# Incidence and Risk Factors for Injuries in Girls' High School Volleyball: A Study of 2072 Players

# Timothy A. McGuine, PhD, ATC\*; Eric G. Post, PhD, ATC†; Kevin M. Biese, MA, ATC‡; Stephanie Kliethermes, PhD\*; David R. Bell, PhD, ATC§; Andrew M. Watson, MD, MS\*; Alison Brooks, MD\*; Pamela J. Lang, MD\*

\*School of Medicine and Public Health, Department of Orthopedics and Rehabilitation, and §School of Education Department of Kinesiology, University of Wisconsin Madison; †Department of Applied Medicine and Rehabilitation, Indiana State University Terre Haute; ‡Department of Kinesiology and Athletic Training, University of Wisconsin-Madison

**Context:** Girls' high school volleyball is very popular across the United States. Prospective data are limited regarding the incidence and risk factors of time-loss (TL) and non-time-loss (NTL) injuries sustained in this population.

**Objective:** To estimate the incidence and describe the characteristics of injuries (TL and NTL) sustained in a girls' high school volleyball season.

Design: Descriptive epidemiology study.

*Setting:* Convenience sample of 78 high school interscholastic volleyball programs.

**Patients or Other Participants:** Female high school volleyball players participating during the 2018 interscholastic season.

Main Outcome Measure(s): Injury rates, proportions, and rate ratios were measured for TL and NTL injuries with 95% CIs.

**Results:** A total of 2072 girls enrolled in the study, and 468 participants (22.5%) sustained 549 injuries (TL = 71.6%, NTL = 28.4%) for an overall injury rate of 5.31 (95% CI = 4.89, 5.79) per 1000 athlete-exposures. The competition injury rate was greater

than the practice injury rate for all injuries (injury rate ratio [IRR] = 1.19; 95% CI = 1.00, 1.41) and TL injuries (IRR = 1.31; 95% CI = 1.07, 1.60). Players with a previous musculoskeletal injury had a higher rate of TL than NTL injuries (IRR = 1.36; 95% CI = 1.12, 1.65). Ankle injuries accounted for the greatest proportion of TL injuries (n = 110, 28%), while the greatest proportion of NTL injuries occurred in the hand or fingers (n = 34, 22%). Ligament sprains accounted for 40% of TL injuries (n = 156), whereas muscle or tendon strains (n = 79, 51%) accounted for more than half of all NTL injuries.

**Conclusions:** Although most injuries sustained by adolescent girls' volleyball athletes were TL in nature, nearly a third of all injuries were NTL injuries. Injury characteristics differed widely between TL and NTL injuries. Understanding the most common types and characteristics of injuries among high school volleyball players is critical for the development of effective injury-prevention programs.

Key Words: female athlete, athlete, sport, epidemiology

#### **Key Points**

- The rate of time-loss injuries was twice as high as that of non-time-loss injuries and varied by sport session, time in season, body location, injury type, injury onset, player position, and player activity.
- Volleyball players who were older or had a higher body mass index were more likely to sustain an injury during the season.
- Players who reported sustaining a musculoskeletal injury or concussion within the 12 months before the start of the season sustained more time-loss injuries but not more non-time-loss injuries.

olleyball was the most popular team sport for high school–aged girls in the United States, with participation surpassing team sports such as basketball, soccer, and softball.<sup>1</sup> Participation in high school volleyball increased by 9% in the past decade.<sup>1</sup> Furthermore, at the high school level, 7 times as many girls played volleyball as boys, making it one of the few predominantly girls' sports.<sup>1</sup> In addition to its popularity, volleyball is becoming a year-round sport, with up to 50% of athletes participating on nonscholastic club teams.<sup>2,3</sup>

The overall injury burden associated with volleyball is significant. More than 60 000 injuries were estimated as being sustained by female athletes competing in high

school volleyball annually.<sup>4</sup> Further, between 1990 and 2009, an estimated 490 000 female volleyball players (median age = 15.0 years) sought treatment in US emergency departments.<sup>5</sup>

Previous research on volleyball focused on reporting the incidence of injuries in collegiate populations<sup>6–9</sup> or elite adult players.<sup>10–13</sup> Many of these studies concentrated on injuries that caused the players to miss time from their sport.<sup>6,8,10–14</sup> *Time-loss (TL) injuries* were characterized as incidents that caused the player to miss  $\geq$  24 hours of participation, whereas *non–time-loss (NTL) injuries* were characterized as injuries that required medical attention but caused the athlete to miss <24 hours of participation.<sup>14–16</sup>

