01$)] and had more free play hours per week [male athletes, mean 4.5 (SD = 5.2), female athletes, mean 2.5 (SD = 3.3); $P < 0.01$)]. Athlete age was correlated negatively with free play hours for both male and female athletes (female r_s = -0.18; P = 0.01; male r_s = -0.12, P = 0.04). Similarly, the percentage of athletes that exceeded the recommended 2:1 ratio of organized sport to free play hours was significantly higher in female (89.7%) than in male (79.3%) athletes ($P < 0.01$) (Table 1). The median ratio of organized sport to free play hours of the subset of athletes who had >0 hours of free play was significantly higher for female [mean 7.65 (SD = 6.8)] than male [mean 5.91 (SD = 5.6); $P < 0.01$] athletes (Table 1).

There was no significant difference between sexes in organized sport participation hours per week during the 4 weeks before their injury [male athletes, mean 16.5 (SD = 8.8); female athletes, mean 15.7 (SD = 8.7); P = 0.32] and ACWR [male athletes, mean 0.96 (SD =0.6), female athletes, mean 0.99 (SD = 0.6); P = 0.51]. The majority of both male and female athletes had a competition-to-training ratio (CTR) of <0.3 (male athletes, 80.0%, female athletes, 75.8%; P = 0.43) and no significant difference in CTR was found between sexes (Table 1).

Injury Type

In our population, female athletes had greater odds of sustaining any type of overuse injury, serious or nonserious, compared with an acute injury than male athletes (OR, 1.6; P = 0.02) (Table 2). Female sex maintained higher odds of sustaining an overuse injury than male sex even after adjusting

Table 1. Participant characteristics and training patterns by sex

	N	Total	Male	Female	*P* value
Participants		485	290	195	
Age, y	484	16 ± 2, 484	16 ± 2, 289	16 ± 2, 195	0.57
BMI, kg/m^2	484	22.1 ± 3.9, 484	22.2 ± 4.4, 289	21.9 ± 3.1, 195	0.42
Specialization	485				0.15
Low		194/485 (40.0%)	126/290 (43.4%)	68/195 (34.9%)	
Moderate		160/485 (33.0%)	88/290 (30.3%)	72/195 (36.9%)	
High		131/485 (27.0%)	76/290 (26.2%)	55/195 (28.2%)	
Injury type	485				0.06
Acute		236/485 (48.7%)	154/290 (53.1%)	82/195 (42.1%)	0.02
Nonserious overuse		178/485 (36.7%)	97/290 (33.4%)	81/195 (41.5%)	0.07
Serious overuse		71/485 (14.6%)	39/290 (13.4%)	32/195 (16.4%)	0.37
Developmental stage	483				<0.01
Pre PHV (<85%)		25/483 (5.2%)	22/288 (7.6%)	3/195 (1.5%)	<0.01
Circa PHV (85%-96%)		87/483 (18.0%)	72/288 (25.0%)	15/195 (7.7%)	
Post PHV (>96%)		371/483 (76.8%)	194/288 (67.4%)	177/195 (90.8%)	
Total physical activity hours per week	485	19.83 ± 10.39	20.98 ± 10.64	18.12 ± 9.78	<0.01
Organized sports, hours per week	485	16.15 ± 8.75	16.47 ± 8.79	15.66 ± 8.70	0.32
Free play, hours per week	485	3.7 ± 4.6	4.5 ± 5.2	2.5 ± 3.3	<0.01
Ratio of organized sports:free play >2:1	485				<0.01
High (>2:1)		405/485 (83.5%)	230/290 (79.3%)	175/195 (89.7%)	
Low (≤2:1)		80/485 (16.5%)	60/290 (20.7%)	20/195 (10.3%)	
Median ratio organized sports: free play	404	6.53 ± 6.08	5.91 ± 5.59	7.65 ± 6.76	<0.01
Weekly sports hours > age in years	484				0.20
High		198/484 (40.9%)	125/289 (43.3%)	73/195 (37.4%)	
Low		286/484 (59.1%)	164/289 (56.7%)	122/195 (62.6%)	
Training >8 months per year	485	224/485 (46.2%)	121/290 (41.7%)	103/195 (52.8%)	0.02
Time training for main sport, months per year	485	7.87 ± 2.29	7.62 ± 2.29	8.24 ± 2.24	<0.01
ACWR	485	0.97 ± 0.58	0.96 ± 0.58	0.99 ± 0.59	0.51
CTR	484				0.43
<0.3		379/484 (78.3%)	232/290 (80.0%)	147/194 (75.8%)	
≥0.3-1.1		96/484 (19.8%)	54/290 (18.6%)	42/194 (21.6%)	

