The Association of High School Sport Participation and Injury History in Collegiate Club Sport Athletes

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Short Title: Collegiate Club Sport Injuries

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Abbreviations: Upper extremity (UE), Lower extremity (LE)

Key Words: overuse injury, sport specialization, collegiate transition, club athletic trainers

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Abstract

**Context:** Sport specialization during adolescence may affect future injury risk. This association has been demonstrated in some professional sports athletes.

**Objective:** Determine the association between adolescent sport specialization levels in high school and injuries sustained during collegiate club sports.

**Design:** Cross-sectional study.

**Setting:** Paper and online surveys.

**Patients:** Collegiate club sport athletes.

**Intervention:** An anonymous survey was administered from September 2019-May 2020. The survey included sport specialization classification via commonly used 3-point scale (Low, Moderate, High) for each high school year (9th-12th), high school sports participation, and collegiate club sport injury history. The number of years an individual was highly specialized in high school was calculated (0-4 years). Individuals who participated in the same sport in high school and college were compared to individuals who were playing a different sport in college than their high school sports.

**Main Outcome Measures:** An injury related to sport club activities and classified as arising from a contact, non-contact, or overuse mechanism that required the individual to seek medical...
treatment or diagnosis. Injuries were classified into overuse and acute injury mechanisms for the upper and lower extremity, (UE and LE respectively) and head/neck.

Results: Single sport participation or number of years highly specialized in high school sport were not associated with college club sport injuries (p>0.1). Individuals who played a different collegiate club sport than their high school sports were more likely to report a LE and head/neck acute injury compared to athletes who played the same collegiate and high school sport (LE=20% vs 8%, $X^2=7.4$ p=0.006; head/neck=16% vs 3%, $X^2=19.4$ p<0.001).

Conclusions: Adolescent sport specialization was not associated with reported club sport injuries in collegiate club sport athletes. Collegiate club sport athletic trainers should be aware that incoming students exploring a new sport may be at risk for LE and head/neck acute injuries.

Key Words: sport specialization, injury risk, lower extremity injuries, upper extremity injuries

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Key points:

1) High school sport specialization was not significantly associated injury risk in college-aged club athletes.

2) Participating in a new club sport in college may increase the risk of acute lower extremity and head and neck injuries.
With the rise of the youth club sport industry and the increased number of students participating in high school sports,\textsuperscript{1,2} healthy adolescent sport participation has been a growing area of research. Several studies have demonstrated that sport opportunities outside of interscholastic sports have been associated with sport specialization.\textsuperscript{2,3} Sport specialization is commonly defined as year-round sport participation at the exclusion of other sports\textsuperscript{4} and has been associated with increased injury risk in adolescent athletes.\textsuperscript{5} Specifically, most studies have demonstrated sport specialization’s association with overuse injuries\textsuperscript{4-7} leading to the hypothesis that high training volume with repetitive movements may be the mechanism for overuse injuries in specialized high school athletes. However, some studies have demonstrated a link between sport specialization and acute injuries.\textsuperscript{3,8,9} Recently, studies have demonstrated sport specialization’s association with movement patterns where specialized adolescent athletes had worse movement patterns compared to non-specialized adolescent athletes.\textsuperscript{10,11} This observation has also been reported in adults who identified only participating in one sport in high school compared to adults who participated in two or more high school sports.\textsuperscript{12} These findings propose an alternate or added hypothesis that sport specialization increases injury risk because of its effects on movement quality. Both theories require serious consideration that the effects of sport specialization during adolescence, and particularly high school sport specialization, may persist into young adulthood and beyond.

Two studies have demonstrated that professional athletes that were single sport athletes in high school had an increase in major injuries during their professional career as well as shorter professional sporting careers compared to professional athletes that were multisport athletes in high school.\textsuperscript{13,14} These findings may be explained by the previous hypothesis that sport specialization has a long-term effect on movement patterns that increase the risk of sport-related
injuries. An alternative explanation for these findings may be related to how prior injuries may predispose an athlete to future injuries.\(^{15}\) Therefore, it is possible that injuries sustained early in an athlete’s sporting career due to early sport specialization have a compounding effect throughout their collegiate and professional careers. Even though previous studies have demonstrated that a proportion of collegiate athletes were highly specialized in high school,\(^{16,17}\) minimal studies have explored how sport specialization may affect injury risk in collegiate athletes. Furthermore, even less is known about sport specialization and injuries in collegiate club sport athletes.

