Title: The Incidence and Risk Factors for Injuries in Girls Volleyball: A Prospective Study of 2072 Players

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

ABSTRACT

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

Objectives: 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: High school volleyball players participating during the 2018 interscholastic season.

Main Outcome Measures: TL and NTL injury rates, proportions, rate ratios, and with 95%CI.

Results: A total of 2,072 girls enrolled in the study with 468 subjects (22.5%) sustaining 549 injuries (NTL=28.4%, TL=71.6%) for an overall injury rate of 5.31 [4.89, 5.79] per 1000 AEs. The competition injury rate was greater than the practice injury rate for all injuries (IRR: 1.19, [1.00, 1.41]) and TL injuries (IRR: 1.31, [1.07, 1.60]). Players with a previous musculoskeletal injury had a higher rate of TL than NTL injuries (IRR; 1.36 [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/fingers (n=34,
Moreover, ligament sprains accounted for 40% of TL injuries (n=156), whereas muscle/tendon strains (n=79, 51%) accounted for over half of all NTL injuries.

**Conclusions:** While the majority of 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 injury among high school volleyball players is critical for the development of effective injury prevention programs.

**Word Count:** 281

**Key Words:** Female, Athlete, Sport, Epidemiology

**Key Points:** The rate for TL injuries was twice as high as the NTL 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 BMI were more likely to sustain an injury during the season.

Players who reported sustaining a musculoskeletal injury or concussion within the 12 months prior to the start of the season sustained more TL injuries but not NTL injuries.

**INTRODUCTION**

Volleyball is the most popular team sport for high school aged girls in the United States (US), with participation surpassing team sports such as basketball, soccer, and softball.\(^1\) Participation in high school volleyball has increased by 9% in the past decade.\(^1\) Furthermore, at the high school level, 7 times as many girls play volleyball compared to boys, making it one of the few predominantly girl sports.\(^1\) In addition to its popularity,
volleyball is becoming a year-round sport, with up to 50% of athletes participating in non-scholastic club teams.\textsuperscript{2,3} The overall injury burden associated with volleyball is significant. Recent reports estimate that more than 60,000 injuries are sustained by females competing in high school volleyball annually.\textsuperscript{4} Further, a recent report found that between 1990 to 2009 an estimated 490,000 female volleyball players (median age = 15.0 yrs) sought treatment in US emergency departments.\textsuperscript{5} Previous research on volleyball has focused on reporting the incidence of injuries in collegiate populations\textsuperscript{6–9}, or elite adult players.\textsuperscript{10–13} Much of this previous research has focused on injuries that caused the players to miss time from their sport.\textsuperscript{6,8,10–14} Time-Loss (TL) injuries are characterized as incidents that caused the player to miss at least 24 hours of participation, while Non-Time-Loss (NTL) injuries are characterized as injuries that require medical attention but cause the athlete to miss less than 24 hours of participation.\textsuperscript{14–16} To date, research regarding NTL injuries among volleyball athletes has been limited to the collegiate level and a single study of high school athletes, even though NTL injuries may account for >50% of all injuries.\textsuperscript{17} Understanding the attributes of these injuries can lead to preventive measures aimed at limiting minor repetitive use or acute onset injuries, which have the potential to lead to more significant injuries if left unrecognized or untreated.\textsuperscript{18}

The lack of research regarding NTL injuries in adolescent girls' volleyball players highlights the need for prospective research to identify and compare the incidence and characteristics of TL and NTL 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 to mitigate these predisposing factors and reduce the impact that sport related injuries have on their health and well-being. Therefore, the objective of this 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 XXXXXXXXXX health sciences IRB in March 2018.

**Subjects**

A convenience sample of 78 high schools within the state of X 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 subjects during pre-season team meetings. To be included in the study, each subject was required to be: 1) a member on the roster of one (freshman, sophomore, junior varsity, or varsity) of their interscholastic volleyball teams and 2) able to fully participate (no disabling injuries) in team activities on the first day of practice.

**Data Collection Procedures**

At time of enrollment, subjects 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 subject in order to calculate BMI. Informed consent was collected in person with each participant required to sign a combined informed assent / consent
document. Participants who were under the age of 18 were also required to have a parent / guardian sign the same form.