To date, research regarding NTL injuries among volleyball players was limited to the collegiate level and a single study of high school athletes, even though NTL injuries may have accounted for >50% of all injuries.<sup>17</sup> Understanding the attributes of these injuries could lead to preventive measures aimed at limiting minor repetitive-use or acute-onset injuries, which could potentially lead to more significant injuries if left unrecognized or untreated.<sup>18</sup>

The lack of research regarding NTL injuries in adolescent girls' volleyball players highlighted the need for prospective investigations to identify and compare the incidence and characteristics of TL and NTL injuries in these athletes. By identifying injury characteristics in this population, we may be able to educate medical providers, volleyball coaches, and players on the best methods of mitigating the predisposing factors and reducing the effect of sport-related injuries on their health and well-being. Therefore, the objective of our study was to estimate the incidence and describe the characteristics of injuries (TL and NTL) sustained in a girls' high school volleyball season.

# METHODS

This prospective cohort study was approved by the University of Wisconsin Health Sciences institutional review board in March 2018.

#### **Participants**

A convenience sample of 78 high schools in the state of Wisconsin agreed to serve as data-collection sites for this study. All female volleyball players (grades 9–12) who were members of their interscholastic volleyball teams at participating schools were eligible. The research team identified and recruited students during preseason team meetings. To be included in the study, each participant was required to be (1) a member on the roster of 1 (freshman, sophomore, junior varsity, or varsity) of their interscholastic volleyball teams and (2) able to fully engage (ie, have no disabling injuries) in team activities on the first day of practice.

#### **Data-Collection Procedures**

At the time of enrollment, participants completed a demographic questionnaire regarding their self-reported history of previous TL sport-related musculoskeletal and concussion injuries within the previous 12 months. The study team collected the height and weight of each student to calculate body mass index (BMI). Informed consent was obtained in person, with each participant required to sign a combined informed assent—consent document. Players who were under the age of 18 years were also required to have a parent or guardian sign the same form.

The athletic trainer (AT) at each school recorded all volleyball-related athlete-exposures (AEs) and sport-related injuries for each participant during the fall 2018 season. For this study, an AE was defined as any volleyball coachdirected practice or competition event. When an injury occurred, the AT completed a thorough report providing details of the injury, including the initial injury evaluation and onset characteristics into an online reporting system (Research Electronic Data Capture [REDCap]; University of Wisconsin-Madison). The AT entered and updated subsequent data for the injury that included a specific diagnosis, days lost, referral to other medical providers, diagnostic tests, treatments, and surgeries required to treat each injury as it became available during the weeks and months after the injury. Injuries were classified as *TL* if the player missed  $\geq$ 24 hours of participation and *NTL* if the athlete was able to return to volleyball <24 hours after restriction from participation.

#### **Injury Definitions and Classifications**

An *injury* was defined as any acute- or gradual-onset injury to the musculoskeletal or neurologic system that must have (1) occurred as a result of participation in an interscholastic volleyball event (practice or competition) and (2) required medical attention by the school AT or a physician. An AE was defined as 1 volleyball player participating in a single volleyball practice or competition. The primary variables of interest were defined as follows: (1) time in season: *preseason* (from the first date of practice up to the first regular season competition), in season (from the first date of competition to the last date of regular season competition), or postseason (from the date of the last regular season competition through the last game of the interscholastic state tournament series); (2) injury activity: typical volleyball actions (attacking, blocking, digging, etc); (3) injury onset: *acute* (occurring as the result of a specific action or activity) or gradual (a gradual increase in pain or disablement that could not be attributed to a single specific action; (4) contact type: contact with the ball, surface, teammate, other (bleacher, net, wall), or none; (5) court location: at the net, back row, front row, or off the court; (6) time in session, competition: warm up or the first through fifth sets; and (7) time in session, practice: during the warm-up session before practice, first half, second half, or postpractice conditioning.

A study team member reviewed the data for each injury recorded during the season for completeness and accuracy. School ATs were required to confirm the accuracy of each injury they recorded at the end of data collection.

# Analyses

Demographics and distributions of injury characteristics were described using mean  $\pm$  SD and frequencies (%) for continuous and categorical variables, respectively. Injury rates and 95% CIs for TL, NTL, and overall injuries were calculated using generalized estimating equations with a Poisson distribution and log link, thereby accounting for multiple injuries sustained by study participants. We additionally used these models to compute injury rates by session, time in season, injury location, injury type, and injury onset. All injury rates were determined per 1000 AEs. Injury rate ratios (IRRs, 95% CIs) comparing rates of demographic and injury characteristics for TL, NTL, and overall injuries were calculated. All 95% CIs that did not include 1.0 were considered statistically significant. All data were analyzed using SAS (version 9.4; SAS Institute Inc).

