

Injury Risk Factors Related to Sport Specialization in High School Basketball: A Prospective Study

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Context: Research that has examined the association between specialization and injury in basketball has been limited to cross-sectional or retrospective studies.

Objective: To determine whether specialization is a risk factor for injury among high school basketball athletes.

Design: Prospective cohort study.

Setting: Basketball players from 12 high schools participating in the National Athletic Treatment, Injury, and Outcomes Network Surveillance Program (NATION-SP) were recruited before the 2022–2023 interscholastic basketball season.

Patients or Other Participants: One-hundred thirty athletes (mean age \pm SD = 15.6 \pm 1.3; girls' basketball: n = 68 [52.3%]).

Main Outcome Measure(s): Before the start of the school basketball season, participants completed a questionnaire that had questions regarding participation in various specialized sport behaviors. During the basketball season, the school's athletic trainer reported all athlete-exposures and injuries (regardless of time loss) for participating athletes into NATION-SP. Injury incidence and

incidence rate ratios (IRRs) with 95% CIs were calculated for the specialized sport behaviors previously described.

Results: No difference in injury risk between highly specialized and low specialized athletes was found (IRR [95% CI] = 1.9 [0.9, 3.7]). Players who participated in basketball year round were twice as likely to sustain an injury than those who did not play year round (IRR [95% CI] = 2.1 [1.1, 3.6]). Similarly, players who reported participating in basketball skills camps were at increased risk of injury compared with athletes who did not participate in basketball skill camps (IRR [95% CI] = 2.5 [1.2, 5.7]).

Conclusions: Injury risk related to sport specialization in basketball may be specific to certain behaviors such as year-round play and participation in skills camps. Validated measures of comprehensive sport activity are needed to better measure specialization in youth sports to better determine injury risk related to sport specialization and develop injury prevention programs for basketball athletes.

Key Words: long-term athlete development, youth sport, injury prevention, sport sampling

Key Points

- Specialization in basketball was not a risk factor for injury, but other specialized behaviors, such as year-round basketball or participation in skills camps, were associated with increased risk of injury.
- Validated measures of specialization are needed to determine injury risk related to sport specialization and develop injury prevention programs for basketball athletes.

An estimated 12 million youth athletes sustain a sport-related injury each year, highlighting the importance of understanding risk factors for injury within youth sports.¹ Sport specialization, defined as “intentional and focused participation in a single sport for a majority of the year that restricts opportunities for engagement in other sports and activities,” has been increasingly identified as a risk factor for injury within various youth sport populations.^{2,3} While a 3-point specialization scale exists that categorizes athletes as low, moderate, or highly specialized, researchers have recently highlighted the importance of examining other variables that measure sport specialization behaviors and are more specific to certain sport contexts, such as pitch counts

within baseball or mileage within runners.^{4–6} The examination of these unique sport participation behaviors within various sports can provide helpful additional context when trying to understand potential associations with injury.

Basketball continues to be one of the most popular youth sports in the United States, with approximately 5 million youth participating in the sport at some level.^{7–9} Concerns about sport specialization in basketball led the National Basketball Association (NBA) and USA Basketball to release safe sport participation guidelines that include recommendations to avoid specialized behaviors.¹⁰ Authors of previous studies on sport specialization within basketball have reported conflicting results on the risk relationship between specialization

(measured by the 3-point scale) and injury but also reported a range of specialized behaviors that were associated with injury, such as participating on club teams or receiving private coaching.^{11–13} However, these previous basketball studies have been limited to retrospective data reported by NBA athletes or parents of youth basketball athletes and a cross-sectional survey of athletes from a limited geographic area.^{11–13} Due to the limited quality evidence surrounding sport specialization and injury, both overall and within basketball specifically, a recent consensus statement from the American Medical Society for Sports Medicine highlighted the need for both prospective and sport-specific studies on this topic.¹⁴

Therefore, the purpose of this study was to determine whether certain specialized sport behaviors increased the risk of injury over the course of a high school basketball season, using a prospective cohort design. We hypothesized that specialization in basketball, club basketball participation, participating in basketball skill camps, travel for basketball competitions, and receiving private basketball coaching would all be associated with an increased risk of injury among high school basketball players.

