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Examining Play Counts and Measurements of Injury Incidence in Youth Football

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Context: Whereas researchers have provided estimates for the number of head impacts sustained within a youth football season, less is known about the number of plays across which such impact exposure occurs.

Objective: To estimate the number of plays in which youth football players participated during the 2013 season and to estimate injury incidence through play-based injury rates.

Design: Descriptive epidemiology study.

Setting: Youth football.

Patients or Other Participants: Youth football players (N = 2098; age range, 5–15 years) from 105 teams in 12 recreational leagues across 6 states.

Main Outcome Measure(s): We calculated the average number of athlete-plays per season and per game using independent-samples *t* tests to compare age groups (5–10 years old versus 11–15 years old) and squad sizes (<20 versus ≥20 players); game injury rates per 1000 athlete-exposures (AEs) and per 10 000 athlete-plays; and injury rate ratios (IRRs) with 95% confidence intervals (CIs) to compare age groups.

Results: On average, youth football players participated in 333.9 ± 178.5 plays per season and 43.9 ± 24.0 plays per game. Age groups (5- to 10-year-olds versus 11- to 15-year-olds) did not differ in the average number of plays per season (335.8 versus 332.3, respectively; $t_{2086.4} = 0.45$, $P = .65$) or per game (44.1 versus 43.7, respectively; $t_{2092.3} = 0.38$, $P = .71$). However, players from smaller teams participated in more plays per season (373.7 versus 308.0; $t_{1611.4} = 8.15$, $P < .001$) and per game (47.7 versus 41.4; $t_{1523.5} = 5.67$, $P < .001$). Older players had a greater game injury rate than younger players when injury rates were calculated per 1000 AEs (23.03 versus 17.86/1000 AEs; IRR = 1.29; 95% CI = 1.04, 1.60) or per 10 000 athlete-plays (5.30 versus 4.18/10 000 athlete-plays; IRR = 1.27; 95% CI = 1.02, 1.57).

Conclusions: A larger squad size was associated with a lower average number of plays per season and per game. Increasing youth football squad sizes may help reduce head-impact exposure for individual players. The AE-based injury rates yielded effect estimates similar to those of play-based injury rates.

Key Words: epidemiology, exposure, risk

Key Points

- Youth football players participated in approximately 44 plays per game and 334 plays per season.
- Injury risk, athlete-exposure–based injury rate, and athlete-plays–based injury rate provided similar effect estimates for age differences.
- Larger squad size was associated with lower average numbers of athlete-plays per season and per game.

Using injury rates (ie, the number of events divided by the amount of person-time observed) to express injury incidence is common. Injury rates are frequently expressed per unit of playing time (ie, minutes or hours)[1–4] or per frequency of *athlete-exposure* (AE; ie, 1 player participating in 1 game or practice).[5–10] Using AE as a unit is typical in sports-injury surveillance, as it minimizes the burden placed on the data collector, usually an athletic trainer (AT) providing service and care to athletes while collecting data. However, AEs may be limited because they do not account for variations in actual playing time (ie, number of minutes or plays). Consequently, an athlete who plays throughout the entire game and an athlete who plays in only 1 segment of a game equally contribute 1 AE.

In football, 1 exposure measure that may account for variations in playing time is the *athlete-play*, defined as 1 athlete participating in 1 play during a game. Although online resources related to overall play counts per team in the collegiate and professional levels are available,[11–13] little is known about the distribution of athlete-play counts in youth football. This is most likely due to the lack of resources (eg, cost, staffing) available at the youth level to provide such counts. However, youth sports provide an appropriate platform to explore these variations because of the large age range and the volume of participants compared with other competitive levels. Long-term orthopaedic effects due to youths participating in sports with limited oversight have been identified.[14,15] Nonorthopaedic conditions, such as exertional heat illness, can occur from overextended play time as the primary mechanism, resulting in catastrophic effects.[16] In addition, given recent research in which authors[17–19] have noted a potential link between cumulative head-impact exposure and cognitive decline later in life, researchers need to generate estimates of at-risk exposure time to strategize ways to reduce or mitigate injury risk.

At the same time, injury rates may not be intuitive for policy makers, parents, or coaches for quantifying injury incidence. *Risk*, or the probability that an injury will occur during a given activity (ie, sport) for a defined population (eg, a team) over a specific timeframe (eg, 1 season) is a less frequently used measure of injury incidence. However, risk may be more intuitive to such stakeholders.