#### RESULTS

A total of 2072 female volleyball players enrolled in the study. During the season, the players participated in a total

Table 1. Baseline Characteristics and Injury Rate Ratios (IRRs) for Time-Loss (TL) and Non–Time-Loss (NTL) Injuries in Girls' High School Volleyball Players

			Injuries							
	Value		TL (n = 393)		NTL (n = 156)		All (n = 549)			
Variable	$\text{Mean} \pm \text{SD}$	No. (% of Total)	IRR (95% CI)	P Value	IRR (95% CI)	P Value	IRR (95% CI)	P Value		
Age, y	15.6 ± 1.1		1.10 (1.004, 1.20)	.04	1.15 (1.004, 1.33)	.04	1.11 (1.03, 1.20)	.006		
Height, cm	167.4 ± 7.1		1.06 (1.02, 1.09)	.002	1.02 (0.96, 1.07)	.55	1.04 (1.01, 1.08)	.003		
Weight, kg	$67.9 \pm 10.3$		1.06 (1.02, 1.10)	.004	1.07 (1.00, 1.14)	.04	1.06 (1.03, 1.10)	<.001		
Body mass index	$22.4 \pm 3.5$		1.02 (0.99, 1.05)	.18	1.04 (0.99, 1.08)	.07	1.02 (1.00, 1.05)	.04		
Grade				.13		.52		.052		
9		754 (36.4)	Referent		Referent		Referent			
10		624 (30.1)	1.29 (1.00, 1.66)	.052	1.20 (0.79, 1.80)	.39	1.26 (1.02, 1.57)	.04		
11		403 (19.4)	1.25 (0.95, 1.66)	.12	1.32 (0.85, 2.05)	.21	1.27 (1.00, 1.61)	.05		
12		292 (14.1)	1.36 (1.01, 1.83)	.06	1.35 (0.84, 2.16)	.21	1.35 (1.05, 1.74)	.02		
Sport participation										
Multiple sports		1534 (74.0)	Referent		Referent		Referent			
Volleyball only		529 (26.0)	1.08 (0.86, 1.34)	.52	0.67 (0.45, 1.00)	.05	0.95 (0.78, 1.15)	.61		
Musculoskeletal sp	orts injury withir	n last 12 mo?								
No		1684 (81.3)	Referent		Referent		Referent			
Yes		388 (18.7)	1.39 (1.09, 1.77)	.008	1.30 (0.89, 1.90)	.18	1.36 (1.12, 1.65)	.002		
Surgery within last	12 mo?									
No		2014 (97.2)	Referent		Referent		Referent			
Yes		58 (2.8)	0.62 (0.29, 1.31)	.21	1.15 (0.47, 2.80)	.76	0.77 (0.43, 1.36)	.36		
Concussion within	last 12 mo?									
No		1951 (94.1)	Referent		Referent		Referent			
Yes		121 (5.9)	1.65 (1.17, 2.32)	.004	1.13 (0.59, 2.14)	.71	1.50 (1.11, 2.03)	.01		

of 103 489 AEs (competition = 35%, practice or conditioning = 65%). A total of 549 injuries were sustained by 468 participants during the season, with an overall injury rate of 5.3 (95% CI = 4.89, 5.79) per 1000 AEs. The majority of injuries sustained were TL injuries (TL = 393, 71.6%), with 28% classified as NTL (NTL = 156). The rate of TL injuries was 3.8/1000 AEs, compared with 1.51/1000 AEs for NTL injuries. Participants who sustained a TL injury missed a median (interquartile range) of 4.0 days (1.0, 11.0 days) from volleyball.

Fewer than half (n = 235, 42.8%) of all injuries resulted in the athlete being removed from play for the remainder of the event by medical staff. Of these, 78 injuries (14.2%) resulted in a referral to a physician, and 39 (7.1%) injuries required immediate referral to an emergency department for evaluation and treatment. Diagnostic imaging was performed for 16.1% (n = 89) of all injuries, with 14.5% (n = 80) requiring additional treatment or rehabilitation outside the school setting. Surgery was performed for 1.4% (n = 8) of all injuries.

#### **Player Characteristics and Injury Rates**

Baseline characteristics of the study population and IRRs of TL, NTL, and overall injuries are provided in Table 1.

Age and BMI. The mean age of study participants was  $15.6 \pm 1.1$  years, and the mean BMI was  $22.4 \pm 3.5$  (Table 1). Age was associated with an increased rate of any type of injury (IRR = 1.11; 95% CI = 1.03, 1.20), TL injury (IRR = 1.10; 95% CI = 1.004, 1.20), and NTL injury (IRR = 1.15; 95% CI = 1.004, 1.33). For every unit increase in BMI, the injury rate increased, on average, by 2% (IRR = 1.02; 95% CI = 1.00, 1.05). This pattern was consistent for TL (IRR = 1.02; 95% CI = 0.99, 1.05) and NTL injuries (IRR = 1.04; 95% CI = 0.99, 1.08); however, the association was not significant.