The athletic trainer (AT) at each school recorded all volleyball related athletic exposures (AE) and sport related injuries for each study participant during the fall 2018 season. For this study, an AE was defined as any volleyball coach-directed practice, or competition event. When an injury occurred, the AT completed a thorough report providing details of the injury, including their initial injury evaluation and onset characteristics into an online reporting system (REDCap). The AT would enter and update 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 or months following the injury. Injuries were classified as NTL if the subject was able to return to volleyball AE within 24 hours of restriction from participation and as TL if the subject missed ≥ 24 hours of 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 interscholastic volleyball event (practice, or competition), and 2) required medical attention by the school AT or a physician.

An athlete exposure (AE) was defined as one volleyball player participating in a single volleyball practice or competition. Primary variables of interest were defined as follows: 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 the post-season (from the date of the last regular season
competition through the last game of the interscholastic state tournament series).
Injury activity was defined as typical volleyball actions (attacking, blocking, digging,
etc.), Injury onset was categorized as 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 or action. The type of contact was described as contact
with the ball, surface, teammate, other (bleacher, net, wall) or none. Court location was
categorized as at the net, back row, front row or off the court. The time in session was
defined in competition as warm up as well as the 1<sup>st</sup>–5<sup>th</sup> sets and practice as taking
place during the warm up session prior to practice, 1<sup>st</sup> half, 2<sup>nd</sup> half or post practice
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
means(SD) and frequencies (%) for continuous and categorical variables, respectively.
Injury rates and 95% confidence intervals [CI] for all, TL and NTL injuries were
calculated using Generalized Estimating Equations (GEE) with a Poisson distribution
and log link, thus accounting for multiple injuries sustained by study participants. These
models were additionally used to calculate injury rates by session, time in season, injury
location, injury type and injury onset. All injury rates were calculated per 1000 AEs.
Injury rate ratios (IRRs [95%CI]) comparing rates of demographic and injury
characteristics for all, TL and NTL injuries were calculated. All 95% CIs that did not contain 1.0 were considered statistically significant. All data were analyzed using SAS v9.4 (SAS Institutes, Cary, NC).

RESULTS

A total of 2,072 study female volleyball players enrolled in the study. During the season, the players participated in a total of 103,489 AEs (Competition= 35%, Practice/Conditioning = 65%). Four hundred sixty-eight subjects sustained a total of 549 injuries during the season, with an overall injury rate of 5.3 [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 to 1.51/1000 AEs for NTL injuries. Subjects who sustained a TL injury missed a median [IQR] of 4.0 [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. Seventy-eight injuries (14.2%) resulted in a referral to a physician while 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 overall, TL and NTL injuries are provided in Table 1.
**Age and BMI**

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

**Prior Injury History**

Nineteen percent of the athletes reported sustaining a time loss musculoskeletal injury had surgery to treat an injury (3%) or sustained a sport related concussion (6%) in the previous 12 months. The most common previous injuries were to the lower extremity and previous injuries most commonly consisted of sprains/strains (58%), fractures (23%) and tendonitis/tenosynovitis (9%). The rate of injury was 50% greater in athletes who experienced an SRC within the past year, compared to those who did not (IRR: 1.50, [1.11, 2.03]). This association was significant for TL injuries (1.65 [1.17,2.32]), but not for NTL injuries (1.13 [0.59,2.14]). Similarly, there was an overall increased rate of injury among athletes who sustained a prior musculoskeletal sport injury (IRR: 1.36 [1.12, 1.65]), but this association was only significant for TL injuries (IRR:1.39 [1.09, 1.77]) but not NTL injuries (IRR: 1.30 [0.89, 1.90]).

**Distribution of the Rates for Time Loss and Non time loss 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 in practice/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]). Eighty-one (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% CI0.71, 1.16]). However, the injury rate was approximately two times as high in both the pre-season (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, [1.29, 3.40]) compared to the post-season.