The strengths and limitations of epidemiologic measures of injury incidence in youth football need to be considered while assessing the burden these measures place on data collectors. Research in which investigators have examined injury-incidence measures and the resulting comparisons (eg, injury rate ratios [IRRs], risk ratios [RRs]) is affected by the fact that at-risk exposure time is lacking. In addition, although researchers have provided estimates about the number of head impacts sustained across a season,[20–24] less is known about the number of athlete-plays across which such impact exposure occurs. Nicholas et al[25] examined injury in the context of athlete-plays but were vague in describing the data-collection process. Therefore, the purpose of our study was to describe injury incidence during the 2013 youth football season using 3 measures: injury risk, AE-based injury rates, and athlete-plays–based injury rates using data from the Youth Football Surveillance Study.[26] Our research questions were as follows:

Research question 1. On average, in how many plays do youth football players participate across a season?

a. Does the average number of athlete-plays per season vary by age (5–10 versus 11–15 years)?
b. Does the average number of athlete-plays per season vary by squad size?

Research question 2. On average, in how many plays do youth football players participate per game?

a. Does the average number of athlete-plays per game vary by age (5–10 versus 11–15 years)?
b. Does the average number of athlete-plays per game vary by squad size?

Research question 3. What are the injury risk, AE-based injury rate, and athlete-plays–based injury rate in youth football games?

a. Do game injury risks, AE-based injury rates, and athlete-plays–based injury rates differ between 5- to 10-year-olds and 11- to 15-year-olds?
b. Do game injury risks, AE-based injury rates, and athlete-plays–based injury rates differ by the number of athlete-plays per season?

Research question 4. Do the types of injuries sustained by youth football players vary by the number of athlete-plays per season?

METHODS

We relied on data collected for a prospective 2-year (2012 and 2013) observational cohort study of the association of playing standards and injury incidence.[26] Thus, our study is a secondary analysis of previously collected data and was approved by the Western Institutional Review Board (Puyallup, WA).

Study Period

For the current study, we focused on the 2013 season. In the original study,[26] the examination of athlete-plays was exploratory, as no studies to our knowledge provided well-documented instructions about collecting athlete-plays in a large sports setting. For the current study, we had to consider the factors involved in using a new measure that was not typically tracked by our data collectors (ATs, coaches, parents). Given the novelty of the data collection and concerns about the use of athlete-plays coupled with data collectors' needing time to acclimate to the data-collection procedures, we considered the first year of data collection (ie, the 2012 season) to be pilot data that were excluded from analysis in this study.

Sample

Our sample included a total of 2098 youth football players from 105 youth teams in 12 individual recreational youth football leagues in 6 geographically diverse states (Arizona, Indiana, Massachusetts, Ohio, South Carolina, and West Virginia). Leagues were selected if they met the requirements detailed in an earlier study.[26] Provision of ATs for each league and their requirements were also described in another study.[26]

General Data-Collection Protocol

All data points were recorded in an injury-documentation software application (Injury Surveillance Tool [IST]; Datalys Center for Sports Injury Research and Prevention, Inc, Indianapolis, IN). This process[6,10] and the dual roles of the IST[26] have been described in detail. Athletic trainers' attendance at practices and games during the 2013 season, reporting of injuries, training before IST data entry, and requirements for inputting AEs were presented in another study.[26] All leagues provided a schedule of games at the start of the season. These counts were modified based on any games that may have been cancelled due to lightning or other reasons and not rescheduled.

Data Collection of Athlete-Plays

The ATs were instructed to keep track of players' play counts across a season. Each AT had a large number of players, so he or she relied on the assistance of coaches and parents. Most leagues required that players participate in a minimum number of plays per half (generally 6 per half). However, we were unable to standardize this factor because the minimum number of plays varied across leagues. In many leagues, the coaches were already keeping a log for each player that was completed during and after each game. However, when such logs were not being kept or when not enough coaches were available, the ATs recruited parents to carry out this duty. Given the variations across teams, even within leagues, we were unable to standardize this protocol; each league was provided standardized instructions and offered spreadsheets to help organize the data. The athlete-play data were input into the IST on completion of the season. Although our resulting dataset included information on the number of games and athlete-plays in the 2013 season, it did not allow us to ascertain the specific number of athlete-plays for each player for each game. In the original study,[26] our covariate of interest was specifically the number of athlete-plays in 1 season; this variable was ultimately removed in the model-building process.

Data-Quality Protocol

The data-quality protocol was described in another study.[26]

Operational Definitions

Operational definitions of *injury*, *time-loss (TL) injury*, *non-TL (NTL) injury*, *concussion*, and *AE* were provided in another study.[26] For concussions, we relied on the medical expertise of the professionals providing the data to properly diagnose a concussion, but they were encouraged to follow the definition provided by the Consensus Statement on Concussion in Sport.[27] All athletes with suspected concussions were initially examined by an on-site AT and were required to have physician clearance for returning to play. Only athletes with concussions occurring from sports participation were included. We defined *season* as the league's regular and postgame schedule, encompassing both home and away officially sanctioned games. An *athlete-play* indicated 1 athlete participating in 1 play during a game, including any play for offense, defense, or special teams. Athlete-play counts could not be assessed by specific play type, as such in-depth information was not collected. *Average number of athlete-plays per game* was defined as the total number of athlete-plays reported for 1 athlete-season divided by the total number of games played.