Injury History. In the previous 12 months, 19% of athletes reported having sustained a TL musculoskeletal injury; 3%, having surgery to treat an injury; or 6%, having experienced a sport-related concussion. The most commonly reported previous injuries were to the lower extremity; these injuries primarily consisted of sprains or strains (58%), fractures (23%), and tendinitis or tenosynovitis (9%). The rate of injury was 50% greater in athletes who experienced a sport-related concussion within the past vear, compared with those who did not (IRR = 1.50; 95%) CI = 1.11, 2.03). This association was significant for TL injuries (IRR = 1.65; 95% CI = 1.17, 2.32) but not for NTL injuries (IRR = 1.13; 95% CI = 0.59, 2.14). Similarly, there was an overall increased rate of injury among athletes who sustained a previous musculoskeletal sport injury (IRR = 1.36; 95%  $\overline{CI} = 1.12$ , 1.65); this association was significant for TL injuries (IRR = 1.39; 95% CI = 1.09, 1.77) but not NTL injuries (IRR = 1.30; 95% CI = 0.89, 1.90).

#### Distribution of the Rates for TL and NTL Injuries

Injury rates for TL, NTL, and all injuries by injury location, type, and onset are provided in Table 2. The majority of injuries were sustained during practice or conditioning (n = 334, 60.8%), while the rest were sustained during competition (n = 215, 39.2%). The competition injury rate was greater than the practice injury rate for TL injuries (4.49 versus 3.43/1000 AEs; IRR = 1.31; 95% CI = 1.07, 1.60) but not for NTL injuries (1.43 versus 1.55/1000 AEs; IRR = 0.92; 95% CI = 0.66, 1.29). Totals of 81 (15%), 455 (83%), and 13 (2%) injuries were sustained during the preseason, regular season, and postseason, respectively. Preseason and regular season injury rates did not differ (5.00 versus 5.53/1000 AEs; IRR = 0.90; 95% CI = 0.71, 1.16). However, the injury rate was approximately 2 times as high in both the preseason