In 2012, it was estimated that there were two-million collegiate club sport athletes in the United States.\(^{18}\) As collegiate club sports popularity grows, so does the increased awareness for healthcare professionals to understand the injury risk and patterns associated with this population.\(^{19-21}\) In particular, many campus recreational organizations employ athletic trainers to oversee the health and well-being of club sport athletes. With improved knowledge about club sport injury risk, athletic trainers can better serve this large population and advocate for the need of athletic trainers in these settings. Therefore, the purpose of this study was to determine the association between adolescent sport participation behaviors and injuries sustained during collegiate club sports. We hypothesized that collegiate club sport athletes who were specialized in high school would report more collegiate sports injuries than collegiate club sport athletes who were not specialized in high school. Additionally, we hypothesized that collegiate club sport athletes who were continuing participation in one of their high school sports would be more likely to report an injury compared to collegiate club sport athletes who were exploring a new sport in the collegiate club setting.

Methods
This study was approved by the Institutional Review Board of **blinded**. The overall study design was a cross-sectional design that utilized a paper and online anonymous surveys. The anonymous surveys were administered from September of 2019 to May of 2020. In the fall of 2019, club sport presidents and organizers at the **blinded** were contacted by the primary investigator via e-mail to ask permission for the primary investigator to present the study to their respective sport club team. All club sports at **blinded** were contacted except for Esports, water ski and wakeboard, and fishing. The primary investigator was then invited to present the study and distribute the survey to sport club teams during practices or team meetings. The surveys were completed during this time and were returned to the primary investigator. In the spring of 2020, due to COVID-19 restrictions, the survey was moved online and created with Qualtrics (Provo, UT). The survey link was forwarded to club sport presidents and organizers which were then e-mailed to their respective team participants. All participants were students at the same university in the Midwest region of the United States. Of the sports clubs contacted by the primary investigator, 31/48 (65%) clubs were represented in our dataset. The sports represented include baseball, men’s and women’s basketball, cheer, dance elite, gymnastics, men’s and women’s ice hockey, men’s and women’s lacrosse, women’s soccer, softball, swim/dives, tennis, track, men’s and women’s volleyball, wrestling, women’s rugby, aikijujitsu, archery, boxing, fencing, field hockey, figure skating, Irish dancing, taekwondo, triathlon, water polo, and men’s and women’s ultimate frisbee. Because the survey was anonymous, athletes were not required to sign a consent form. Athletes were provided a written description of the study and completing the survey was deemed consent.

*Survey*
The survey included sport specialization classification for each high school year (9th-12th), high school sports participation, and injuries sustained during their collegiate club sport career. The original 3-point scale proposed by Jayanthi et al. was adjusted based on previous research identifying misclassification by single-sport athletes and by previous research which used the scale retrospectively to assess high school sport specialization in Division-1 collegiate athletes. For each grade, athletes were classified in the 3-point scale based on the answers to three questions: 1) “in high school, did you consider one of your sports more important than your other sports and if you only played on sport, select ‘yes’?” 2) “In high school, did you train more than eight months a year in one sport?” 3) “In high school, did you quit a sport to focus more on a single sport OR have you only played a single sport?” Participants selected either “yes” or “no” to each question, which was scored as 1 or 0 points, respectively. Scores for each question were summed to determine the specialization category in the 3-point scale as low (0-1), moderate (2), or high (3) for 9th, 10th, 11th, or 12th grade. Once an athlete selected, “yes” to question 3, that question was marked as “yes” for their subsequent grades in high school. The number of years an individual was classified as highly specialized (range: 0-4 years) in high school was then calculated.