Statistical Analyses

Multiple epidemiologic measures were calculated for the 4 research questions. When assessing comparisons by age, we used the categories of 5 to 10 years (n = 1137) and 11 to 15 years (n = 961). This categorization was used primarily because players in the former category would likely be in elementary school, whereas those in the latter category would likely be in middle school or junior high school. For squad size, we used a median cutoff based on the distribution of squad sizes among the 105 teams, which resulted in 2 groups: players from teams with fewer than 20 players (n = 826) and players from teams with greater than or equal to 20 players (n = 1272). For number of athlete-plays per season, we used a median cutoff with a below-median group (n = 1049) and an above-median group (n = 1049). We had explored other methods of categorizing the data (eg, quartile-, decile-, ventile-splits) but opted for the median cutoff because it allowed for accessible interpretation of analyses. For all analyses, given concerns about outliers in the data for the average number of athlete-plays per season and per game, all analyses were performed excluding outliers. These outliers were calculated using the Tukey interquartile range (IQR) procedure that identified the difference between the 75th and 25th percentiles and then deemed those values as either below the 25th percentile, that is, $- 1.5 \times$ IQR, or above the 75th percentile, that is, $+ 1.5 \times$ IQR, as outliers.[28] We identified 2 outliers (0.1%) for athlete-plays per season and 34 outliers (1.6%) for average athlete-plays per game. Given that the findings did not differ when outliers were excluded, we presented findings using all data points. In addition, given the large sample size and the small number of outliers identified using the Tukey IQR procedure,[28] parametric tests were used.

Research Question 1. We calculated the number of athlete-plays per season and used independent-samples *t* tests with Satterthwaite approximation of degrees of freedom to compare findings by age and squad size. The α level was set a priori at .05.

Research Question 2. We computed the average number of athlete-plays per game calculated from each athlete's number of athlete-plays per season divided by the number of games played per season. To compare findings by age and squad size, we used independent-samples *t* tests with Satterthwaite approximation of degrees of freedom and set the α level a priori at .05.

Research Question 3. Our outcomes of interest were determined before data analysis and were based on the outcomes of the original study[26]: all injuries, TL injuries only, NTL injuries only, and concussions only. We computed 1-year risks by dividing the number of players with at least 1 injury in the 2013 season by the total number of players in the 2013 season. Next, we calculated injury rates by dividing the sum of all injuries (numerator) by the sum of exposure time (denominator). This study had 2 types of denominators. The first injury rate used AEs and was expressed per 1000 AEs; the second injury rate used athlete-plays and was expressed per 10 000 athlete-plays. Finally, we computed the RR and IRR to compare between ages (ie, 5–10 versus 11–15 years) and the number of athlete-plays per season (ie, median cutoff groups).

The following is an example of an RR comparing injury risk in players aged 11 to 15 years and aged 5 to 10 years:

$$\mathrm{RR} = \frac{\left[\dfrac{\sum \text{Injured players 11–15 years of age}}{\sum \text{Players 11–15 years of age}}\right]}{\left[\dfrac{\sum \text{Injured players 5–10 years of age}}{\sum \text{Players 5–10 years of age}}\right]}$$

The following is an example of an IRR comparing injury rates per 1000 AEs in players aged 11 to 15 years and aged 5 to 10 years:

$$\mathrm{IRR} = \frac{\left[\dfrac{\sum \text{Injuries among players 11–15 years of age}}{\sum \text{AEs among players 11–15 years of age}}\right]}{\left[\dfrac{\sum \text{Injuries among players 5–10 years of age}}{\sum \text{AEs among players 5–10 years of age}}\right]}$$

All RRs and IRRs that did not include 1.00 in the 95% confidence interval (CI), as calculated by the methods described in Knowles et al,[29] were considered different.