Table 2.	Rates for Time-Loss (TL	) and Non–Time-Loss	(NTL) Injuries in Girls'	High School	Volleyball Players
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	Injuries						
	TL (n = 393)		NTL (n = 156)		All (n = 549)		
Variable	No. (%)	Rate/1000 AEs (95% CI)	No. (%)	Rate/1000 AEs (95% CI)	No. (%)	Rate/1000 AEs (95% CI)	
Session							
Competition	163 (41.5)	4.49 (3.83, 5.26)	52 (33.3)	1.43 (1.09, 1.88)	215 (39.2)	5.92 (5.16, 6.78)	
Practice or conditioning	230 (58.5)	3.43 (3.01, 3.90)	104 (66.7)	1.55 (1.27, 1.90)	334 (60.8)	4.98 (4.45, 5.56)	
Time in season							
Preseason	57 (14.5)	3.52 (2.72, 4.55)	24 (15.4)	1.48 (0.98, 2.24)	81 (14.8)	5.00 (4.03, 6.21)	
Regular season	329 (83.7)	4.00 (3.58 4.46)	126 (80.8)	1.53 (1.28, 1.83)	455 (82.9)	5.53 (5.03, 6.07)	
Postseason	7 (1.8)	1.42 (0.68, 2.98)	6 (3.8)	1.22 (0.55, 2.71)	13 (2.4)	2.64 (1.53, 4.54)	
Injury onset							
Acute	294 (74.8)	2.84 (2.53, 3.19)	88 (56.4)	0.85 (0.68, 1.06)	382 (69.5)	3.69 (3.33, 4.09)	
Contact	158 (53.7)	1.53 (1.30, 1.79)	54 (61.3)	0.52 (0.40, 0.68)	212 (55.5)	2.05 (1.79, 2.35)	
Noncontact	136 (46.3)	1.31 (1.11, 1.56)	34 (38.7)	0.33 (0.23, 0.47)	170 (44.5)	1.64 (1.40, 1.92)	
Gradual	99 (25.2)	0.96 (0.78, 1.17)	68 (43.6)	0.66 (0.52, 0.84)	167 (30.5)	1.61 (1.38, 1.89)	
Injury location							
Ankle	110 (27.9)	1.06 (0.88, 1.29)	19 (12.2)	0.18 (0.12, 0.29)	129 (23.5)	1.25 (1.05, 1.49)	
Knee	54 (13.7)	0.52 (0.39, 0.69)	25 (16.0)	0.24 (0.16, 0.36)	79 (14.4)	0.76 (0.61, 0.96)	
Hand or fingers	35 (8.9)	0.34 (0.24, 0.47)	34 (21.8)	0.33 (0.23, 0.46)	69 (12.6)	0.67 (0.53, 0.84)	
Shoulder	43 (10.9)	0.42 (0.31, 0.56)	25 (16.0)	0.24 (0.16, 0.36)	68 (12.4)	0.66 (0.52, 0.83)	
Lower leg	33 (8.4)	0.32 (0.23, 0.45)	20 (12.8)	0.19 (0.13, 0.30)	53 (9.7)	0.51 (0.39, 0.67)	
Head	38 (9.6)	0.29 (0.21, 0.42)	_	_	38 (6.9)	0.29 (0.21, 0.42)	
Upper leg	17 (4.3)	0.16 (0.10, 0.26)	5 (3.2)	0.05 (0.02, 0.12)	22 (4.0)	0.21 (0.14, 0.32)	
Hip	14 (3.6)	0.14 (0.08, 0.23)	4 (2.6)	0.04 (0.02, 0.10)	18 (3.3)	0.17 (0.11, 0.28)	
Wrist	14 (3.6)	0.14 (0.08, 0.23)	6 (3.9)	0.06 (0.03, 0.13)	20 (3.6)	0.19 (0.12, 0.31)	
Foot	11 (2.8)	0.11 (0.06, 0.19)	6 (3.9)	0.06 (0.03, 0.13)	17 (3.1)	0.16 (0.10, 0.26)	
Arm or elbow	9 (2.3)	0.09 (0.05, 0.17)	6 (3.9)	0.06 (0.03, 0.13)	15 (2.7)	0.15 (0.09, 0.24)	
Other	16 (4.1)	0.14 (0.08, 0.24)	5 (3.2)	0.08 (0.04, 0.15)	21 (3.8)	0.21 (0.14, 0.33)	
Injury type							
Ligament sprain	156 (39.7)	1.51 (1.29, 1.77)	55 (35.3)	0.53 (0.41, 0.70)	211 (38.4)	2.04 (1.78, 2.34)	
Muscle or tendon strain	146 (37.1)	0.76 (0.61, 0.96)	79 (50.6)	1.41 (1.19, 1.67)	225 (40.9)	2.17 (1.90, 2.49)	
Concussion	38 (9.5)	0.36 (0.27, 0.49)	0 (0.0)		38 (6.9)	0.37 (0.27, 0.50)	
Contusion	14 (3.6)	0.14 (0.08, 0.23)	10 (6.4)	0.09 (0.05, 0.18)	24 (4.4)	0.23 (0.16, 0.35)	
Dislocation or subluxation	8 (2.0)	0.08 (0.04, 0.15)	3 (1.9)	0.03 (0.009, 0.09)	11 (2.0)	0.11 (0.06, 0.19)	
Meniscus tear	7 (1.8)	0.07 (0.03, 0.16)	0 (0.0)		7 (1.3)	0.07 (0.03, 0.16)	
Acute fracture	6 (1.5)	0.06 (0.03, 0.13)	0 (0.0)	_	6 (1.1)	0.06 (0.03, 0.13)	
Stress fracture	5 (1.3)	0.05 (0.02, 0.12)	0 (0.0)		5 (0.9)	0.05 (0.02, 0.12)	
Other	14 (3.6)	0.14 (0.08, 0.24)	8 (5.3)	0.08 (0.04, 0.15)	22 (4.0)	0.21 (0.14, 0.33)	

Abbreviation: AEs, athlete-exposures.

(5.00 versus 2.64/1000 AEs; IRR = 1.90; 95% CI = 1.12, 3.21) and regular season (5.53 versus 2.64/1000 AEs; IRR = 2.10; 95% CI = 1.29, 3.40) compared with the postseason.

#### **Injury Types**

Ligament sprains accounted for 40% of TL injuries, followed by muscle or tendon strains (37%). For NTL injuries, muscle or tendon strains composed 51%, and 35% were reported as ligament sprains. Ankle (24%) and knee (14%) injuries accounted for the greatest proportion of all injuries, followed by the hand or fingers (13%) and shoulders (12%). Ankle injuries constituted the highest proportion of TL injuries (28%), followed by the knee (14%) and shoulder (11%). Among NTL injuries, the hand or fingers were responsible for the highest proportion of injuries (22%), followed by the knee and shoulder (16% each).