**Injury types**

Ligament sprains accounted for 40% of TL injuries, followed by muscle/tendon strains (37%). Muscle/tendon strains accounted for 51% of NTL injuries followed by ligament sprains at 35%. Ankle injuries (24%) and knee injuries (14%) accounted for the greatest proportion of injuries, followed by hand/fingers (13%) and shoulders (12%). Ankle injuries accounted for the highest proportion of TL injuries, followed by knee (14%), and shoulders (11%). Among NTL injuries, hands/fingers accounted for the highest proportion of injuries (22%), followed by knees and shoulders (16% each).

The rate of acute onset injuries was 3.69/1000 AEs and 1.61/1000 AEs for gradual onset injuries. Acute onset injuries (n=382, 69.5%) occurred more often than gradual onset injuries (n=167, 30.5%). The rate of acute onset injuries was greater during competition than it was 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 to 62% sustained in practice.

Contact Versus Non-contact Injuries

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

Player position, activity, and court location

The distribution of injuries by position, activity, location and session are provided in Table 3. TL injuries were sustained most often by outside hitters (36.6%), middle blockers (22.9%), and setters (14.5%) while engaged in general play (30.0%), blocking (20.6%), and 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 2nd set (33.3%), while practice TL injuries occurred most often (58.0%) during the second half of the session.

NTL injuries were sustained most often by outside hitters (31.4%), middle blockers (21.8%), and setters (17.3%) while engaged in general play (30.1%), attacking
(14.1%), and digging (14.1%). NTL injuries occurred equally in the front row and back row (34.6% each). During competition, NTL injuries occurred most often in the 3rd set (30.8%), while NTL injuries sustained in practice occurred most often (46.2%) during the second half of the session.

DISCUSSION

This is the first study to prospectively report the incidence, 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 AE, which is considerably higher than previously reported rates of 1.24/1000 AE and 1.11/1000 AE. The difference in observed rates is certainly due to the fact that we recorded both TL and NTL injuries whereas the previous studies only accounted for TL injuries. However, our observed TL injury rate (3.8/1000 AE) is still higher than previously reported. This could be due to mechanisms through which data were collected. Both of the previous studies collected data through High school Reporting Injuries Online (RIO), which is a web-based multi-sport injury surveillance system that reports injuries and AEs on a weekly basis. In
contrast, we collected data on enrolled subjects in this study with ATs designated to monitor athletes and report injuries on a daily basis.

Our TL and overall estimates align more closely with those reported in the collegiate population. Reeser et al. reported the overall TL injury rate in female collegiate players to be 3.81/1000 AE. While Baugh et al. reported a much higher rate in female collegiate players of 7.07/1000 AE in a study that included both TL and NTL injuries. The inclusion of NTL injuries in our study makes the comparisons with previous volleyball injury rates in high school players difficult. However, we feel this more accurately reflects the true incidence of injuries sustained in high school volleyball. This concern is supported by Fritsch et al., who surveyed high school players and reported that while 40% of female players reported shoulder pain not due to a traumatic injury, only 33% of those athletes took time away from sport to recover from their injury.