(continued)

Table 1. (continued)

	N	Total	Male	Female	*P* value
>1		9/484 (1.9%)	4/290 (1.4%)	5/194 (2.6%)	
RTMS	472				0.85
<10 days		215/472 (45.6%)	125/281 (44.5%)	90/191 (47.1%)	
10-30 days		161/472 (34.1%)	98/281 (34.9%)	63/191 (33.0%)	
>30 days		96/472 (20.3%)	58/281 (20.6%)	38/191 (19.9%)	
RTFS	378				0.72
<10 days		65/378 (17.2%)	41/229 (17.9%)	24/149 (16.1%)	
10-30 days		133/378 (35.2%)	77/229 (33.6%)	56/149 (37.6%)	
>30 days		180/378 (47.6%)	111/229 (48.5%)	69/149 (46.3%)	

Values are number (%) of athletes, or mean (SD). ACWR, acute-to-chronic workload ratio; BMI, body mass index; CTR, competition-to-training ratio; PPAH, percent of predicted adult height; RTFS, return to full sport; RTMS, return to modified sport.

Table 2. Univariable and multivariable analysis of characteristics associated with overuse compared with acute injury

Risk factors	Univariable model OR [95% CI]	*P* value	Adjusted OR[a] [95% CI]	*P* value
Female vs male sex	1.56 [1.08, 2.23]	0.02	1.53 [1.04, 2.24]	0.03
High vs low specialization	3.94 [2.46, 6.32]	<0.01	3.84 [2.38, 6.19]	<0.01
High vs moderate specialization	1.92 [1.18, 3.13]	<0.01	1.89 [1.15, 3.30]	<0.01
Moderate vs low specialization	2.07 [1.35, 3.16]	<0.01	2.05 [1.33,3.17]	<0.01
Age, per 1-year decrease	1.09 [1.01, 1.20]	0.03	1.10 [1.01, 1.85]	0.03

OR, odds ratio.
[a]Multivariate model female vs male category is adjusted for specialization and age; specialization categories are adjusted for sex and age; age is adjusted for sex and specialization.

for sports specialization and age (OR, 1.5; $P = 0.03$) (Table 2). Female athletes did not have a statistically significant higher prevalence of serious overuse injury than male athletes (16.4% vs 13.4%; $P = 0.37$) (Table 1).

In addition, a higher degree of sports specialization, even after adjusting for sex and age, was associated with an increased risk of any overuse injury (moderate specialization OR, 2.1; $P < 0.01$; high specialization OR, 3.8; $P < 0.01$) (Table 2).

Return to Sport

Of the 485 enrolled athletes, RTMS was determined on 472 athletes (99.3%), and RTFS was determined on 378 (77.9%) using EMR. Approximately half (45.6%) of the athletes RTMS in <10 days, while 47.6% of the athletes RTFS in >30 days (Table 1).

Injury type was associated with RTMS (chi-square, $P < 0.01$) and RTFP (chi-square, $P < 0.01$). Those with serious overuse injuries were more likely to take >30 days to RTS as compared with <30 days in both RTMS (Figure 1b) and RTFS (Figure 1a).

No association was demonstrated between degree of specialization and RTMS or RTFS. There were also no significant differences in RTMS and RTFS durations between sex. Among male athletes, high sports specialization was associated with longer self-reported time away from sport (chi-square, $P < 0.01$). Among female athletes, there was no association between