Research Question 4. Injury frequencies and distributions were calculated for body region (head/face/neck;

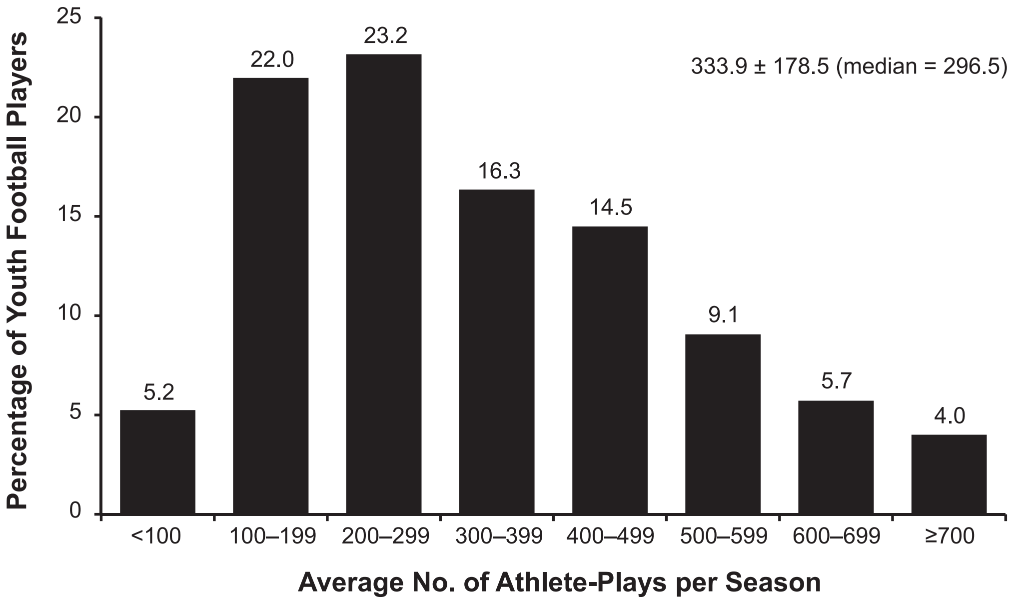

Figure 1. Distribution of number of plays per season in youth football players in the 2013 season.

upper extremity, including the shoulder, arm/elbow, and hand/wrist/fingers; trunk; lower extremity, including the hip/groin, thigh/upper leg, knee, lower leg, ankle, and foot/toes; and other) and diagnosis (abrasion, concussion, contusion, dislocation, fracture, heat-related event, inflammatory condition, laceration, nervous system, respiratory, spasm, sprain, strain, subluxation, other). We used injury proportion ratios (IPRs) to compare the distributions of injuries by the number of athlete-plays per season.

The following is an example of an IPR comparing the proportion of injuries affecting the head/face/neck in the median cutoff groups:

$$\text{IPR} = \frac{\left[\dfrac{\sum \text{Injuries among players in above–median group that were to the head/face/neck}}{\sum \text{Injuries among players in above–median group}}\right]}{\left[\dfrac{\sum \text{Injuries among players in below–median group that were to the head/face/neck}}{\sum \text{Injuries among players in below–median group}}\right]}$$

All IPRs that did not include 1.00 in the 95% CI, as calculated by the methods described in Knowles et al,[29] were considered different.

RESULTS

Among the 2098 youth football players in the 2013 season, a total of 329 game injuries were reported in 234 players. Of these 329 injuries, 86 (26.1%) were TL injuries sustained in 73 players. In addition, 32 concussions were reported in 32 players during games. These injuries occurred during 16 274 AEs and 700 489 athlete-plays.

Research Question 1: Average Number of Athlete-Plays per Season and Age Comparisons

Youth football players averaged 333.9 ± 178.5 (median = 296.5) athlete-plays per season (Figure 1). In particular, 4.0% (n = 84) participated in at least 700 athlete-plays per season. An average of 7.8 ± 1.6 (median = 8.0) games were played per season.

Age Differences. Youth football players aged 5 to 10 years averaged 332.3 ± 186.5 (median = 283.0) athlete-plays per season. Youth football players aged 11 to 15 years averaged 335.8 ± 168.7 (median = 311.0) athlete-plays per season. Age groups did not differ in the average number of athlete-plays per season ($t_{2086.4} = 0.45$, $P = .65$) or the average number of games per season (7.8 ± 1.5 versus 7.7 ± 1.8; $t_{1888.5} = 0.74$, $P = .46$).

Squad-Size Differences. Youth football players from teams with fewer than 20 players averaged 373.7 ± 188.2 (median = 374.0) athlete-plays per season. Youth football players from teams with 20 or more players averaged 308.0 ± 167.0 (median = 271.0) athlete-plays per season. Youth football players from smaller teams averaged more athlete-plays per season ($t_{1611.4} = 8.15$, $P < .001$).

Research Question 2: Average Number of Athlete-Plays per Game and Age Comparisons

Youth football players averaged 43.9 ± 24.0 (median = 39.1) athlete-plays per game (Figure 2). In particular, 66.5% (n = 1395) had fewer than 50 athlete-plays per game, and 2.3% (n = 49) were involved in at least 100 plays per game.