Injury Distribution
The distribution of the injuries by body location, type, onset, and court location in our study is similar to previous research conducted on volleyball at the high school, collegiate, and elite adult levels of play. Specifically, there is agreement that acute ankle ligament sprains caused by contact with another player is a common injury. Research at the adult level, 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 retrospectively reported that using hard shell (rigid) braces reduced the incidence of ankle injuries at the collegiate level. While prophylactic ankle bracing using lace-up ankle braces has been shown to be effective
in high school basketball\textsuperscript{24} and football players\textsuperscript{25}, the effect of ankle bracing on injuries in high school volleyball players has not been reported and should be studied further. Previous reviews have reported the phenomenon of repetitive use shoulder injuries in volleyball.\textsuperscript{14,19,20} Our data demonstrates that shoulder injuries represent a significant proportion of all injuries with most of these resulting in TL. Given the incidence of gradual onset shoulder injuries in our study, the utilization of an effective training program at the high school level deserves further attention. Interestingly, most knee injuries were also classified as tendonitis which is the result of repetitive stress. Previous injury prevention efforts have been shown to reduce the incidence of repetitive use knee injuries.\textsuperscript{26,27} In addition, previous research has shown that a comprehensive program that includes a structured warm-up, core stability exercises, balance, strength, and technical training should be implemented to prevent volleyball injuries.\textsuperscript{28} 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 females, sports medicine providers and volleyball stakeholders should advocate for research on the effectiveness of a comprehensive injury prevention program in this population. Our results provide evidence that these injury prevention programs should target 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 for TL injuries was greater than NTL injuries, with fewer than 30\% of all injuries categorized as NTL injuries. This finding contradicts a study by Kerr et al. who reported that over 85\% of the injuries sustained by high school female volleyball players were NTL injuries.\textsuperscript{17} We cannot
account for these differences, as our definitions are the same for TL and NTL injuries. It should be noted that Kerr et al.\textsuperscript{17} utilized data from the National Athletic Treatment, Injury and Outcomes Network (NATION). In contrast to our methodology with unique individual data, NATION is a web-based surveillance system that reports grouped player data with limited individual subject identifiers or characteristics.\textsuperscript{29} It should also be noted that Kerr et al.\textsuperscript{17} reported that NTL rate in volleyball was 6.27/1000 AE which was 4 times higher than our reported NTL rate of 1.51/1000 AE. Further, Kerr et al.\textsuperscript{17} noted that the highest percentage of NTL injuries consisted of injuries that occurred to the hand / wrist, consisted of contusions and were the result of player contact. Similarly, we also found that the hand / fingers were the site of the most NTL injuries but consisted most often of muscle/tendon strains due to contact with the ball.

Our results agree with previous research among collegiate soccer athletes that found that competition injury rates were greater than practice injury rates for overall and TL injuries, but not for NTL injuries.\textsuperscript{30} This finding is likely a result of the increased physical demands of competition compared to practice, which results in increased risk of more severe TL injuries. Overall, both TL and NTL injuries were sustained most often by outside hitters and middle blockers and were most common 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 impact of neuromuscular fatigue over the course of a match. It is also interesting to note that 58% of TL injuries and 46% NTL injuries occur in the 2nd half of practice for our players. It may be possible to reduce these injuries with an increased emphasis on proper
training, mechanics, and time management. Studying the impact of interventions to implement proper training and mechanics should be considered by future researchers.

**Player Characteristics**

Our results show that the players with higher BMI were at a slight increased risk of injury. This finding is not unique to female volleyball players but has been reported previously in other populations. LaBella et al. reported that in athletes younger than 18, a higher BMI was associated with increased risk of anterior cruciate ligament injury.\(^{31}\) Another study reported that middle school age individuals with higher BMIs were at an increased risk of TL and knee injuries.\(^{32}\) Therefore, it may be advantageous for injury prevention programs also include achieving and maintaining a healthy body weight.

We also found that a history of previous concussion or musculoskeletal injury were risk factors for sustaining a TL injury. Previous injury history has been widely identified as a risk factor for future injury in collegiate athlete populations, but our study is the first to confirm this finding for high school girls' volleyball.\(^{33-35}\) Similarly, there is emerging evidence that sustaining a concussion increases the risk of an athlete sustaining an injury in the future.\(^{36,37}\) Our results suggest that athletes with a previous history of either concussion or musculoskeletal injury represent a “high-risk” population that would potentially benefit from individualized injury prevention programs.

Our data are also notable in that they show that the rate for TL injuries were similar for players who participated in multiple sports and players who only participated in volleyball. On the other hand, NTL injuries were 33% lower in for the volleyball only participants. These results are somewhat surprising since there is a growing body of evidence that sport specialization is associated with an increased risk of injury in high
school and adolescent athletes. This may be due to the fact that two papers only
reported lower extremity injuries rather than reporting all injuries as we have. Further,
data collection for our study took place over a single season (3 to 3.5 months) while
volleyball training may take place over much of an entire year for the players. Reporting
injuries for players who exclusively participate in volleyball over the entire year may yield
different results.