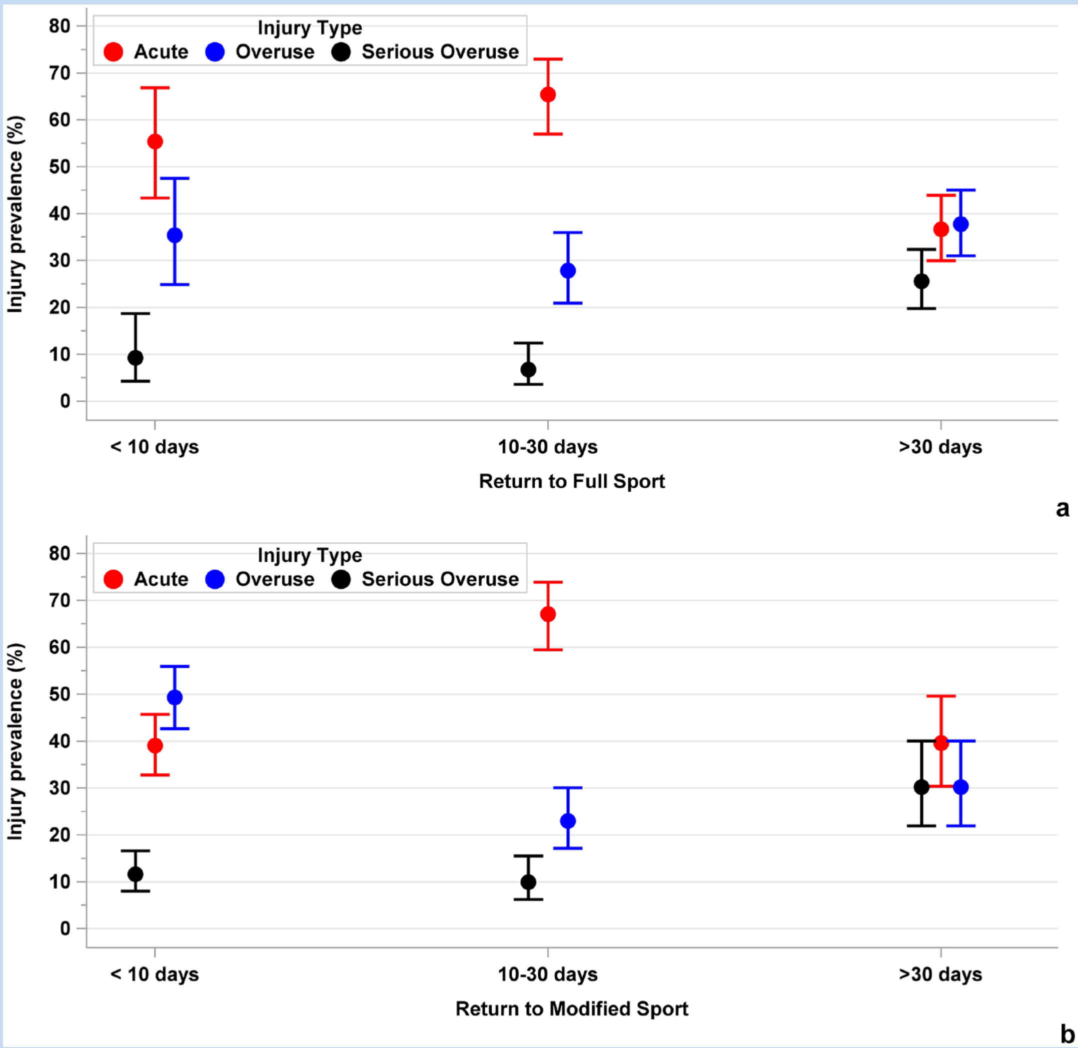

Figure 1. Injury prevalence and 95% CIs by RTS. RTS, return to sport. Vertical lines, 95% CI.

specialization and self-reported time away from sport (chi-square, $P = 0.08$).

Percent of Predicted Adult Height

Most of the athletes were post-PHV at the time of their injury (female athletes, 90.8%; male athletes, 67.4%). Female athletes were more likely to be at a higher developmental stage than their male counterparts ($P < 0.01$). There was no association between specialization and PPAH for either sex (male chi-square, $P = 0.42$; female chi-square, $P = 0.72$).

Time to Presentation

For athletes with acute injuries, there was an association between increased time to presentation and increased RTMS (chi-square, $P < 0.01$) and RTFS (chi-square, $P < 0.01$). This association was not demonstrated for athletes with overuse injuries (RTMS chi-square, $P = 0.22$; RTFS chi-square $P = 0.12$).

DISCUSSION

To our knowledge, this is the first study to outline sex differences in training patterns, specialization, and RTS in a clinical population of youth athletes. Understanding these sex differences and potential risk factors may be important to structuring RTS plans following an injury and injury risk mitigation strategies through counseling.