MATERIALS AND METHODS

Participants

This prospective cohort study was approved by the Institutional Review Board at Indiana State University. Participants were recruited from 12 high schools across the United States in fall 2022, before the start of their school's 2022–2023 interscholastic basketball season. High schools were selected to participate if they had an athletic trainer (AT) at the school who was participating in the National Athletic Treatment, Injury, and Outcomes Network Surveillance Program (NATION-SP). To qualify for the study, participants must have been active members of their high school's basketball team. Parents of potential participants were provided with information regarding the study during preseason sport informational meetings. If parents provided consent for their child to participate, the child was approached and provided information about the study. If participants agreed to participate, they were asked to provide consent and then complete an online preseason questionnaire. While we are unable to determine a response rate due to presentation of the study to large groups of parents and their children during preseason meetings, a total of 209 parents provided consent for their child to participate. Of these, 130 athletes (62.2%) qualified for the study, provided consent, and completed all study activities.

Preseason Questionnaire

Participants completed an online preseason questionnaire via Qualtrics before the start of their high school basketball season. The questionnaire consisted of participant demographics (age, team type—boys' or girls'—and grade in school) and sport participation characteristics. For the sport participation characteristics section, participants were asked to list all organized school and club sports that they had participated in within the past year (other than basketball) to determine their total number of nonbasketball sports. Participants were also asked about several specialized sport behaviors, which were determined based on behaviors previously identified as being associated with injury or identified within the NBA Youth Basketball guidelines as behaviors to avoid due

to hypothesized increased risk of injury.^{10,13} Participants were asked if they had participated on a club basketball team in addition to their high school team in the past year. Additionally, participants were asked to list the number of months in the previous year that they had participated on a school basketball team, a club basketball team (if applicable), and the number of months they had traveled and stayed overnight at least once for a basketball competition or tournament. Athletes were asked whether they had received private lessons from a basketball coach outside of their school team and how many basketball camps they attended to improve their skills in the past year.

Finally, sport specialization status (low, moderate, or high) in basketball was determined using the 3-point Jayanthi scale, as modified by Miller et al in 2019.^{4,5} The 4 questions that comprise this scale are based on the definition of sport specialization as “year-round intensive training in a single sport at the exclusion of other sports.”² The actual questions included in the scale are “Do you participate in basketball for more than 8 months of the year?” “Do you consider basketball to be your primary sport?” and “Have you only ever played basketball?”⁴ If a participant answered *no* to “Have you only ever played basketball?” they were asked, “Have you ever quit another sport to focus on basketball?” A categorical classification system was used to assess the responses to these sport specialization questions (*yes* = 1, *no* = 0), with a total score of 3 considered high specialization, a score of 2 considered moderate specialization, and a score of 0 or 1 considered low specialization.⁴

Prospective Injury and Athlete-Exposure Tracking

Throughout the 2022–2023 high school basketball season, each school's AT recorded injuries and athlete-exposures (AEs) for participating athletes as part of their participation in NATION-SP. The methods of ATs reporting into NATION-SP have been previously described in detail, but in brief, ATs at each participating school reported injuries and AEs into an electronic medical record system, which were then de-identified and sent to the Datalyis Center using secure data-transmission protocols.^{15–17} These prospective records were linked with each participant's preseason questionnaire using a randomly assigned subject ID number. The NATION-SP is compliant with the Health Insurance Portability and Accountability Act (HIPAA) and the Federal Educational Rights and Privacy Act (FERPA).¹⁷

For NATION-SP, a reportable *injury* is defined as one that occurs as a result of participation in an organized high school athletic event for a school-sponsored sport and required attention from an AT or physician, regardless of time loss.¹⁷ For each injury, the AT completed a detailed report as part of their documentation and was able to view and update records over the course of the academic year. Additionally, each AT recorded information about each basketball practice and competition, including the number of athletes participating. An AE was defined as 1 player's participation in 1 high school-sanctioned practice or competition. Individual AEs were summed to determine the total number of AEs, both within the total participant sample and for each variable of interest, which served as the denominator for calculating injury incidence, as described below.