Limitations

There are several limitations for this study. First, there is the possibility of recall
bias with regards to the previous injuries sustained by the subjects. To mitigate this, we
encouraged parents to assist the subjects when recalling details regarding their
previous TL injuries on the baseline form. Second, as with any prospective study, there
is a risk of bias with regards 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
with regards to characteristics such as student enrollment (large, medium and small),
location (rural, suburban, urban) and funding status (public vs 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 XXXXX and as
such may not be representative of all high schools across the US. However, the state of
XX conforms to National Federation of High School Associations rules and regulations
regarding volleyball participation, which are in agreement with the vast majority of states
across the US. Therefore, it is likely that the parameters of the high school volleyball
season in XX are similar to the other states. Finally, our sample only recruited subjects
from high schools with an AT on site. Recent reports show that the recognition and
management of sports injuries varies depending on AT availability at the school. Therefore, our results may not be generalizable to high school athletes with limited or no access to a school-based ATs.

**Conclusion**

In this prospective study of 2072 high school girls' volleyball players, there was an overall injury rate of 5.3 per 1000 AE. The rate of TL injury was two times as high as the NTL injury rate and injury rates varied based on sport session (competition or practice/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. This study provides evidence of injury characteristics that can be used for the implementation of targeted injury prevention programs.
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Table 1. Baseline Characteristics and Injury Rate Ratios (IRR) for Time Loss and Non Time Loss Injuries in Girls High School Volleyball Players

| Variable                        | Mean (SD) or N (%) | Time Loss Injuries (n = 393) | Non Time Loss Injuries (n = 156) | All Injuries (n = 549) |
|---------------------------------|--------------------|------------------------------|---------------------------------|-----------------------|
|                                 |                    | IRR (95% CI) | p-value | IRR (95% CI) | p-value | IRR (95% CI) | p-value |
| Age                             | 15.6 (1.1)         | 1.10 (1.004, 1.20) | 0.04    | 1.15 (1.004, 1.33) | 0.04    | 1.11 (1.03, 1.20) | 0.006  |
| Height (inches)                 | 65.9 (2.8)         | 1.06 (1.02, 1.09) | 0.002   | 1.02 (0.96, 1.07) | 0.55    | 1.04 (1.01, 1.08) | 0.003  |
| Weight (lbs)                    | 138.6 (22.8)       | 1.06 (1.02, 1.10) | 0.004   | 1.07 (1.00, 1.14) | 0.04    | 1.06 (1.03, 1.10) | <0.001 |
| BMI                             | 22.4 (3.5)         | 1.02 (0.99, 1.05) | 0.18    | 1.04 (0.99, 1.08) | 0.07    | 1.02 (1.00, 1.05) | 0.04   |
| Grade                           |                    | 0.13            |         | 0.52          |         | 0.052          |        |
| 9                               | 754 (36.4%)        | Ref.            |         | Ref.          |         | Ref.           |        |
| 10                              | 624 (30.1%)        | 1.29 (1.00, 1.66) | 0.052   | 1.20 (0.79, 1.80) | 0.39    | 1.26 (1.02, 1.57) | 0.04   |
| 11                              | 403 (19.4%)        | 1.25 (0.95, 1.66) | 0.12    | 1.32 (0.85, 2.05) | 0.21    | 1.27 (1.00, 1.61) | 0.05   |
| 12                              | 292 (14.1%)        | 1.36 (1.01, 1.83) | 0.06    | 1.35 (0.84, 2.16) | 0.21    | 1.35 (1.05, 1.74) | 0.02   |
| Sport Participation             |                    |                |         |              |         |                |        |
| Play multiple sports            | 1534 (74.0%)       | Ref.            |         | Ref.          |         | Ref.           |        |
| Play volleyball only            | 529 (26.0%)        | 1.08 (0.86, 1.34) | 0.52    | 0.67 (0.45, 1.00) | 0.05    | 0.95 (0.78, 1.15) | 0.61   |
| Previous musculoskeletal sport injury within the last 12 months | | | | | | | |
| No                              | 1684 (81.3%)       | Ref.            |         | Ref.          |         | Ref.           |        |
| Yes                             | 388 (18.7%)        | 1.39 (1.09, 1.77) | 0.008   | 1.30 (0.89, 1.90) | 0.18    | 1.36 (1.12, 1.65) | 0.002  |
| Previous surgery within the last 12 months | | | | | | | |
| No                              | 2014 (97.2%)       | Ref.            |         | Ref.          |         | Ref.           |        |
| Yes                             | 58 (2.8%)          | 0.62 (0.29, 1.31) | 0.21    | 1.15 (0.47, 2.80) | 0.76    | 0.77 (0.43, 1.36) | 0.36   |
| Previous concussion within the last 12 months | | | | | | | |
| No                              | 1951 (94.1%)       | Ref.            |         | Ref.          |         | Ref.           |        |
| Yes                             | 121 (5.9%)         | 1.65 (1.17, 2.32) | 0.004   | 1.13 (0.59, 2.14) | 0.71    | 1.50 (1.11, 2.03) | 0.01   |
Table 2: Rates for Time Loss and Non Time Loss Injuries in Girls High School Volleyball Players