Sex Differences in Training Patterns

In our population of injured young athletes, male athletes participated in more hours of physical activity per week than female athletes due, in part, to an increased number of reported free-play hours. Female and male athletes had no statistically significant difference in the average number of reported organized sport hours per week.

Previous studies have demonstrated that young athletes that exceed an organized sport-to-free play ratio of 2:1 are at increased risk of injury.[12,17,20] In 2 separate cohorts of injured youth athletes, 55% to 60% of athletes exceeded this 2:1 ratio of organized sport to free-play.[20,30] Similarly, in our population, the majority of both sexes were likely to exceed this ratio, although female athletes were more likely to do so than male athletes (male, 79.3%; female, 89.7%; $P < 0.01$). However, these athletes exceeded this ratio by large margins. The median ratio of organized sport to free play of the subset of athletes who had >0 hours of free play was >3 times greater than the expected ratio of 2:1 (Table 1). The increased percentage of organized sport-to-free play hours found in our data, as compared with previous studies, may be explained by the older age of our cohort. Our data indicated that there is a negative correlation of free play participation with increasing age for both male and female athletes. The mean age of this study population was 16 years, whereas the mean age of both aforementioned studies was approximately 14 years.[20,30] Young adult athletes may not participate in free play to the same degree as younger age groups. In addition, a recent literature review concluded that, over the last few decades, US youth spend decreasing amounts of time in unstructured, outdoor play.[3] Another explanation for the increased percentage of athletes exceeding the 2:1 rule is the enrolling clinics' locations in the Atlanta suburbs, as compared with the Wisconsin and Chicago suburbs where the aforementioned previous 2 studies were conducted. The southeast has a warmer year-round climate, which may foster an environment for more year-round outdoor organized sports participation. Moreover, the clinic to which the majority of these athletes presented is in a high socioeconomic area, and athletes of higher socioeconomic status have previously been shown to have increased ratios of organized sport-to-free play hours.[19] This correlation may be due to higher financial costs associated with year-round organized youth sports and the ability for those of higher socioeconomic status to pay for those costs.

Previous studies have determined that youth athletes that train for >8 months of the year have an increased risk of overuse injury.[25,26,30] In our population, female athletes were more likely than male athletes to train in their main sport for >8 months of the year (female, 52.8%; male, 41.7%; $P = 0.02$). On average, female athletes trained for 8.24 months as compared with male athletes, who trained for 7.62 months ($P < 0.01$). This increased year-round (>8 months/year) training in female athletes could explain, in part, the increased prevalence of overuse injuries observed in female athletes in our sample. Of note, this pattern of increased year-round training is different from a study of youth soccer players, in which male athletes were more likely to train for more months of the year than female athletes.[23] Soccer players comprised only 18.37% of our participants who played only 1 sport or had a main sport (Table 4), which may account for this discrepancy.

Both increased year-round training in an organized sport and decreased free play promote repetition of the same movement patterns. Free play is theorized to be protective against injury as it allows young athletes to develop movement patterns complementary to those used in their main sport in a self-regulated fashion where they may feel less pressure to play through pain.[19] Thus, the combination of neuromuscular deficits from decreased free play and increased repetitive movement patterns from year-round play in female athletes likely contribute to their risk of overuse injuries. This concept is supported in the literature as young athletes from lower socioeconomic backgrounds log more free play hours and have fewer serious overuse injuries than their higher socioeconomic counterparts who had less free play hours and more serious overuse injuries.[19]

The remaining training patterns that were analyzed in this study did not show statistical differences between male and female athletes. There was no difference in the distribution pattern of sport specialization between male and female athletes ($P = 0.15$). In previous studies, female athletes have demonstrated higher degrees of specialization than male athletes[28,30]; however, specialization is associated with sport type, and the distribution of sport type within each study population is likely to be different.[27] Female athletes may be more likely to choose sports such as gymnastics that lend themselves to specialization. In a study of 1550 former NCAA athletes, female athletes were more likely than male athletes to play a single sport before the age of 15 years but, in the subanalysis of sex-equivalent sports, there was no significant difference in early specialization between sexes.[32] It is possible that female athletes may tend to specialize more than male athletes in other populations, but this may need to be studied further.