Age Differences. Youth football players age 5 to 10 years averaged 43.7 ± 25.4 (median = 37.2) athlete-plays per game. Youth football players aged 11 to 15 years averaged 44.1 ± 22.3 (median = 41.6) athlete-plays per game. The age groups did not differ in the average number of athlete-plays per game ($t_{2092.3} = 0.38$, $P = .71$).

Squad-Size Differences. Youth football players from teams with fewer than 20 players averaged 47.7 ± 26.5 (median = 44.5) athlete-plays per game. Youth football players from teams with 20 or more players averaged 41.4 ± 21.9 (median = 37.3) athlete-plays per game. Youth football players from smaller teams averaged more athlete-plays per game ($t_{1523.5} = 5.67$, $P < .001$).

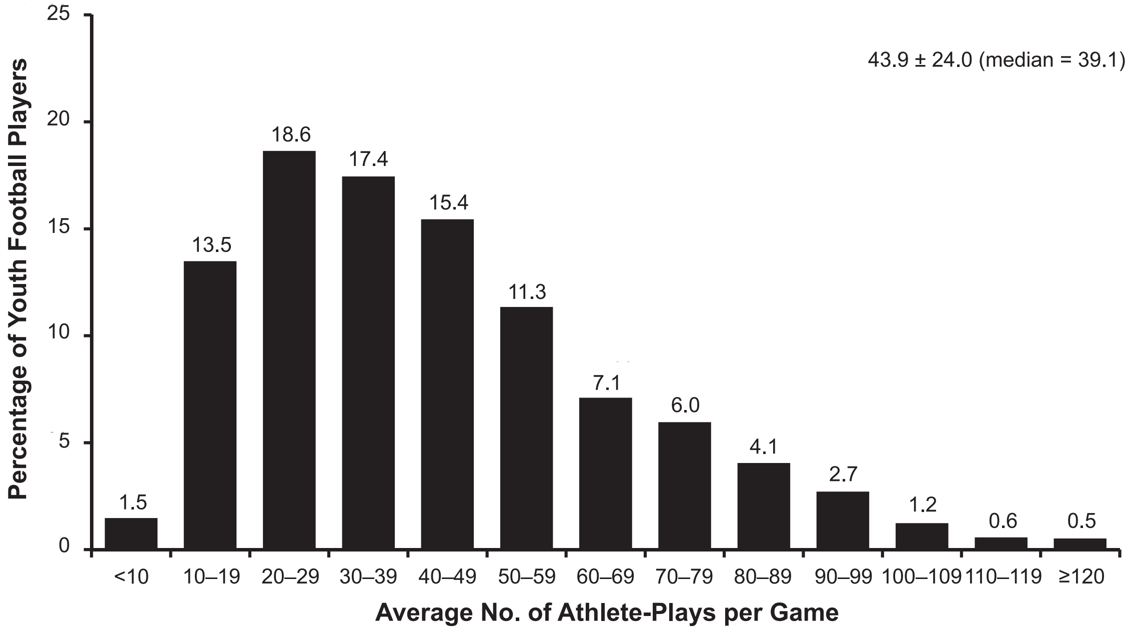

Figure 2. Distribution of the average number of plays per game in youth football players in the 2013 season.

Research Question 3: Injury Risks and Rates by Age Groups and by Athlete-Plays per Season for Median Groups

In youth football games during the 2013 season, 234 of the 2098 players reported at least 1 injury of any severity, leading to a 1-year all-injury risk of 11.15%. In addition, 73 players reported at least 1 TL injury during games, resulting in a 1-year TL injury risk of 3.48%. A total of 177 players reported an NTL injury during games, leading to a 1-year NTL injury risk of 8.44%. Finally, 32 players reported a concussion during games, resulting in a 1-year concussion risk of 1.53%. The 329 game injuries occurred during 16 274 AEs and 700 489 athlete-plays, leading to all-injury rates of 20.22/1000 AEs and 4.70/10 000 athlete-plays.

Of the 329 injuries sustained in games, 171 (52.0%) were sustained by 127 players 11 to 15 years old and 158 (48.0%) were sustained by 107 players 5 to 10 years old. In addition, 196 (59.6%) were sustained by the above-median group; 133 (40.4%), the below-median group.

Age-Group Comparisons. The 1-year all-injury risk in games was greater in players aged 11 to 15 years (13.22%) than in those age 5 to 10 years (9.41%; RR = 1.40; 95% CI = 1.10, 1.79; Table 1). This finding was retained when restricted to TL injuries only (5.20% versus 2.02%, respectively; RR = 2.57; 95% CI = 1.58, 4.18) and concussions only (2.29% versus 0.88%, respectively; RR = 2.60; 95% CI = 1.24, 5.47). However, injury risk did not differ when restricted to NTL injuries (9.05% versus 7.92%, respectively; RR = 1.14; 95% CI = 0.86, 1.52).