| Variable       | Time Loss Injuries (n = 393) |                  | Non Time Loss Injuries (n = 156) |                  | All Injuries (n = 549) |                  |
|----------------|-------------------------------|-------------------|---------------------------------|-------------------|-----------------------|-------------------|
|                | n (%)                         | Rate (95% CI) per 1000 AEs | n (%)                          | Rate (95% CI) per 1000 AEs | n (%)                | Rate (95% CI) per 1000 AEs |
| 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       | 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 |                               |                      |                                 |                    |                       |                   |
| Pre-season     | 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 (1.36, 1.83)  | 455 (82.9)           | 5.53 (5.03, 6.07)  |
| Post Season    | 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)  |
| Non-Contact    | 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 (0.17, 0.33)  | 79 (14.4)            | 0.76 (0.61, 0.96)  |
| Hand / 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, 0.59)   | 25 (16.0)                       | 0.24 (0.17, 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 / 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    |                               |                      |                                 |                    |                       |                   |
| Variable               | Time Loss Injuries (n = 393) | Non Time Loss Injuries (n = 156) | All Injuries (n = 549) |
|------------------------|------------------------------|----------------------------------|-----------------------|
|                        | n (%)                        | Rate (95% CI) per 1000 AEs       | n (%)                 | Rate (95% CI) per 1000 AEs |
| Ligament Sprain        | 156 (39.7)                   | 1.51 (1.29, 1.77)                | 55 (35.3)             | 0.53 (0.41, 0.70) |
| Muscle / Tendon strain | 146 (37.1)                   | 0.76 (0.61, 0.96)                | 79 (50.6)             | 1.41 (1.19, 1.67) |
| Concussion             | 38 (9.5)                     | 0.36 (0.27, 0.49)                | 0 (0.0)               | --                   |
| Contusion              | 14 (3.6)                     | 0.14 (0.08, 0.23)                | 10 (6.4)              | 0.09 (0.05, 0.18) |
| Dislocation / Subluxation | 8 (2.0)                  | 0.08 (0.04, 0.15)                | 3 (1.9)               | 0.03 (0.009, 0.09) |
| Meniscus Tear          | 7 (1.8)                      | 0.07 (0.03, 0.16)                | 0 (0.0)               | --                   |
| Acute Fracture         | 6 (1.5)                      | 0.06 (0.03, 0.13)                | 0 (0.0)               | --                   |
| Stress Fracture        | 5 (1.3)                      | 0.05 (0.02, 0.12)                | 0 (0.0)               | --                   |
| Other                  | 14 (3.6)                     | 0.14 (0.08, 0.24)                | 8 (5.3)               | 0.06 (0.04, 0.15) |

Ligament Sprain
Muscle / Tendon strain
Concussion
Contusion
Dislocation / Subluxation
Meniscus Tear
Acute Fracture
Stress Fracture
Other
Table 3 Distribution of Time Loss and Non Time Loss Injuries by Position, Activity, Location and Session

| Variable          | Time Loss n (%) | Non Time Loss n (%) | All Injury n (%) |
|-------------------|-----------------|---------------------|-----------------|
| **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       |                 |                     |                 |
| Warmup            | 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)       |
| Practice   | 3rd Set  | 4th Set  | 5th 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)  |
| **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)  |