The rate of acute-onset injuries was 3.69/1000 AEs and for gradual-onset injuries was 1.61/1000 AEs. Acute-onset injuries (n = 382, 69.5%) occurred more often than gradualonset injuries (n = 167, 30.5%). The rate of acute-onset injuries was greater during competition than during practice (4.79 versus 3.10/1000 AEs; IRR = 1.55; 95% CI = 1.26, 1.89), with acute-onset injuries accounting for 81% of all injuries sustained in competition compared with 62% sustained in practice.

#### **Contact Versus Noncontact Injuries**

More than half (55.5%) of the acute injuries were the result of contact. Contact injuries occurred more often in competition than in practice (3.14 versus 1.56/1000 AEs; IRR = 2.01; 95% CI = 1.54, 2.62). Contact was most frequently due to the ball (45.3%) or a teammate (25.9%). Acute noncontact injuries were mainly the result of jumping or landing (51.8%). Contact injuries were sustained primarily while blocking (30%), digging (22.0%), or general play (15.0%) and occurred most often in the front line or at the net (63.0%). The most frequent noncontact injury mechanism in competition was jumping or landing (47.5%), while the greatest number of noncontact injuries sustained during practice was the result of overuse (56.5%).

#### Player Position, Activity, Location and Session

The distribution of injuries by position, activity, location, and session is provided in Table 3. The TL injuries were

Table 3. Distribution of Time-Loss (TL) and Non–Time-Loss (NTL) Injuries by Position, Activity, Location, and Session

	No. (%)					
Variable	TL Injuries	NTL Injuries	All Injuries			
Player position						
Outside hitter	144 (36.6)	49 (31.4)	193 (35.2)			
Middle blocker	90 (22.9)	34 (21.8)	124 (22.6)			
Setter	57 (14.5)	27 (17.3)	84 (15.3)			
Libero	43 (10.9)	25 (16.1)	68 (12.4)			
Defensive specialist	18 (4.6)	8 (5.1)	26 (4.7)			
Not applicable	41 (10.4)	13 (8.3)	54 (9.8)			
Injury activity						
General play	118 (30.0)	47 (30.1)	165 (30.1)			
Blocking	81 (20.6)	19 (12.2)	100 (18.2)			
Attacking	62 (15.8)	22 (14.1)	84 (15.3)			
Digging	59 (15.0)	22 (14.1)	81 (14.8)			
Setting	25 (6.4)	21 (13.5)	46 (8.4)			
Passing	24 (6.1)	9 (5.8)	33 (6.0)			
Serving	16 (4.1)	13 (8.3)	29 (5.3)			
Court location						
Front row	178 (45.3)	54 (34.6)	232 (42.3)			
Back row	104 (26.5)	54 (34.6)	158 (28.8)			
At the net	52 (13.2)	18 (11.5)	70 (12.8)			
Off the court	59 (15.0)	30 (19.2)	89 (16.2)			
Time in session						
Competition						
Warm-up	15 (8.9)	9 (17.3)	24 (10.9)			
1st set	28 (16.7)	11 (21.2)	39 (17.7)			
2nd set	56 (33.3)	14 (26.9)	70 (31.8)			
3rd set	52 (31.0)	16 (30.8)	68 (30.9)			
4th set	12 (7.1)	1 (1.9)	13 (5.9)			
5th set	5 (3.0)	1 (1.9)	6 (2.7)			
Practice						
Warm-up	22 (9.8)	16 (15.4)	38 (11.6)			
1st half	70 (31.3)	37 (35.6)	107 (32.6)			
2nd half	130 (58.0)	48 (46.2)	178 (54.3)			
Conditioning	0 (0.0)	1 (1.0)	1 (0.30)			
Cool-down	2 (0.9)	2 (1.9)	4 (1.2)			

sustained primarily by outside hitters (36.6%), middle blockers (22.9%), and setters (14.5%) while engaged in general play (30.0%), blocking (20.6%), or attacking (15.8%). The front row was the court location with the highest percentage of TL injuries (45.3%), followed by the back row (26.5%). During competition, TL injuries occurred most often in the second set (33.3%), while practice TL injuries occurred mainly (58.0%) during the second half of the session.

The NTL injuries were sustained mostly by outside hitters (31.4%), middle blockers (21.8%), and setters (17.3%) while engaged in general play (30.1%), attacking (14.1%), or digging (14.1%). These injuries occurred equally in the front and back rows (34.6% each). During competition, NTL injuries were incurred primarily in the third set (30.8%), while NTL injuries sustained in practice happened most often (46.2%) during the second half of the session.