Multisport participation or single-sport participation was determined based on the number of sports an athlete identified participating in during their high school career. Participants who selected two or more sports for the question, “what sports did you participate in high school” were categorized as multisport athletes. Conversely, athletes who only selected one sport for this question were categorized as single-sport athletes. Individuals who participated in the same sport in high school and college were considered an athlete who was continuing their high school sport into college.
Previous injury

Figure 1 is an example of the survey format for collecting injury data. An injury must have been related to collegiate club sport activities and could be classified as arising from a contact, non-contact, or overuse mechanism (figure 1, column 4) that required the individual to seek treatment or diagnosis from an athletic trainer or physician (figure 1, column 5). Injuries selected as overuse injuries were analyzed as overuse injuries and injuries that were either contact or non-contact were designated as acute injuries. Therefore, for analysis, injuries were classified into overuse and acute injuries for the upper and lower extremity (UE and LE respectively) and overuse and acute injuries for the head and neck. The marked mechanism of injury was reviewed by two authors (*blinded for review*) on the research team who are certified athletic trainers to verify that the mechanism of injury aligned with any further injury description given by the participant. Furthermore, athletes that wrote “concussion” in column 2 (figure 1) of their head/neck injury section were classified as having suffered a concussion. An LE injury was considered an injury to the hip, upper leg, knee, lower leg, ankle, or foot (figure 1, column 1). A UE injury was considered an injury to the shoulder, elbow and wrist/hand (figure 1, column 1). Back injuries were not included in this analysis because of their difficulty to be classified as upper and lower extremity without expanding the survey further. Reported injuries could have occurred at any point during their collegiate club sport career (figure 1). Participants were then dichotomized as either having reported a UE overuse, UE acute, LE overuse, LE acute, head/neck overuse, head/neck acute, or head/neck concussion injury during their club sport career or not reporting a UE overuse, UE acute, LE overuse, LE acute, head/neck overuse, head/neck acute, or head/neck concussion injury during their club sport career. This was done as few participants had more than one UE overuse, UE acute, LE overuse, LE acute injuries,
head/neck overuse, head/neck acute, or head/neck concussion injury (table 1). No more than 2
people in each category reported multiple UE overuse, UE acute, and LE acute injuries (table 1).
Several people (n=15) reported greater than two LE overuse injuries (table 1). Furthermore, no
one reported more than one head/neck injury (table 1).

Statistical Analysis

Data is presented as means and standard deviations (SD) for continuous variables while
frequencies and percentages were used for categorical variables. Head/neck overuse injury was
not used for analysis as only two injuries in the entire sample were reported (table 1). A 2x2 chi-
square analyses was used to compare reported UE overuse (yes/no), UE acute (yes/no), LE
overuse (yes/no), LE acute (yes/no), head/neck acute (yes/no), and concussion (yes/no) injuries
between males and females. A 2x2 chi-square analysis was used to compare reported UE overuse
(yes/no), UE acute (yes/no), LE overuse (yes/no), LE acute (yes/no), head/neck acute (yes/no),
and concussion (yes/no) injuries between multisport and single-sport high school athletes. This
same 2x2 chi-square analysis was used to compare each injury variable between those continuing
their high school sport into college to those not continuing their high school sport into college.
The number of years in high school being classified as highly specialized was aggregated into
three categories, 0 years, 1-2 years, and 3-4 years of high specialization for each participant. This
was done to avoid violating the assumption that each expected cell count must be above 5 for a
chi-square analysis. A 2x3 chi-square analysis was used to compare reported UE overuse
(yes/no), UE acute (yes/no), LE overuse (yes/no), LE acute (yes/no), head/neck acute (yes/no),
and concussion (yes/no) injuries between the three categories of the number of years a
participant was classified as highly specialized (0 years, 1-2 years, and 3-4 years). Statistical
significance was set \textit{a priori} at \( p < 0.05 \) and all analyses were performed using IBM SPSS

statistics (V26.0; IBM Corp).

\textbf{Results}

Demographic information is provided in Table 2. Men’s and women’s volleyball contributed
the largest number of athletes (table 2), but representation of club sports in this population was
rather heterogeneous. Approximately 47\% of collegiate club athletes were classified as highly
specialized during their high school careers (table 3). Reported levels of sport specialization
increased as high school grade increased (table 3).