For injury rates per 1000 AEs, the game all-injury rate was greater in players aged 11 to 15 years (23.03/1000 AEs) than in those aged 5 to 10 years (17.86/1000 AEs; IRR = 1.29; 95% CI = 1.04, 1.60; Table 2). This finding was retained when restricted to TL injuries only (7.54 versus 3.39/1000 AEs, respectively; IRR = 2.22; 95% CI = 1.43, 3.47) and concussions only (2.96 versus 1.13/1000 AEs, respectively; IRR = 2.62; 95% CI = 1.24, 5.54). However, game injury rates did not differ when restricted to NTL injuries (15.49 versus 14.47/1000 AEs, respectively; IRR = 1.07; 95% CI = 0.83, 1.38).

For injury rates per 10 000 athlete-plays, the game all-injury rate was greater in players aged 11 to 15 years (5.30/10 000 athlete-plays) than in those aged 5 to 10 years (4.18/10 000 athlete-plays; IRR = 1.27; 95% CI = 1.02, 1.57; Table 2). This finding was retained when restricted to TL injuries only (1.74 versus 0.79/10 000 athlete-plays, respectively; IRR = 2.19; 95% CI = 1.40, 3.41) and concussions only (0.68 versus 0.26/10 000 athlete-plays, respectively; IRR = 2.58; 95% CI = 1.22, 5.44). However, game injury rates did not differ when restricted to NTL injuries (3.59 versus 3.39/10 000 athlete-plays, respectively; IRR = 1.05; 95% CI = 0.82, 1.35).

Table 1. One-Year Injury Risk by Age in Youth Football Players During Games in the 2013 Season

	Age, y				Risk Ratio for Players Aged 11–15 y Versus 5–10 y
	5–10 (n = 1137)		11–15 (n = 961)		
Type of Injury	Injured Athletes, n	Risk, %	Injured Athletes, n	Risk, %	(95% Confidence Interval)
All injuries	107	9.41	127	13.22	1.40 (1.10, 1.79)[a]
Time-loss injuries only	23	2.02	50	5.20	2.57 (1.58, 4.18)[a]
Non–time-loss injuries only	90	7.92	87	9.05	1.14 (0.86, 1.52)
Concussion only	10	0.88	22	2.29	2.60 (1.24, 5.47)[a]

[a] Indicates difference (95% confidence interval did not include 1.00).

Table 2. Injury Rates by Age in Youth Football Players During Games in the 2013 Season

	Age, y											
	5 to 10 (n = 1137)					11 to 15 (n = 961)					Injury Rate Ratio for Players Aged 11–15 y Versus 5–10 y (95% Confidence Interval)	
		Exposures		Rates			Exposures		Rates			
Type of Injury	Injury Count	Total Athlete-Plays	Athlete-Exposures	Per 10 000 Athlete-Plays	Per 1000 Athlete-Exposures	Injury Count	Total Athlete-Plays	Athlete-Exposures	Per 10 000 Athlete-Plays	Per 1000 Athlete-Exposures	Rate per 10 000 Athlete-Plays	Rate per 1000 Athlete-Exposures
All injuries	158	377 800	8848	4.18	17.86	171	322 689	7426	5.30	23.03	1.27 (1.02, 1.57)[a]	1.29 (1.04, 1.60)[a]
Time-loss injuries only	30	377 800	8848	0.79	3.39	56	322 689	7426	1.74	7.54	2.19 (1.40, 3.41)[a]	2.22 (1.43, 3.47)[a]
Non–time-loss injuries only	128	377 800	8848	3.39	14.47	115	322 689	7426	3.59	15.49	1.05 (0.82, 1.35)	1.07 (0.83, 1.38)
Concussion only	10	377 800	8848	0.26	1.13	22	322 689	7426	0.68	2.96	2.58 (1.22, 5.44)[a]	2.62 (1.24, 5.54)[a]

[a] Indicates difference (95% confidence interval did not include 1.00).

Plays per Season Median Cutoff Group Comparisons. The 1-year all-injury risk was greater in the above-median group (13.25%) than in the below-median group (9.06%; RR = 1.46; 95% CI = 1.14, 1.87; Table 3). This finding was retained when restricted to NTL injuries only (9.91% versus 6.95%, respectively; RR = 1.42; 95% CI = 1.07, 1.90). However, this finding was not retained when restricted to TL injuries only (4.19% versus 2.76%, respectively; RR = 1.52; 95% CI = 0.96, 2.41) or concussions only (1.91% versus 1.14%, respectively; RR = 1.67; 95% CI = 0.82, 3.39).