Both male and female athletes averaged an ACWR of just <1.0, which is within the recommended range for injury prevention (0.8-1.3).[13] Previous studies have demonstrated an increased risk of overuse and serious overuse injury when weekly training hours exceed age.[12,17,20] In our study, 40.9% of athletes participated in more sport hours per week than their age in years, with no difference between sexes ($P = 0.20$). This is within the previously demonstrated distribution range of 26.6% to 54.4% of athletes whose workload hours per week exceeded age.[20,30]

Sex Differences in Injury Type

In our study, the odds of sustaining any overuse injury as compared with an acute injury was almost 50% higher in female athletes than in their male counterparts, even after adjusting for specialization. This is consistent with previous studies that note that female athletes are more likely to sustain overuse injuries.[12,17,34,39] Although female athletes had mildly higher prevalence of serious overuse injuries than male athletes, it did not reach statistical significance (Table 1).

It should be noted that our study examined sport injuries from a variety of sports, rather than sex-equivalent sports. Different sports have been demonstrated to result in different injury types. American football—an almost exclusively male sport—was the sport with the highest proportion of acute injuries in a previous study of young athletes,[27] and, in our study, American football was the fourth most prevalent sport type for all athletes

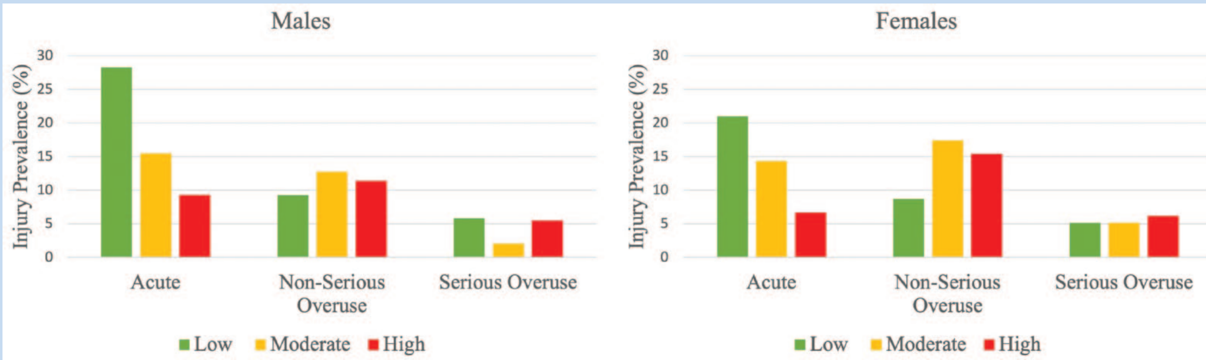

Figure 2. Frequency of type of injury by degree of specialization for male and female athletes.

who had a main sport or single sport (Table 4). Conversely, the sports with the highest proportion of serious overuse injuries are gymnastics, tennis, and dance.[27] Female athletes more commonly participate in these individual, technical sports, such as gymnastics and dance,[18] which may contribute to their higher prevalence of overuse injuries as there is less opportunity for contact and collision injuries. Thus, not accounting for sport-type differences could skew the data. In fact, an epidemiological study of high-school sports showed that, across 9 different sports, male athletes had a higher rate of acute injuries than female athletes, but when the subanalysis only included sex-equivalent sports, female athletes had higher incidences of both acute and overuse injuries.[31]

Jayanthi and Dugas[18] previously reported that increasing levels of sports specialization increased the frequency of serious overuse injuries in adolescent female athletes and the inverse relationship with adolescent male athletes. In our data, however, we did not see this trend (Figure 2). Athletes who participated in gymnastics and dance as their only sport or main sport contributed to a total of only 1.65% of our total population, whereas these sports with known serious overuse injury risk were a larger percentage (4.12%) in the study that found this trend.[18,27] Again, future studies should continue to examine this finding as there is a paucity of literature that specifically examines how sex differences in the training patterns of young athletes may affect injury type.

Sex differences and PPAH

In our cohort of 10- to 23-year-olds, the mean age for male and female athletes was the same, although female athletes were more likely to be further along in their skeletal development than male athletes ($P < 0.01$) (Table 1). This is not surprising as girls tend to have their growth spurt approximately 2 years earlier than boys.[36] However, our data confirm that age and skeletal maturity differ by sex; thus, future work should investigate the relationship between early sports specialization and biological maturation in greater depth in an injured and noninjured cohort, rather than categorizing by chronological age.

