

A Closer Look at Overuse Injuries in the Pediatric Athlete

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Objective: To examine male-female differences in pediatric overuse sports injuries.

Study Design: Cross-sectional epidemiological study.

Setting: Tertiary level sports medicine division in a large academic pediatric medical center.

Participants: Five percent probability sample of patients 5 to 17 years seen from January 1, 2000 to December 31, 2009. About 3813 charts reviewed. Final study cohort included 1614 patients.

Intervention: Nonlinear decomposition analysis of male-female differences in overuse injuries.

Main Outcome Measures: Age, body mass index, history of previous injury, and activity type (contact/collision, team vs individual, "high overuse").

Results: Females sustained approximately half of the total injuries. Fifty-two percent of the injuries were overuse, 61% to the lower extremity. A high proportion of tennis players, swimmers, dancers, track athletes, runners, gymnasts, and cheerleaders were seen for overuse injuries. Females sustained more overuse injuries versus males (63% and 40%, respectively). Males playing team sports have a 5.3 times higher likelihood of being seen for an overuse injury compared with males not playing team sports ($P < 0.01$). High-overuse sport participation increased overuse injury odds by a factor of 10 for males versus 3.6 for females ($P \leq 0.01$ for males and females). Forty-six percent of the male-female difference in overuse injuries could be attributed to sport/activity characteristics—contact/collision, team, and high overuse.

Conclusions: A large proportion of the sex discrepancy in overuse injuries in this cohort was attributed to compositional differences in

sports played. Future research is needed to investigate the independent effect of sex on risk for pediatric sports injuries.

Clinical Relevance: This study provides a unique analysis of male-female differences in pediatric sports injuries and is the first study to estimate the impact of the different characteristics (ie, collision, team, high overuse) of sports children play on overuse injuries sustained by young athletes. The findings will help guide future prevention efforts.

Key Words: sports injuries, female, male, gender differences, sports injury prevention

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INTRODUCTION

The National Council of Youth Sports survey reported that 60 million children aged 6 to 18 years participate in organized athletics.¹ Female athletes continue to increase their participation in competitive sports, despite being plagued with injury.² A summary report of high school sports injuries during the 2010 to 2011 academic year of 100 US high schools by Dr Dawn Comstock reported that the overall rate of sports injuries, both acute and chronic, was 1.71/1000 athletic exposures.³ The current literature is relatively deficient regarding the risk for overuse injuries in young children. These injuries can range from the sometimes devastating diagnosis of osteochondritis dissecans of the elbow or knee,⁴ to the more common and more benign quintessential overuse injury of the young growing athlete, Osgood-Schlatter Disease.⁵

Male and female athletes sustain different types of sports injuries to different areas of the body. There is some evidence to show that females sustain more overuse injuries, as compared with their male counterparts.⁶ The medical literature suggests a variety of reasons for male-female discrepancies in injury patterns, including differences in strength and flexibility,^{7–9} and differences in other physiological and anatomical parameters.^{10–16} Furthermore, the proportion of male and female athletes participating in athletics varies by sport.^{17,18} Certain sports are more highly associated with specific injuries.^{11,19–22} For sports such as basketball and soccer, which have similar structure and rules for both male and female athletes, there is some evidence that female players sustain more overall injuries, more injuries to the knee, and more severe injuries than their male counterparts.^{10,23} Other research suggests that female basketball players are more likely to experience head and knee injuries, whereas male basketball players are more likely to sustain fractures and lacerations.²⁴ This suggests that differences in injury patterns between male and female athletes cannot be explained

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entirely by differences in the types of sports male and female athletes prefer.

The purpose of this study was to compare pediatric overuse injuries between males and females in a cohort of patients seen in a pediatric sports medicine clinic at a tertiary level academic medical center. Specifically, for this cohort of patients, we analyzed the role of multiple patient variables and activity characteristics on the likelihood of sustaining an overuse injury in the male patients versus female patients. Finally, we sought to evaluate the extent to which the discrepancy in overuse sports injuries between the male and female patients in this cohort can be explained by different patient background characteristics, and activity/sport characteristics. To clarify, if participating in gymnastics is positively associated with sustaining overuse injuries, and a higher proportion of females compete in gymnastics, then, all other factors being equal, we would expect females to suffer more overuse injuries than males. Suppose, however, there is a gym where male and female athletes of similar age, athletic background, body mass index (BMI), and other characteristics participate in 15 intense hours of training per week for the same gymnastic events. If females training in that gym were still more likely than males to sustain overuse injuries, then we might suspect that females possess a greater risk (eg, due to biomechanical, genetic, or neuromuscular factors) of overuse injuries. Simply restated, for a large range of reasons, the risk of suffering an overuse injury during gymnastics would be greater for females than males. Using data from the electronic medical records of a large pediatric hospital, we examined the extent to which differences in overuse injuries between the sexes can be attributed to differences in the types of sports in which males and females participate. The null hypotheses being tested in this research include: (1) there is no difference in the proportion of males and females being seen for overuse injuries, after taking into account patient background characteristics such as history of chronic injury and BMI, and activity characteristics, such as contact/collision and team sports and (2) sport compositional differences (characteristics) have no impact on the likelihood of sustaining an overuse injury in the male patients as compared with female patients in this study cohort.