#### DISCUSSION

This is the first study to prospectively report the incidences, characteristics, and distributions of TL and NTL injuries sustained in a large cohort of girls' high school volleyball players. Injury rates varied based on the time in season, session (practice or competition), injury location, injury type, and injury onset. Older players and those with a higher BMI

were at increased risk of injury. Further, players with a previous musculoskeletal injury or concussion were at greater risk of TL injuries but not NTL injuries.

# **Injury Incidence**

The overall injury rate for this study was 5.31/1000 AEs, which was considerably higher than previously reported rates of 1.24/1000 AEs<sup>9</sup> and 1.11/1000 AEs.<sup>8</sup> The difference in observed rates was probably because we recorded both TL and NTL injuries, whereas the earlier researchers only accounted for TL injuries. However, our observed TL injury rate (3.8/1000 AEs) was still higher than reported in the past. This could have been due to the mechanisms of data collection. Both of the previous groups collected data through the high school Reporting Injuries Online (RIO) tool, a web-based, multisport injury-surveillance system that reports injuries and AEs weekly. In contrast, data for girls enrolled in this study were collected by ATs who were designated to monitor the athletes and report injuries daily.

Our TL and overall estimates align more closely with those described in the collegiate population. Reeser et al<sup>9</sup> observed the overall TL injury rate in female collegiate players was 3.81/1000 AEs, although Baugh et al<sup>7</sup> noted a much higher rate in female collegiate players of 7.07/1000 AEs in a study that included both TL and NTL injuries. The inclusion of NTL injuries in our study made the comparisons with earlier volleyball injury rates in high school players difficult. However, we feel this more accurately reflected the true incidence of injuries sustained in high school volleyball. This concern was supported by Fritsch et al,<sup>19</sup> who surveyed high school players and indicated that even though 40% of female players reported shoulder pain that was not due to a traumatic injury, only 33% of those athletes took time away from a sport to recover from their injury.

# **Injury Distribution**

The distribution of injuries by body location, type, onset, and court location in our investigation was similar to previous work conducted on volleyball athletes at the high school, collegiate, and elite adult levels of play.<sup>13,14,20</sup> Specifically, acute ankle ligament sprains caused by contact with another player were a common injury. Research at the adult level<sup>21,22</sup> showed that an exercise program could reduce the incidence of ankle sprains. To our knowledge, a randomized trial has not replicated this finding at the high school level. Pedowitz et al<sup>23</sup> retrospectively found that using hard shell (rigid) braces reduced the incidence of ankle injuries at the collegiate level. Prophylactic ankle bracing using lace-up ankle braces was effective in high school basketball<sup>24</sup> and football players,<sup>25</sup> yet the effect of ankle bracing on injuries in high school volleyball players has not been reported and should be studied further.

Previous authors of reviews<sup>14,19,20</sup> described the phenomenon of repetitive-use shoulder injuries in volleyball. Our data demonstrated that shoulder injuries represented a significant proportion of all injuries, with most of these resulting in TL. Because of the incidence of gradual-onset shoulder injuries in our examination, the use of an effective training program at the high school level deserves further attention. Interestingly, most knee injuries were also classified as tendinitis and resulted from repetitive stress.

Prior injury-prevention efforts reduced the incidence of repetitive-use knee injuries.<sup>26,27</sup> In addition, earlier authors<sup>28</sup> showed that a comprehensive program including a structured warm-up, core-stability exercises, balance, strength, and technical training should be implemented to prevent volleyball injuries. To our knowledge, the effectiveness of this type of program has not been studied in a large cohort of female volleyball players. Given the popularity of volleyball for high school-aged girls, sports medicine providers and volleyball stakeholders should advocate for research on the effectiveness of a comprehensive injury-prevention program in this population. Our results provided evidence that these injury-prevention programs should target the prevention of ankle, knee, and shoulder injuries, as these were among the most common injury locations in this sample for both TL and NTL injuries.

We found that both the percentage and injury rate of TL injuries were greater than for NTL injuries, with fewer than 30% of all injuries categorized as the latter. This finding contradicts the results of Kerr et al,<sup>17</sup> who reported that more than 85% of the injuries sustained by high school female volleyball players were NTL injuries. We cannot account for these differences, as our definitions were the same as those of Kerr et al<sup>17</sup> for TL and NTL injuries. However, it should be noted that Kerr et al<sup>17</sup> used data from the National Athletic Treatment, Injury and Outcomes Network (NA-TION). In contrast to our methods with unique individual data, NATION is a web-based surveillance system that reports grouped player data with limited individual participant identifiers or characteristics.29 Also, Kerr et al17 observed that the NTL rate in volleyball was 6.27/1000 AEs, which was 4 times higher than our reported NTL rate of 1.51/1000 AEs. Further, Kerr et al<sup>17</sup> noted that the highest percentage of NTL injuries consisted of injuries to the hand or wrist, included contusions, and were the result of player contact. Similarly, we also found that the hand or fingers was the site of most NTL injuries but typically consisted of muscle or tendon strains due to contact with the ball.