Specialization and Injury Type

Previous studies have found that highly specialized athletes are more likely to sustain overuse injuries than their lower-specialized counterparts.[17,20,28,30] Our data confirmed this finding, as the odds of any overuse injury were almost 4 times higher for athletes with a high degree of sports specialization as compared with low specialization (Table 2). When adjusted for sex and age, the odds of an overuse injury were 3.84 times higher for high specialization ($P < 0.01$) and 2.05 times higher for moderate specialization compared with low specialization ($P < 0.01$). Thus, regardless of sex and age, specialization increases the risk of overuse injury in our dataset. This is in contrast to a study of >2000 adolescent athletes that found that only female athletes had an association between higher degrees of specialization and reported overuse and acute injuries, after adjusting for training hours and age.[7] One explanation for this difference is again the increased organized sport training hours and decreased weekly free-play hours for all athletes in the present study.

Similarly, the odds of sustaining a serious overuse injury compared with an acute injury were 3 times higher for those with high specialization compared with low specialization (Table 3). However, in this cohort, a high degree of specialization was not associated with an increased risk of serious overuse injuries compared with nonserious overuse injuries (Table 3), which is contrary to previously reported data.[20] This should be evaluated further in future studies to examine trends in other populations. It has previously been theorized that the repetitive movements of specialization in youth athletes predispose the athletes to overuse injuries because of their relatively decreased bone density, lower lean tissue mass, and increased joint hypermobility compared with adults.[9] This is still supported in our data as specialization is a risk factor for any type of overuse injury.

Specialization and RTS

Given that specialization has been associated with an increased risk of overuse injury, and specifically serious overuse injuries,[17] we hypothesized that highly specialized athletes would sustain

Table 3. Univariable analysis of characteristics potentially associated with type of injury

	Serious vs acute univariable model OR [95% CI]	*P* value	Serious vs nonserious univariable model OR [95% CI]	*P* value
Female vs male athletes	1.54 [0.90, 2.64]	0.12	0.98 [0.57, 1.71]	0.95
High vs low specialization	3.19 [1.69, 6.03]	<0.01	0.72 [0.38, 1.39]	0.33
Low vs moderate specialization	1.00 [0.50, 1.98]	1.00	2.72 [1.32, 5.62]	<0.01
Age, per 1-year increase	1.02 [0.89, 1.16]	0.83	1.15 [1.01, 1.30]	0.03

OR, odds ratio.

injuries that require higher RTS timeframes. Currently, there is no unified definition for RTS in sports medicine research. Some refer to RTS as returning to competition, whereas others refer to RTS as returning to practice with restrictions on competition.[10] As such, we measured both RTMS and RTFS per physician clearance. Our results confirmed that serious overuse injuries had both longer RTMS and RTFS than other injury types (Figure 1). This was to be expected as serious overuse injuries were defined as diagnoses that commonly take >30 days to heal. Our results, however, did not demonstrate an association between specialization and RTMS ($P = 0.24$) or RTFS ($P = 0.39$). One explanation for this is that RTS timeframes do not always capture injury healing status. For example, a soccer player with a hand fracture may be able to RTFS quickly with a cast, while this same injury in a tennis player would likely prevent that player from RTMS or RTFS. It is also important to note that our data did not establish a correlation between increased specialization and increased serious overuse injury type compared with nonserious overuse. Thus, it is consistent within our data that high specialization would not have increased RTS >30 days. Regardless, our data suggest that specialization may not affect RTS duration.

There was also no difference between sexes when examining specialization and RTMS ($P = 0.85$) and RTFS ($P = 0.72$). Interestingly, when RTS was subjectively measured by asking athletes on their 1-month follow-up survey how long they had to "completely miss training or competition" due to their injury, there was an association with higher degrees of specialization and increased number of weeks missed in male but not female athletes (chi-square, $P < 0.01$).

Time to Presentation and RTS

Increased TTP was associated with increased RTMS for acute injuries only (chi-square, $P < 0.01$). TTP was also associated with longer RTFS time periods in acute injuries only (chi-square, $P < 0.01$). This supports the idea that earlier intervention by medical professionals after an acute injury may help athletes return to their sport more quickly following injury. One explanation for this may be that some injuries require immediate rehabilitation whereas others require rest, and athletes may choose the incorrect option without physician oversight.