Table 4 reports the number of athletes who reported at least one UE overuse, LE overuse, UE
acute, and LE acute injury during their collegiate club sports career as well as the chi-square
analysis for each sport participation variable. High school single-sport or multisport participation
was not associated with any reported injury mechanism or limb in collegiate club sport athletes
(table 4). Similarly, the number of years an athlete was classified as highly specialized in high
school was not associated with any reported injury mechanism or limb in collegiate club sport
athletes (table 4). Athletes who played a new collegiate club sport compared to their high school
sport were more likely to report an acute LE injury compared to athletes who were continuing
one of their high school sports into college (Table 4; 20\% v 8\%, \( p=0.006 \)).

Table 5 demonstrates the number of athletes who reported a head/neck acute injury and
concussion during their collegiate club sports career as well as the chi-square analysis for each
sport participation variable. All concussion injuries occurred from head/neck acute injuries.
There was no association of high school single-sport or multisport participation with head/neck
acute injuries or concussion (table 5) and there was no association of head/neck acute injuries
and concussion with the number of years an athlete was classified as highly specialized (table 5).
Athletes who played a new collegiate club sport compared to their high school sport were more likely to report a head/neck acute injury and a concussion compared to athletes who were continuing one of their high school sports into college (table 5; acute head/neck 16% v 3%, p<0.001; concussion 13% v 2%, p<0.001).

Discussion

Our findings did not support our hypothesis that high school sport specialization would be associated with reported injuries in collegiate club sport athletes. There may be a few explanations as to why sport specialization in high school was not associated with injuries in collegiate club sport athletes. Though we were able to represent many collegiate club sports in this study, it is important to recognize that each sports’ playing style, practices, length of season, and competition level are widely varied. Therefore, it is possible that high school sport specialization is more detrimental for one sport and not the other. Post et al. reported that high school volleyball athletes who specialized were at an increased risk for overuse injuries compared to low specialized volleyball athletes whereas the same relationship was not found in basketball and soccer high school athletes.24 Similarly, a recent study in soccer players demonstrated no link between specialization and injury risk.25 Therefore, a sport specific study in collegiate athletes may be beneficial to better understand the possible association of high school sport specialization with collegiate injuries and how this may vary between sports.

To the best of our knowledge, we are the first to report on the association of high school sport specialization and sport participation with collegiate club sports injuries. Several studies have examined the association of injuries with early sport specialization in Division-I and professional athletes.13,14,16,26 Unlike our results, all of these studies found an association with
high school sport specialization and injuries in Division-I and professional athletes.\textsuperscript{13,14,16,26} Confino et al. and Rugg et al. both found that athletes who were single-sport athletes in high school had more publicly reported major injuries during their professional careers than professional athletes who were multisport athletes in high school.\textsuperscript{13,14} Another study by Buckley et al. surveyed high school, collegiate, and professional athletes.\textsuperscript{16} This study sought to cross-sectionally evaluate sport specialization habits in current high school, collegiate, and professional athletes and to evaluate the association between reported injuries with sport specialization. Buckley et al. found that current high school and collegiate players recalled more injuries the athletes attributed to specializing in one sport compared to current professional athletes.\textsuperscript{16} Lastly, Ahlquist et al. found that Division-I athletes that specialized in a single sport before the age of 14 years old were more likely to report multiple college sport-related injuries compared to athletes that specialized later than the age of 14.\textsuperscript{26} These studies support the hypothesis that sport specialization may affect injury risk throughout an individual’s sporting career. There may be several reasons for our different results in comparison to these previous studies. Given the demands of professional sports, long term training load is likely higher in professional athletes compared to club sport athletes. It is equally likely that long-term training volume and repetitive motions are significantly higher in professional athletes than our club sport athletes. Anecdotally, club sport athletes practice a few times a week, have a shorter competition season, and few organized team events outside of their regular season compared to Division-I collegiate athletes or professional athletes. It is possible that club sport athletes decreased volume and training load compared to Division-I and professional athletes negates the potential negative effects of high school sport specialization. This would be supported by previous literature that training volume is a more important predictor for injury than early sport specialization. For
example, Sugimoto et al. found that increases in training volume were associated with injury risk in adolescent females. However, Sugimoto et al. did not find single-sport athletes to be more associated with injury than multisport athletes like they hypothesized. Post et al. reported similar findings; however, McGuine et al. demonstrated that sport specialization is a risk factor independent of training volume. Therefore, future studies should prospectively study training volume, sport specialization, and sport-related injuries in high school athletes as they transition to collegiate sports to better illuminate how these two variables may effect collegiate sport injury risk.