For injury rates per 1000 AEs, the game all-injury rate was greater in the above-median group (22.95/1000 AEs) than in the below-median group (17.20/1000 AEs; IRR = 1.33; 95% CI = 1.07, 1.66; Table 4). This finding was retained when restricted to NTL injuries only (17.09 versus 12.55/1000 AEs, respectively; IRR = 1.36; 95% CI = 1.05, 1.76). However, this finding was not retained when restricted to TL injuries only (5.85 versus 4.66/1000 AEs, respectively; RR = 1.26; 95% CI = 0.82, 1.93) or concussions only (2.34 versus 1.55/1000 AE, respectively; RR = 1.51; 95% CI = 0.74, 3.09).

For injury rates per 10 000 athlete-plays, the game all-injury rate was lower in the above-median group (3.89/10 000 athlete-plays) than in the below-median group (6.77/10 000 athlete-plays; IRR = 0.57; 95% CI = 0.46, 0.72; Table 4). This finding was retained when restricted to TL injuries only (0.99 versus 1.83/10 000 athlete-plays, respectively; IRR = 0.54; 95% CI = 0.35, 0.83) and NTL injuries only (2.90 versus 4.94/10 000 athlete-plays, respectively; IRR = 0.59; 95% CI = 0.45, 0.76). However, this finding was not retained when restricted to concussions only (0.40 versus 0.61/10 000 athlete-plays, respectively; RR = 0.65; 95% CI = 0.32, 1.33).

Research Question 4: Distribution of Injuries by Plays per Season for Median Groups

Body Region Injured. The most commonly injured body region was the upper extremity in the below-median group (33.1% [n = 44]) and the lower extremity in the above-median group (34.2% [n = 67]; Table 5). However, no differences were found in the distribution of body regions injured between the median groups.

Diagnosis. In both median groups, the most common diagnosis was contusion (below-median group = 40.6% [n = 54]; above-median group = 29.1% [n = 57]) followed by sprain (below-median group = 15.8% [n = 21]; above-median group = 16.8% [n = 33]; Table 6). The proportion of injuries that were contusions was greater in the below-median group than in the above-median group (IPR = 1.40; 95% CI = 1.03, 1.88).

DISCUSSION

To our knowledge, we are the first to estimate and compare various measures of injury incidence in the youth football setting. In our exploratory study, data collection required collaborative efforts between the data collectors (ie, ATs) and the stakeholders (eg, coaches, parents) in youth football. We present data from one of the largest samples of youth football players: 2098 youth football players from 12 leagues in 6 geographically diverse states. The 3 injury-incidence measures (ie, injury risk, AE-based

Table 3. One-Year Injury Risk by Number of Plays per Season in Youth Football Players During Games in the 2013 Season

Type of Injury	Plays per Season, No.				Above-Median Group Versus Below-Median Group Injury Rate Ratio (95% Confidence Interval)
	Below-Median[a] Group (n = 1049)		Above-Median[a] Group (n = 1049)		
	Injured Athletes	Risk, %	Injured Athletes	Risk, %	
All injuries	95	9.06	139	13.25	1.46 (1.14, 1.87)[b]
Time-loss injuries only	29	2.76	44	4.19	1.52 (0.96, 2.41)
Non–time-loss injuries only	73	6.95	104	9.91	1.42 (1.07, 1.90)[b]
Concussion only	12	1.14	20	1.91	1.67 (0.82, 3.39)

[a] Median = 296.5 plays per season.
[b] Indicates difference (95% CI did not include 1.00).

injury rate, athlete-play–based injury rate) provided similar effect estimates related to age differences. However, when we compared incidence by median athlete-plays-per-season groups, athlete-play–based injury rates suggested that those playing less were at greater risk for injury. In addition, despite differences in injury incidence by athlete-plays per season, distributions of the type of injuries (eg, by body region injured or diagnosis) did not differ. Methodologically, the findings suggest that using injury-incidence measures, such as injury risk or AE-based injury rates, may be more beneficial in the youth football setting than athlete-play–based injury rates given the additional burden of collecting athlete-plays per game. Clinically, reducing playing time may reduce injury incidence but not injuries specific to particular body regions or diagnoses in most cases, although the distributions of contusions varied between the athlete-plays-per-season groups. Nevertheless, these data warrant continued examination of our research questions in additional samples and more refined data-collection protocols to validate our findings.

Athlete-Plays per Game and Season

As with baseball and pitch-count tallies, research on play counts has helped to identify injury risk factors[14,15] and led to the creation of injury-prevention recommendations, such as age-specific pitch-count recommendations.[30] Additional sport organizations could consider this model for preventing youth sport injuries. The average youth football player in our sample had approximately 44 athlete-plays per game and 334 athlete-plays per season. Despite our studying a sample of 2098 youth football players from 12 individual recreational youth football leagues in 6 geographically diverse states, these findings may not be generalizable to the entire youth football player population.