METHODS

Data and Participants

The study population consisted of all patients aged 5 to 17 years evaluated in the division of sports medicine at an academic pediatric hospital, from January 1, 2000 to December 31, 2009. There were 121 047 total unique patients in this age category, from which we randomly drew a 5% sample using the “sample” command in Stata. We then accessed the electronic medical records corresponding to each selected new patient visit. Because of budget and time constraints, 3813 charts (of the approximate 6000) were reviewed, coded, and entered into a database.

All visits for injuries sustained as a result of the patient’s participation in 1 or more organized physical activities were eligible for inclusion. Visits for injuries sustained as

a result of everyday accidents (eg, falling down the stairs or falling off a bike while riding recreationally) or underlying congenital disorders were excluded. Only medical records that clearly described the activity in which the patient was participating during the time of injury were included. Many cases were excluded from the analysis due to incomplete data regarding the variables under study. Only the primary injury at the time of the new patient visit was coded and analyzed. Multiple injuries were not included in the statistical analysis for this study. Based on these criteria, the final sample comprised 1614 unique patients. Anthropometric measures (height and weight), mechanism of injury, previous injuries, and organized activities were recorded by 6 coders. Inter-coder reliability was assessed using Krippendorff alpha.²⁵

Measures

We recorded primary injury diagnosis as made by an attending level orthopedic surgeon or primary care sports medicine physician, body area injured (head, chest, upper extremity, lower extremity, spine), and type of injury. Injuries were subdivided into overuse or acute/traumatic by an attending level pediatric sports medicine physician (A.S.). For overuse injuries that could be considered either acute or chronic (eg, subluxation), an athletic trainer performed a chart review and properly categorized the injury according to the medical record.

Physical activities were coded by sport and used to create 2 binary measures: (1) indicating whether the patient participated in 1 or more team sports and (2) indicating whether the patient participated in 1 or more contact/collision sports. The classification scheme suggested by the American Academy of Pediatrics was used: contact/collision, limited contact, or non-contact.²⁶ Team sport was coded if children were playing *with* others at the time of play (ie, swimming and golf are not coded as team sports, although there is a team element to these sports).²⁶ A continuous measure was created, indicating the total number of activities reported for each patient. Given that certain sports have known associations with overuse injuries,²⁰ we created a measure indicating whether a patient participated in a “high-overuse” sport. “High-overuse sports” were defined as any sport for which $\geq 65\%$ or more of the patients were seen for overuse injuries (Table 1). Other covariates included patient sex, age, and BMI z-score.

We used a Student *t* test to compare differences in mean values. To examine whether the correlates of pediatric overuse injuries differ for males and females, we used multivariate logistic regression models to predict overuse injuries separately for each sex and then executed a likelihood ratio test to determine whether there was a significant difference between the models. We controlled for age, BMI z-score, previous overuse injuries (binary), and activity characteristics, including total number of sports played, and participation in a high-overuse sport, team sport, or contact/collision sport. Finally, to investigate how much of the overall difference in overuse injuries between the sexes was attributable to differences in the types of sports males and females play, we used a nonlinear decomposition method commonly used to decompose sex or racial differences in outcomes (see Appendix, **Supplemental Digital Content 1**, <http://links.lww.com/JSM/A44>).^{27–29} Institutional

TABLE 1. Patients Seen in Clinic by Sport and Percentage Seen for Overuse Injuries