To the best of our knowledge, we are the first to report that collegiate club athletes who did not play their club sport in high school were more likely to report an LE acute injury, head/neck acute injury and concussion compared to club athletes who were continuing their high school sport in college. Most club athletes who were participating in a new sport were participating in club sports like rugby (10/67 [15%]), ultimate frisbee (21/67 [31%]), and martial arts (8/67 [12%]). It is possible that their high school sport specialization for these athletes affected their injury risk in club sports activities; however, we did not have sufficient power to analyze this possibility in this specific subset of individuals. Several studies have demonstrated that adolescent multisport participation is associated with improved motor skills, movement patterns, endurance, and strength. When switching to a new sport, these improvements, or lack of improvements, during adolescence may affect the risk of injury for these athletes. Furthermore, it is possible that switching sports after high school may protect an individual from overuse injuries but may increase their risk for acute injuries. There is limited and conflicting evidence on the association of years of playing experience and sport-related injuries. It has been proposed that athletes starting to compete in a new sport lack a transitional period to
prepare for movements and loads necessary in competition. Thus, a lack of knowledge of the
given sport and physical preparedness for that sport may all lead to an increased risk of injury.

Our results support this hypothesis, though future research is needed to bolster this theory.

Athletic trainers working with collegiate club sport programs or organizers of club sport
programs may benefit from identifying athletes new to their respective club sport and providing
extra lessons and training sessions in that sport to reduce the risk of acute injuries in this
population.

Limitations

Several limitations exist with this study. First, sport specialization was based on
retrospective answers to high school sport participation. Similarly, collegiate club sport injuries
were reported retrospectively; therefore, this data is subject to recall bias. However, we aimed to
improve the accuracy of injury data by restricting analyses to injuries that individuals could
identify a specific mechanism of injury and that was reported to a medical professional (athletic
trainer or physician). The survey could have included more insight into training load and volume
during their high school athletic career as well as different sport organizations they participated
in (example: AAU, club volleyball, etc.). However, these questions were left out to not burden
the participants with too lengthy of a survey. These results may not be generalizable beyond this
specific university or geographical location. Future studies that track sport participation and
specialization through high school and into college may provide a better understanding of how
high school sport specialization effects injury risk for college-aged athletes at all levels.

Conclusion
High school sport specialization was not associated with injuries reported by collegiate club sports athletes. This may be due to reduced sport volume and training load for collegiate club athletes compared to higher level athletes or the heterogeneity of sports analyzed. College athletes who were playing a club sport different from any of their high school sports were more likely to report an LE acute, head/neck acute injury, and concussion compared to college athletes that were continuing to participate in a sport from their high school sporting career. This may be due to a lack of experience in the athletes’ new sport leading to increased injuries. Athletic trainers and other professionals who work with collegiate club sport programs may benefit from identifying individuals who are starting a new sport at the collegiate level.
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Table 1. Number of participants who reported at least one injury for each location and each injury mechanism. Total number of club sport, self-reported injuries for each location and each injury mechanism. Percentage of participants who reported at least one injury.

|                        | Upper Extremity | Lower Extremity | Head/neck |
|------------------------|-----------------|-----------------|-----------|
|                        | overuse injuries | acute injuries | overuse injuries | acute injuries | overuse injuries | acute injuries | concussion |
| Number of participants reporting an injury | 20 | 22 | 51 | 42 | 2 | 22 | 16 |
| Total number of injuries reported | 22 | 23 | 75 | 44 | 2 | 22 | 16 |
| Percentage of participants who reported at least one injury (N=412) | 5% | 5% | 13% | 10% | <1% | 5% | 4% |
Table 2. demographic information for 412 club sport athletes.