Table 1. Participant Demographics and Sport Participation Characteristics (N = 130)

Variable	No. (%) or Mean \pm SD
Team type	
Boys' basketball	62 (47.7%)
Girls' basketball	68 (52.3%)
Age	15.6 \pm 1.3
Grade	
8th	4 (3.1%)
9th	32 (24.6%)
10th	33 (25.4%)
11th	34 (26.2%)
12th	27 (20.8%)
Total No. nonbasketball sports	2.1 \pm 1.2
Specialization Scale	
Low	75 (59.1%)
Moderate	38 (29.9%)
High	14 (11.0%)
Participate on club basketball team?	
Yes	67 (51.5%)
No	63 (48.5%)
Participate in basketball >8 mo/y?	
Yes	29 (22.3%)
No	101 (77.7%)
Participate in basketball camp in past year?	
Yes	88 (68.8%)
No	40 (31.2%)
No. basketball camps in previous year	2.4 \pm 1.4
Receive private coaching outside of team?	
Yes	57 (44.9%)
No	70 (55.1%)

Statistical Analysis

Data were summarized using frequencies with proportions (%) and means \pm SDs. Visual inspection of histograms and calculated skewness/kurtosis values were used to assess continuous variables for normality. Injury incidence rate (IR) was calculated per 1000 AEs using the formula: $[(\text{total number of injuries} / \text{total number of AEs}) \times 1000]$. Injury incidence rate was calculated for overall, team type (boys or girls), and by the different sport participation variables. Incidence rate ratios (IRRs) were calculated to compare injury rates based on the various sport participation variables. Confidence intervals were calculated for IR and IRR. For IRR, any 95% CI that did not contain 1.0 was considered statistically significant. All analyses were performed using R statistical software (R Foundation for Statistical Computing) and all IRs, IRRs, and 95% CIs were calculated as described above using the epiR package.¹⁸

The R package clusterPower was used to estimate an appropriately powered sample size, based on our primary comparison of injury risk between high, moderate, and low specialization athletes. Our sample size calculations were based on previous prospective sport specialization research, in which an 11% risk of lower extremity injury for highly specialized athletes compared with a 3% risk of lower extremity injury for athletes categorized as low specialization was found.¹⁹ Sample size needs were based on achieving 80% power with a type 1 error of 0.05, an average cluster size of 15 to 35 athletes per school, a coefficient of variation of 1.0, and an intraclass coefficient of 0.01. Based on that analysis, we aimed to enroll 12 schools with a goal of recruiting a minimum of $n = 210$ high school basketball

Table 2. Incidence of Injury Based on Sport Participation Characteristics

	Total No. Injuries	Athlete-Exposures	Injury Incidence Rate	95% CI
Overall	58	10074	5.8	4.4, 7.4
Team type				
Boys	32	4917	6.5	4.5, 9.2
Girls	26	5157	5.0	3.3, 7.4
Grade				
8th or 9th (freshman)	16	2915	5.5	3.1, 8.9
10th (sophomore)	20	2649	7.6	4.6, 11.7
11th (junior)	9	2598	3.5	1.6, 6.6
12th (senior)	13	1912	6.8	3.6, 11.6
Specialization scale				
Low	29	5709	5.1	3.4, 7.3
Moderate	17	2928	5.8	3.4, 9.3
High	12	1227	9.8	5.1, 17.1
Participate on club basketball team?				
Yes	31	5376	5.8	3.9, 8.2
No	27	4698	5.8	3.8, 8.4
Participate in basketball >8 mo/y?				
Yes	21	2183	9.6	6.0, 14.7
No	37	7891	4.7	3.3, 6.5
Participate in basketball camp in past year?				
Yes	49	6791	7.2	5.3, 9.5
No	9	3074	2.9	1.3, 5.6
Receive private coaching?				
Yes	29	4470	6.5	4.3, 9.3
No	29	5427	5.3	3.6, 7.7

players and aimed to recruit an even number of participants from boys' and girls' teams.