Activity*	Total N	Overuse Injuries	
		N	%
Basketball	191	90	47.1
Boxing	2	1	50.0
Field hockey	14	8	57.1
Football	165	53	32.1
Hockey	93	39	41.9
Lacrosse	66	34	51.5
Martial arts	10	6	60.0
Rugby	4	2	50.0
Soccer	258	129	50.0
Polo	1	0	0.0
Wrestling	15	4	26.7
Baseball	107	67	62.6
Bicycling	13	1	7.7
Cheerleading	32	21	65.6
Fencing	1	0	0.0
Flag football	4	1	25.0
Gymnastics	110	76	69.1
Horseback riding	12	5	41.7
Figure skating	38	24	63.2
Skating	8	1	12.5
Skiing	56	14	25.0
Skateboarding	16	2	12.5
Snowboarding	36	3	8.3
Softball	34	20	58.8
Squash	2	1	50.0
Frisbee	2	1	50.0
Volleyball	15	6	40.0
Surfing	2	1	50.0
Archery	1	1	100.0
Crew	6	5	83.3
Dancing	143	117	81.8
Track & field	60	45	75.0
Golf	2	1	50.0
Hiking	1	0	0.0
Weightlifting	1	0	0.0
Running	22	17	77.3
Sailing	1	0	0.0
Swimming	31	26	83.9
Tennis	22	19	86.4
Trampoline	2	1	50.0
Whiffle ball	2	0	0.0
Color guard	1	0	0.0
Roller hockey	1	0	0.0
Gym class	9	0	0.0
Rock climbing	1	0	0.0
Water polo	1	0	0.0
Total	1614	842	52.2

*"High-overuse" activities ($\geq 65\%$ overuse) in bold. Only sports played by 10 or more cases were used when defining high-overuse sports.

internal review board approval was obtained before the initiation of the research protocol.

RESULTS

For all variables reported in this analysis, Krippendorff alpha for intercoder reliability was 0.746, above the level of acceptability suggested by Krippendorff.²⁵ The full study cohort of 1614 patients contained slightly more female athletes than male, and the 2 populations were identical in age (Table 2). The majority of females were treated for overuse injuries as compared with males (63% vs 40%, respectively). Injury location differed significantly by sex. Females were treated more for lower extremity, hip/pelvis, and spine injuries as compared with males, who sustained more injuries to the head, chest, and upper extremity (Table 2). A greater proportion of males played team sports and contact/collision sports when compared with the females. A smaller proportion of males participated in one of the high-overuse sports versus females with sports injuries 5 to 17 years. Males played more sports overall than females (Table 2).

Adjusted odds ratios from logistic regression models predicting treatment for an overuse injury (reference = traumatic/acute injury) were performed separately by sex (Table 3). Notably, the odds of being seen for an overuse injury are approximately 5 times higher for males playing a team sport than for males who do not play a team sport ($P < 0.01$). In comparison, the odds of being seen for an overuse injury were 1.3 times greater for females participating in team sports than for females not playing a team sport ($P = 0.274$). Participating in

TABLE 2. Mean Characteristics for Full Sample by Sex

	Full	Male	Female	P*
Mean Age, y	14.2	14.2	14.2	0.756
Female, %	54.1	—	—	—
BMI z-score	0.5	0.6	0.4	<0.001
Injury characteristics, %				
Seen for overuse injury	52.2	39.7	62.8	<0.001
Location				
Head	1.9	3.4	0.7	<0.001
Chest	1.4	2.4	0.6	0.002
Upper extremity	21.7	30.5	14.2	<0.001
Lower extremity	60.7	53.4	66.8	<0.001
Hip/pelvis	5.6	3.8	7.1	0.004
Spine	9.7	7.7	11.3	0.013
Previous injuries, %				
Overuse	26.8	18.8	33.7	<0.001
Traumatic	23.5	27.5	20.0	<0.001
Activity characteristics, %				
Plays at least 1				
Team sport	61.7	77.9	48.0	<0.001
Contact/collision sport	54.3	69.5	41.5	<0.001
Plays high-overuse sport	26.0	5.9	43.0	<0.001
No. sports	2.4	2.5	2.2	<0.001
Total N	1614	741	873	

*Sig. based on 2-tailed *t* test on difference between males and females.

TABLE 3. Adjusted Odds Ratios, 95% CIs, and *P* Values From Logistic Regressions Predicting Injury Type (Reference = Traumatic), by Sex

	Overuse Injuries					
	Males			Females		
	Odds Ratio	95% CI	<i>P</i>	Odds Ratio	95% CI	<i>P</i>
Background characteristics						
Age, y	1.098	1.022-1.180	0.011	1.037	0.973-1.107	0.262
BMI z-score	0.856	0.727-1.009	0.063	0.918	0.778-1.084	0.313
History of chronic injury	1.119	0.751-1.665	0.581	1.408	1.030-1.926	0.032
Activity characteristics						
Participates in at least 1						
Team sport	5.329	3.026-9.383	0.000	1.277	0.824-1.979	0.274
Contact/collision sport	0.498	0.335-0.741	0.001	1.001	0.639-1.567	0.998
Total no. sports	1.069	0.947-1.206	0.280	1.132	1.005-1.274	0.040
High-overuse sport	10.310	4.429-24.000	0.000	3.641	2.303-5.758	0.000
Constant	0.0580	0.017-0.194	0.000	0.376	0.131-1.078	0.069
N	741			873		
Log likelihood	75.81			72.28		
Pseudo R ²	0.076			0.063		