| Variable                        | Frequency(n) | Percentage(%) |
|---------------------------------|--------------|---------------|
| **Sex**                         |              |               |
| Male                            | 167          | 40.5%         |
| Female                          | 245          | 59.5%         |
| **Age (mean[SD])**              | 20.1 (mean)  | 2.0 (SD)      |
| **High school sport same as club sport** |          |               |
| Yes                             | 345          | 83.7%         |
| No                              | 67           | 16.3%         |
| **Club sport participation**    |              |               |
| Baseball                        | 25           | 6.1%          |
| Basketball                      | 39           | 9.5%          |
| Cheer / Dance                   | 11           | 1.7%          |
| Gymnastics                      | 2            | 0.5%          |
| Ice hockey                      | 26           | 6.3%          |
| Lacrosse                        | 36           | 8.7%          |
| Soccer                          | 18           | 4.4%          |
| Softball                        | 17           | 4.1%          |
| Swim / Dive                     | 29           | 7.0%          |
| Tennis                          | 13           | 3.2%          |
| Track                           | 25           | 6.1%          |
| Volleyball                      | 46           | 11.2%         |
| Wrestling                       | 8            | 1.9%          |
| Other*                          | 117          | 28.4%         |

*women’s rugby, aikijuitsu, archery, boxing, fencing, field hockey, figure skating, Irish dancing, taekwondo, triathlon, water polo, men’s and women’s ultimate frisbee
Table 3. High school sport specialization frequencies and percentages in collegiate club sport athletes.

| Variable                                      | Frequency (n) | Percentage (%) |
|-----------------------------------------------|---------------|----------------|
| **a Multisport high school athlete**
  n=412                                         |               |                |
| Yes                                           | 325/412       | 78.9%          |
| No                                            | 87/412        | 21.1%          |
| **a 9th grade sport specialization**
  n=398                                         |               |                |
| Low                                           | 149/398       | 37.4%          |
| Moderate                                      | 135/398       | 33.9%          |
| High                                          | 114/398       | 28.6%          |
| **a 10th grade sport specialization**
  n=398                                         |               |                |
| Low                                           | 119/398       | 29.9%          |
| Moderate                                      | 140/398       | 35.2%          |
| High                                          | 139/398       | 35.0%          |
| **a 11th grade sport specialization**
  n=401                                         |               |                |
| Low                                           | 90/401        | 22.4%          |
| Moderate                                      | 135/401       | 33.6%          |
| High                                          | 176/401       | 43.9%          |
| **a 12th grade sport specialization**
  n=399                                         |               |                |
| Low                                           | 98/399        | 24.6%          |
| Moderate                                      | 127/399       | 31.8%          |
| High                                          | 174/399       | 43.6%          |
| **b Number of years in high school being highly specialized**
  n=396                                         |               |                |
| 1 year                                        |               |                |
| 2 years                                       |               |                |
| 3 years                                       |               |                |
|        |        |        |
|--------|--------|--------|
| 0 years| 210/396| 53.0%  |
| 1 year | 17/396 | 4.3%   |
| 2 years| 35/396 | 8.8%   |
| 3 years| 29/396 | 7.3%   |
| 4 years| 105/396| 26.5%  |

*a missing data for these questions may be due to participants not wanting to answer that question or missing the question all together on survey

*b Only participants with sport specialization levels for each grade were included in this number
Table 4. Chi-square analysis of high school sport specialization by overuse and acute injuries to the upper and lower extremities (UE and LE respectively).