RESULTS

A total of 130 high school basketball athletes (girls' basketball: $N = 68$ [52.3%]; mean age \pm SD = 15.6 ± 1.3) participated in a total of 10 074 AEs during their 2022–2023 high school basketball season. Participant demographics and sport participation characteristics are provided in Table 1. In addition to basketball, athletes participated in an average of approximately 2 sports (2.1 ± 1.2) other than basketball, and only 11.0% ($N = 14$) of participants were classified as highly specialized. Over half of all participants ($N = 67$, 51.5%) participated on a club basketball team in addition to their high school team, and most ($N = 88$, 68.8%) participants reported an average of 2.4 ± 1.4 basketball camps in the previous year to improve their skills.

Forty-four athletes (33.9%) sustained 58 injuries during the 2022–2023 basketball season, for an overall injury IR (95% CI) of 5.8 (4.4, 7.4) per 1000 AEs (Table 2). No differences were found in injury rates between boys' and girls' basketball athletes (IRR [95% CI] = 0.8 [0.4, 1.3]) or based on athlete grade (Table 3). Highly specialized athletes sustained injuries at a rate of 9.8 (5.1, 17.1) injuries per 1000 AEs while low specialized athletes sustained injuries at a rate of 5.1 (3.4, 7.3) per 1000 AEs, but this difference in rates was not significant (IRR [95% CI] = 1.9 [0.9, 3.7]). Players who participated in basketball year round were twice as likely to sustain an injury during their high school basketball season than those who did not play year round (IRR [95% CI] = 2.1

Table 3. Incidence Rate Ratios (IRRs) Based on Sport Participation Characteristics

	Incidence Rate Ratio	95% CI
Team type		
Boys	Ref	NA
Girls	0.8	0.4, 1.3
Grade		
8th or 9th (freshman)	Ref	NA
10th (sophomore)	1.4	0.7, 2.8
11th (junior)	0.6	0.3, 1.5
12th (senior)	1.2	0.6, 2.8
Specialization scale		
Low	Ref	NA
Moderate	1.1	0.6, 2.2
High	1.9	0.9, 3.9
Participate on club basketball team?		
No	Ref	NA
Yes	1.0	0.6, 1.8
Participate in basketball >8 mo/y?		
No	Ref	NA
Yes	2.1	1.1, 3.6
Participate in basketball camp in past year?		
No	Ref	NA
Yes	2.5	1.2, 5.7
Receive private coaching?		
No	Ref	NA
Yes	1.2	0.7, 2.11

Abbreviation: NA, not available.

[1.1, 3.6]). Similarly, players who reported participating in basketball skills camps were at increased risk of injury compared with athletes who did not participate in basketball skill camps (IRR [95% CI] = 2.5 [1.2, 5.7]). No significant differences were found in injury rates based on club basketball team participation (IRR [95% CI] = 1.0 [0.6, 1.8]) or whether an athlete received private basketball coaching outside of their normal school team (IRR [95% CI] = 1.2 [0.7, 2.1]).

DISCUSSION

To our knowledge, this is the first prospective study specifically within basketball, in which sport specialization and specialized sport behaviors as risk factors for injury were reported using a prospective cohort design. Authors of previous studies have found associations between specialization and injury in youth basketball, but they relied on the retrospective recall of current NBA players or from data provided by parents of high school basketball athletes.^{11,13} In the study of parents of high school basketball athletes, several variables were associated with history of injury, including specialization in basketball according to the 3-point scale, participating on multiple teams at the same time, receiving private basketball coaching, and traveling for basketball showcases or camps.¹³ In contrast, we did not find specialization on the 3-point scale, club basketball participation, or private coaching to be prospective risk factors for injury. However, athletes who participated in basketball year round or participated in basketball skills camps were at greater risk for injury during the interscholastic basketball season. Interestingly, while it may be assumed that many club basketball players would also be categorized as playing year round, we found much fewer athletes reported playing basketball more than 8

months out of the year (only 22%) than the number who reported playing on a club team (52%). This likely means that most club teams do not add enough additional months of participation to an athlete's year to cause them to participate in basketball for more than 8 months. Therefore, it seems that simply playing on a club team is not a risk factor for injury, but rather playing on a combination of basketball teams that results in the athlete not receiving adequate time off throughout a year is a risk factor.