CI, confidence interval.

a high-overuse sport increased the odds of being seen for an overuse injury by a factor of 10 for males versus 3.6 for females ($P \leq 0.01$ for both males and females). A likelihood ratio test rejected the null hypothesis that there was no difference in the proportion of males and females being seen for overuse injuries after taking into account patient background characteristics such as history of chronic injury and BMI, and activity characteristics, such as contact/collision and team sports.

Decomposing Gender Differences in Pediatric Overuse Injuries

Strong differences between males and females were seen in the proportion of athletes participating in team sports, contact/collision sports, and high-overuse sports in this study cohort of pediatric patients with sports injuries presenting to sports medicine clinic. A decomposition analysis was performed to investigate the extent to which these differences are responsible for differences in the likelihood of being treated for an overuse injury in this cohort of patients. Table 4 presents the decomposition analysis results based on the models presented in Table 3. The total male-female difference in proportions treated for overuse injuries is -0.231 (equal to $0.397-0.628$). The decomposition analysis suggests that approximately 45.9% ($100 \times [-0.106/-0.231]$) of this difference can be explained by differences in the distributions of males' and females' background and activity characteristics (age, BMI, history of chronic injury and team sport, contact/collision, total number of sports, high overuse). Restated, if females and males had the same background and activity characteristics, then the male-female gap in proportion treated for overuse injuries would be reduced by nearly half. Table 4 also shows the extent to which each activity and background characteristic contributes to the overall male-female difference. These estimates are

equal to the *change* in the overall probability of being treated for an overuse injury that would occur if we substituted the female distribution of a particular characteristic (eg, total number of sports) with the male distribution of that variable, holding the distributions of the other variables constant. Specifically, the estimate on the "team sport" measure is 0.054 suggesting that the contribution of this variable to the overall sex difference in overuse injuries is 23% ($100 \times [0.054/0.231]$). Restated, if the females in this study cohort played team sports in the same proportion to males, the difference in overuse injuries between males and females would increase by 23%. Furthermore, the estimate on the high-overuse measure suggests that the male-female sex gap in proportion of patients treated for overuse injuries would decrease by 54% ($100 \times [0.125/0.231]$) if the patients had participated in gymnastics, tennis, swimming, running, and other high-overuse sports in equal proportions (Table 4). Finally, if females played the same overall number of sports as males, on average, the sex difference in overuse injuries would increase by 0.006 points or roughly 3% (Table 4).

DISCUSSION

The notion that females and males differ significantly in sports injury patterns is not a new concept to pediatricians, sports medicine physicians, and investigators of sports injury epidemiology. Our goal for this research was to investigate overuse injuries in pediatric patients evaluated and treated for a sports injury in our sports medicine clinic. We sought to investigate in detail, and decompose statistically, why male and female children differ in injury patterns. Our findings suggest that the effect of participating in certain types of sports on being treated for an overuse injury is different for males and females in this study population, even when

TABLE 4. Results From Decomposition Analysis, Including (A) a Summary of the Extent to Which Male-Female Differences in Overuse Injuries Can Be Attributed to Differences in Their Background and Activity Characteristics and (B) a Reporting of the Extent to Which Each Characteristic Contributes to the Overall Male-Female Gap (N = 1614)

A. Summary		Overuse Injuries	
Male average		0.397	
Female average		0.628	
Difference (male-female)		−0.231	
Amount of overall difference explained by differences in background and activity characteristics		−0.106	
% of overall difference explained by differences in background and activity characteristics		45.9	
B. Individual Contributions to Male-Female Difference*			
	Estimate	95% CI	P
Background characteristics			
Age, y	−0.001	−0.002 to 0.000	0.105
BMI z-score	−0.007	−0.013 to −0.000	0.039
History of chronic injury	−0.009	−0.018 to 0.001	0.037
Activity characteristics			
Participates in at least 1			
Team sport	0.054	0.033 to 0.074	<0.001
Contact/collision sport	−0.023	−0.042 to −0.005	0.015
Total no. sports	0.006	0.001 to 0.011	0.029
High-overuse sport	−0.125	−0.153 to −0.097	<0.001

*The estimates in the bottom portion of the table (B) show the extent to which each characteristic contributes to the male-female difference in likelihood of being treated for an overuse injury. The estimates are equal to the *change* in the average probability of being treated for an overuse injury that occurs when we substitute the female distribution of a particular characteristic (eg, total number of sports) with the male distribution of that variable, holding the distributions of the other variables constant.

controlling for age, BMI z-score, and history of chronic injuries. Furthermore, our findings revealed that close to half of the differences in overuse injuries in sport seen between young males and females, in this cohort of pediatric sports medicine patients, can be attributed to sex differences in background characteristics, such as BMI, and sport characteristics, such as contact/collision and team. The remaining sex difference in overuse injuries can likely be explained by biological differences, both those previously documented in the existing literature, and those yet to be discovered.