LIMITATIONS

Our analysis included multiple sport types, although different sports may carry different injury risk profiles and RTS patterns. In addition, our study population also contained a large percentage of tennis players (30.42% of single sport or main sport athletes), due to the principal investigator's expertise in this sport (Table 4). The sample also drew from an affluent suburban population, both of which may limit the generalizability of our results. Our sample also included college athletes, which led to a population that was older in nature than most previously reported youth sport specialization studies. Moreover, ACWR was calculated only via reported weekly sport hours not including any intensity measures such as heartrate, blood lactate, or perceived exertion and thus it may not be a true measure of workload.[2] Weekly sport hours also do not account for training variability within the week.

Another limitation is our use of the Khamis-Roche scale, which has been validated only against white, middle-class Americans and has been shown to have an error of 2.1 cm to 4.4 cm for female participants and 2.4 cm to 7.3 cm for male participants at their 90th percentile[37]. Given this, some athletes may have been placed in an incorrect stage of development.

In assessing RTMS and RTFS, only 49% of athletes in this study responded to the follow-up survey, which may have influenced the results.

In addition, since athletes who were deemed likely to require surgery on presentation were not included in the study, the exact percentages of acute versus overuse injuries may not be reflective of the overall population. Finally, we must assume some degree of recall bias in self-report on survey responses, with athletes either overestimating or underestimating their training volumes.

Table 4. Sport types of participants for single-sport athletes and athletes with a main sport

Sport Type	Total (n)	Total (%)	Male (n)	Male (%)	Female (n)	Female (%)
Archery	1	0.30	0	0.00	1	0.68
Baseball	11	3.31	11	5.95	0	0.00
Basketball	20	6.02	11	5.95	9	6.12
Cheer	12	3.61	0	0.00	12	8.16
Cross-country	2	0.60	1	0.54	1	0.68
Dance	1	0.30	0	0.00	1	0.68
Equestrian	1	0.30	0	0.00	1	0.68
Flag football	2	0.60	0	0.00	2	1.36
Figure skating	0	0.00	0	0.00	0	0.00
Football	31	9.34	31	16.76	0	0.00
Golf	7	2.11	3	1.62	4	2.72
Gymnastics	7	2.11	1	0.54	6	4.08
Hockey	0	0.00	0	0.00	0	0.00
Karate	2	0.60	1	0.54	1	0.68
Lacrosse	33	9.94	17	9.19	16	10.88
Powerlifting	0	0.00	0	0.00	0	0.00
Pickleball	0	0.00	0	0.00	0	0.00
Rugby	1	0.30	1	0.54	0	0.00
Soccer	61	18.37	32	17.30	29	19.73
Softball	5	1.51	0	0.00	5	3.40
Swimming	2	0.60	2	1.08	0	0.00
Tennis	101	30.42	57	30.81	44	29.93
Track	13	3.92	8	4.32	5	3.40
Ultimate Frisbee	0	0.00	0	0.00	0	0.00
Volleyball	10	3.01	0	0.00	10	6.80
Water polo	0	0.00	0	0.00	0	0.00
Wrestling	9	2.71	9	4.86	0	0.00

CONCLUSION

Our data suggest that female athletes' lack of free play hours and increased year-round training in a main sport may contribute to their higher risk of overuse injury. Despite higher weekly sports participation in male athletes, the overuse injury risk is higher in female athletes. Overuse injury risks do not appear to be strictly volume-related, but perhaps are more related to the type of physical activity. As previously theorized, the unstructured movement patterns in youth athletes during free-play may counteract the repetitive movement patterns of specialization, and thus promote more balanced neuromuscular strength and development, which may be protective against injury.[17] As we explored extrinsic differences only in training patterns between the sexes, future research should evaluate intrinsic differences between male and female athletes that could contribute to the increased prevalence of overuse injuries in young female athletes. Such intrinsic differences could include likelihood to seek medical care for symptoms, bone density, and/or flexibility. Even with these demonstrated differences in training patterns between female and male athletes, sport specialization and sex were not associated with increased RTS timeframes.

PRACTICAL RECOMMENDATIONS

- Higher degrees of specialization, year-round training, and female sex are individual risk factors for overuse injuries.
- Increased weekly free play hours and seasonal rest (>4 months/year) may be protective against overuse injuries.
- Delayed RTS time periods are more influenced by injury type (e.g., serious overuse injury) than sex or sport specialization.

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