Our results highlight the ongoing need for additional prospective and sport-specific research to determine whether sport specialization and specialized sport behaviors are truly risk factors for injury and other concerns within various sports.¹⁴ For example, authors of retrospective studies have identified specialization as a potential risk factor for injury within both baseball and volleyball, and authors of higher-quality prospective studies have also reported that specialization increases the risk of negative health outcomes in these sports.^{12,20–28} It is possible and even likely that the injury risk related to sport specialization is highly sport specific and depends on the specific movement profile of the individual sport and the specific behaviors common within those sports.^{12,14} More technical sports that consist of more limited and repetitive movements (such as volleyball, baseball, swimming, and tennis) may be more susceptible to increased risk of overuse injuries due to specialization.¹² In contrast, the stresses of high-volume training may be more evenly distributed across the body in sports with a more varied movement profile (such as soccer or basketball), and therefore, specialization per se may not increase injury risk within those sports, but instead certain behaviors that lead to excessive volume (such as year-round participation) may be risk factors for injury.¹²

Overall, we found that only 11% of participants were classified as highly specialized using the 3-point scale. This finding raises the question of whether specialization is truly as widespread within youth basketball as believed or whether the 3-point specialization scale is not a robust enough tool to accurately classify an athlete's specialization status. For example, while only 11% of participants were classified as highly specialized according to the 3-point scale, a much larger proportion of athletes participated in a variety of specialized sport behaviors, such as playing on a club team in addition to their high school team (51.5%), participating in multiple basketball camps in the past year (68.8%), or receiving private basketball coaching (44.9%). Similarly, authors of previous studies of youth baseball, softball, and basketball athletes have reported that, while the proportion of athletes classified as highly specialized using the 3-point scale was low, a significant portion of athletes demonstrated a variety of other specialized behaviors that were more sport specific, such as excessive pitch or inning counts or travel for participation in showcases or skill camps.^{13,21,29,30} While the 3-point specialization scale has been used extensively in studies of injury risk across sports, it likely does not serve as an accurate measure of sport specialization for all sports due to the inherent differences in sport cultures, rules, and organization.^{3,14} A more detailed and validated measure of sport specialization should be developed based on evidence-based and consensus definitions of sport specialization, and sport-specific modules will likely need to be developed for that measure to capture sport-specific behaviors (such as pitching volume in baseball or softball and mileage in running).

Several important limitations are noteworthy related to this study. Most significantly, while we enrolled our target

number of schools according to our power analysis, we fell short of recruiting the sample size necessary to achieve sufficient power ($N = 210$). While we received parental consent to enroll 209 participants, ultimately, only 130 participants provided assent and enrolled in the study. Therefore, our results should be interpreted with caution, as we were likely underpowered to find differences in risk between high, moderate, and low specialization athletes. The use of the NATION-SP system for this project requires that the participating ATs accurately recorded all prospective injury and exposure information into the system and that the participating athletes reported their injuries to their school's AT. Additionally, we relied on participant self-report of their specialization status and specialized sport behaviors, which may be subject to recall bias if the participants cannot accurately recall their sport participation history. Finally, this study was limited to a single high school basketball season and a relatively small sample ($N = 130$) of high school basketball athletes recruited from 12 high schools across the country. While this represents an improvement from previous research by recruiting from a wider geographic area and using a prospective design, future researchers should aim to recruit even larger samples with even more geographic and demographic representation.

CONCLUSIONS

In this prospective study of high school basketball athletes, we found that the 3-point specialization scale in basketball was not a risk factor for injury, but other specialized behaviors, such as year-round basketball participation or participation in basketball skills camps, were associated with increased risk of injury during the athlete's high school basketball season. Validated measures of specialization are needed to better measure specialization in youth sports to better determine injury risk related to sport specialization and develop injury prevention programs for basketball athletes.

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