Multiple possible reasons for disparity in sports injuries between males and females have been investigated and reported. The biomechanical and neuromuscular changes that occur during the growth process have been investigated recently regarding injury in female athletes. Ford et al³⁰ demonstrated that certain knee biomechanics that place the female at risk for injury were significantly increased in pubertal females during periods of rapid growth.³⁰ Male athletes showed no comparable adaptive deficits related to maturation. Caine et al³¹ reported higher injury rates in peripubertal female gymnasts at Tanner stages 2 and 3 compared with gymnasts at Tanner stages 1, 4, and 5, regardless of competitive level.

DiFiori et al³² reported that adolescent gymnasts between 10 and 14 years of age were significantly more likely than older gymnasts to have chronic wrist pain, even after adjusting for intensity of training, age of initiation of training, years of training, and sex. Other potential reasons for differences in sports injury patterns between males and females previously described in the literature include femoral notch size variation,¹³ hormonal influences on injury risk,^{11,33–35} and variations in lower extremity strength and flexibility.^{7,16,36}

Extensive research to date has shown dynamic knee instability in female athletes due to neuromuscular and biomechanical factors that place young female athletes at increased risk for injury, including but not exclusive to anterior cruciate ligament injuries.^{15,37,38} More recently, researchers examined the relationship between body composition and patellofemoral knee pain—the textbook overuse injury of the female athlete. Despite data indicating a relationship between higher relative body mass and overall knee injury, this study failed to show a relationship between body composition and patellofemoral knee pain in middle school female basketball players.³⁹ Myer et al⁴⁰ found that athletes, who developed patellofemoral knee pain while in season, demonstrated increased knee abduction moments at initial contact on the most-symptomatic limb. They inferred from this finding that the landing mechanics in the athletes who developed patellofemoral knee pain provide a biomechanical explanation for the increased incidence of patellofemoral knee pain among female athletes.⁴⁰ Overuse injuries to tendons and apophyses are being diagnosed with increasing frequency as children and adolescents increase their participation in organized sports, fitness, and dance activities. A retrospective review of 724 overuse tendon and apophyseal injuries seen in the Sports Medicine Clinic at Boston Children's Hospital suggested that growth and maturation constitute additional risk factors for injury occurrence.²⁰

The results of the decomposition analysis suggest that disproportionate participation in certain sports by female athletes accounts for a large share of the differences between the sexes in the proportion of athletes presenting to an out patient clinic with overuse injuries. These data also suggest that the reason more female athletes seek medical care for overuse injuries may be, in part, sociological. By directing females toward particular sports, like dance and gymnastics, society may be increasing their risk of certain injuries. Sociological explanations may also contribute to the higher proportion of males in team sports seeking care for overuse injuries. Perhaps peer pressure, which often pushes boys to play harder and longer than may be healthy or safe, could contribute to the rates of overuse injuries. The ultimate goal, at this time, for all those caring for young athletes is to further sports injury prevention efforts and to help direct future policy recommendations regarding sports participation and children.

Our results must be considered in light of several limitations. The data were collected from a dedicated sports medicine clinic of a large, pediatric, tertiary care center. Therefore, our results may not be generalizable to other settings. In addition, we cannot describe incidence of injury, as we only report information from patients seen in our clinic, without data regarding athletic exposures.

CONCLUSIONS

The literature suggests that different types of sports are likely to produce different injuries in children. Physiological and anatomical differences between males and females exist, which impact injury profile. This study revealed that a large proportion of the male-female discrepancy in overuse injuries in this cohort of pediatric patients evaluated for injury in a pediatric sports medicine practice was attributed to the compositional differences in sports played, including team versus individual sports, contact/collision, and high-overuse sports. This study provides a unique analysis of male-female differences in pediatric sports injuries and is the first article to estimate the compositional effects of different sports children play on overuse injuries sustained by young athletes. Future research is needed to investigate the independent effect of sex on risk for pediatric sports injuries. The findings of this research will help guide future prevention efforts.

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