Our results agreed with those of previous researchers<sup>30</sup> who determined that competition injury rates were greater than practice injury rates among collegiate soccer athletes for overall and TL injuries but not for NTL injuries. This finding likely reflects the increased physical demands of competition compared with practice and the increased risk of more severe TL injuries. Overall, both TL and NTL injuries were sustained most often by outside hitters and middle blockers and occurred mostly during the second and third sets. Therefore, potential injury-prevention programs should target the movements necessary for these positions and should consider strategies to lessen the effect of neuromuscular fatigue throughout a match. It is also interesting to note that 58% of TL injuries and 46% of NTL injuries occurred in the second half of practice for our players. It might have been possible to reduce these injuries with an increased emphasis on proper training, mechanics, and time management. The effects of interventions to implement proper training and mechanics should be considered by future researchers.

#### **Player Characteristics**

Players with higher BMIs were at a slightly increased risk of injury. This finding is not unique to female volleyball players but has been reported in other populations. LaBella et al<sup>31</sup> reported that in athletes younger than 18 years, a higher BMI was associated with an increased risk of anterior cruciate ligament injury. Other authors<sup>32</sup> determined that middle school–aged individuals with higher BMIs were at an increased risk of TL and knee injuries. Thus, it may be advantageous for injury-prevention programs to also include achieving and maintaining a healthy body weight.

We found that a history of previous concussion or musculoskeletal injury was a risk factor for sustaining a TL injury. Injury history has been widely identified as a risk factor for future injury in collegiate athletic populations, but we are the first to confirm this observation for high school girls' volleyball.<sup>33–35</sup> Similarly, emerging evidence<sup>36,37</sup> indicated that sustaining a concussion increased the risk of an athlete sustaining an injury in the future. Our results suggested that players with a history of either a concussion or musculoskeletal injury represented a "highrisk" population that would potentially benefit from individualized injury-prevention programs.

Our data were notable in showing that the rate of TL injuries was similar for players who participated in multiple sports and players who participated only in volleyball. However, NTL injuries were 33% lower for the volleyball-only participants. These results were somewhat surprising given the growing body of support for the association of sport specialization with an increased risk of injury in high school and adolescent athletes<sup>2,39,40</sup>; yet the earlier investigators reported only lower extremity injuries rather than all injuries as we have. Further, data collection for our study took place over a single season (3 to 3.5 months), whereas volleyball training may take place over much of an entire year for the players. Monitoring injuries for players who exclusively participate in volleyball over the entire year may yield different results.

#### Limitations

This study had several limitations. First, recall bias regarding previous injuries sustained by the participants was a possibility. To mitigate this, we encouraged parents to assist the girls with the baseline form when recalling details of their previous TL injuries. Second, as with any prospective study, a risk of bias exists with respect to the study sample. To remedy this, we solicited each school in our state to participate, and we attempted to enroll a diverse sample of schools regarding characteristics such as student enrollment (large, medium, and small), location (rural, suburban, and urban), and funding status (public versus private). Further, every volleyball player at each enrolled school was provided with the same opportunity to enroll and take part in the study. Third, all data were collected within Wisconsin, and as such, may not be representative of all high schools across the United States. However, the state of Wisconsin conforms to National Federation of State High School Associations rules and regulations regarding volleyball participation, which are consistent with the majority of states throughout the US. Therefore, it is likely that the parameters of the high school volleyball season in Wisconsin were similar to those of the other states. Finally, we only recruited girls from high schools with an AT on site, and prior authors<sup>38</sup> showed that the recognition and management of sports injuries varied depending on AT availability at the school. Consequently, our results may not be generalizable to high school athletes with limited or no access to school-based ATs.

# CONCLUSIONS

In this prospective study of 2072 high school girls' volleyball players, the overall injury rate was 5.3/1000 AEs. The rate of TL injury was 2 times as high as the NTL injury rate. Injury rates varied based on the sport session (competition, practice, or conditioning), time in season, body location, injury type, injury onset, player position, and player activity. Due to the increased popularity of high school volleyball, sports medicine providers should take an active role in the prevention and effective treatment of injuries sustained during volleyball. We provided evidence of injury characteristics that can be used for the implementation of targeted injury-prevention programs.

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Address correspondence to Timothy A. McGuine, PhD, ATC, Department of Orthopedics and Rehabilitation, University of Wisconsin, Madison, 1685 Highland Avenue, Madison, WI 53705-2281. Address email to mcguine@ortho.wisc.edu.