| Variable                              | At least 1 UE overuse injury | At least 1 LE overuse injury | At least 1 UE acute injury | At least 1 LE acute injury |
|---------------------------------------|------------------------------|------------------------------|----------------------------|--------------------------|
|                                       | Yes (n[%])                   | No (n[%])                    | p-value                    | Yes (n[%])               | No (n[%])               | p-value | Yes (n[%]) | No (n[%]) | p-value | Yes (n[%]) | No (n[%]) | p-value |
| Sex                                   |                              |                              |                            |                          |                          |                     |            |            |            |            |            |         |            |
| Male                                  | 11 (6%)                      | 156 (93%)                    | 0.177                      | 22 (13%)                  | 145 (87%)                | 0.686               | 10 (6%)   | 157 (94%)  | 0.629      | 15 (9%)   | 152 (91%)  | 0.502    |         |
| Female                                | 9 (4%)                       | 236 (96%)                    |                            | 29 (12%)                  | 216 (88%)                |                     | 12 (5%)   | 233 (95%)  |            | 27 (11%)  | 218 (89%)  |         |
| Same HS and Club sport                |                              |                              |                            |                           |                          |                     |            |            |            |            |            |         |         |
| Yes                                   | 18 (5%)                      | 327 (95%)                    | 0.462                      | 42 (13%)                  | 303 (87%)                | 0.775               | 17 (5%)   | 328 (95%)  | 0.364      | 29 (8%)   | 316 (92%)  | 0.006    |         |
| No                                    | 2 (3%)                       | 65 (97%)                     |                            | 9 (14%)                   | 58 (86%)                 |                     | 5 (8%)    | 62 (92%)   |            | 13 (20%)  | 54 (80%)   |         |
| HS Multisport athlete                 |                              |                              |                            |                           |                          |                     |            |            |            |            |            |         |         |
| Yes                                   | 15 (5%)                      | 310 (95%)                    | 0.663                      | 42 (13%)                  | 283 (87%)                | 0.517               | 17 (5%)   | 308 (95%)  | 0.849      | 37 (11%)  | 287 (89%)  | 0.123    |         |
| No                                    | 5 (6%)                       | 82 (94%)                     |                            | 9 (10%)                   | 78 (90%)                 |                     | 5 (6%)    | 82 (94%)   |            | 5 (6%)    | 82 (94%)   |         |
| Number of years being classified as highly specialized in HS |                              |                              |                            |                           |                          |                     |            |            |            |            |            |         |         |
| 0 years                               | 11 (5%)                      | 199 (95%)                    | 0.533                      | 29 (14%)                  | 181 (86%)                | 0.286               | 10 (5%)   | 200 (95%)  | 0.876      | 24 (11%)  | 186 (89%)  | 0.852    |         |
| 1-2 years                             | 4 (8%)                       | 48 (92%)                     |                            | 3 (6%)                   | 49 (94%)                 |                     | 3 (6%)    | 49 (94%)   |            | 5 (10%)   | 47 (90%)   |         |
| 3-4 years                             | 5 (4%)                       | 129 (96%)                    |                            | 17 (13%)                  | 117 (87%)                |                     | 8 (6%)    | 126 (94%)  |            | 13 (10%)  | 121 (90%)  |         |
Table 5. Chi-square analysis of high school sport specialization by acute head and neck injuries and concussions.

| Variable                              | Head/neck acute injury | Concussion | p-value |
|---------------------------------------|------------------------|------------|---------|
|                                       | Yes (n[%])             | No (n[%])  |         | Yes (n[%]) | No (n[%]) | p-value |
| Sex                                   |                        |            |         |            |           |         |
| Male                                  | 10 (6%)                | 157 (94%)  | 0.629   | 7 (4%)     | 160 (96%) | 0.789   |
| Female                                | 12 (5%)                | 233 (95%)  | <0.001  | 9 (4%)     | 236 (96%) | <0.001  |
| Same HS and Club sport                |                        |            |         |            |           |         |
| Yes                                   | 11 (3%)                | 334 (95%)  | <0.001  | 7 (2%)     | 338 (98%) | <0.001  |
| No                                    | 11 (16%)               | 56 (97%)   | 0.377   | 9 (13%)    | 58 (87%)  | 0.389   |
| HS Multisport athlete                 |                        |            |         |            |           |         |
| Yes                                   | 19 (6%)                | 306 (94%)  | 0.320   | 14 (4%)    | 311 (96%) | 0.705   |
| No                                    | 3 (3%)                 | 84 (97%)   |         | 2 (2%)     | 85 (98%)  |         |
| Number of years being classified as highly specialized in HS |                        |            |         |            |           |         |
| 0 years                               | 11 (5%)                | 199 (95%)  |         | 9 (4%)     | 201 (96%) |         |
| 1-2 years                             | 1 (2%)                 | 51 (98%)   |         | 1 (2%)     | 51 (98%)  |         |
| 3-4 years                             | 10 (6%)                | 124 (94%)  |         | 6 (5%)     | 128 (95%) |         |