Compared with information publically available on the Internet, our estimates were lower than the average number of plays per team reported at the collegiate and professional levels.[11–13] However, the possibility that youth football players are participating in too many plays within a game or season is potentially alarming. In our sample, 4.0% (n = 84) of youth football players had at least 700 athlete-plays in the season, and 2.3% (n = 49) had at least 100 athlete-plays per game. These findings may indicate the size of our youth team rosters that, on average, were smaller (mean = 20.0) than teams in high school and college (mean = 76.6 and 108.6, respectively).[31,32] As team size decreases, the likelihood of individual players having to participate in more plays may increase. In addition, youth football players typically rotate positions and play both offense and defense in the same game to learn skills required for each position. It seems counterintuitive that youth players participate in both offensive and defensive plays during games but high school and collegiate players may be less likely to participate in both types of plays. A simple, cost-free injury and head-impact–exposure mitigation strategy may be to simply prevent youth players from playing both offense and defense in the same game. This strategy would align with the added benefit of requiring a larger squad size, which we found was also associated with players having lower average numbers of athlete-plays per season and per game. Using both strategies in conjunction could potentially lower the risk of head-impact exposure for individual players. However, further research validating our hypothesis may be needed.

The large numbers of athlete-plays within a game and season were also concerning because they may increase exposure to subconcussive impacts, which may be associated with neurologic and cognitive decline.[17,18] However, we did not capture head impacts in this study. Therefore, in future work, investigators should consider the link between athlete-play counts and head impacts, particularly in conjunction with specific ages[17] and positions.[33,34] At the same time, researchers must work with youth football organizations to determine an appropriate cutoff for athlete-play counts (or playing time) in a game. Although investigators have discussed concerns regarding the effects of cumulative head impacts in football[17–19] and methods to reduce head-impact frequency,[20,35] we must also develop an appropriate framework for determining the threshold at which a player should be withheld from further participation.

Given that our comparative analyses were based on median cutoff groups for the number of athlete-plays per season, we were unable to account for game-specific variations in athlete-play counts. Such game-specific data could be used to assess if injury incidence was greater in the games in which players had more athlete-plays or in the games after those games in which players had more athlete-plays. The topic of periodization has been explored in sports such as soccer[36,37] but has not been examined in football. A high work-to-rest ratio may be associated with exertional heat illness, as well as with muscular fatigue and an increased likelihood of sustaining injuries, such as strains and sprains or lower extremity injuries.[16,38–40] However, we observed no differences in injury distributions between the athlete-plays per season median cutoff groups except for contusions, which are typically minor in severity. Guidelines for scheduling games and practices exist at the collegiate and high school levels[41,42] but at the youth level

Table 4. Injury Rates by Number of Plays per Season in Youth Football Players During Games in the 2013 Season

	Plays Per Season, No.										Above-Median Group Versus Below-Median Group Injury Rate Ratio (95% Confidence Interval)	
	Below-Median[a] Group (n = 1049)					Above-Median[a] Group (n = 1049)						
Type of Injury	Injury Count	Total Athlete-Plays	Athlete-Exposures	Per 10 000 Athlete-Plays	Per 1000 Athlete-Exposures	Injury Count	Total Athlete-Plays	Athlete-Exposures	Per 10 000 Athlete-Plays	Per 1000 Athlete-Exposures	Rates per 10 000 Athlete-Plays	Rates per 1000 Athlete-Exposures
All injuries	133	196 529	7732	6.77	17.20	196	503 960	8542	3.89	22.95	0.57 (0.46, 0.72)[b]	1.33 (1.07, 1.66)[b]
Time-loss injuries only	36	196 529	7732	1.83	4.66	50	503 960	8542	0.99	5.85	0.54 (0.35, 0.83)[b]	1.26 (0.82, 1.93)
Non–time-loss injuries only	97	196 529	7732	4.94	12.55	146	503 960	8542	2.90	17.09	0.59 (0.45, 0.76)[b]	1.36 (1.05, 1.76)[b]
Concussion only	12	196 529	7732	0.61	1.55	20	503 960	8542	0.40	2.34	0.65 (0.32, 1.33)	1.51 (0.74, 3.09)

[a] Median = 296.5 plays per season.
[b] Indicates difference (95% confidence interval did not include 1.00).

Table 5. Distributions of Injuries by Body Region Injured and Number of Plays per Season in Youth Football Players During Games in the 2013 Season

	Plays Per Season, No.	
Body Region Injured	Below-Median[a] Group, n (%)	Above-Median[a] Group, n (%)
Head/face/neck	22 (16.5)	38 (19.4)
Upper extremity	44 (33.1)	57 (29.1)
Shoulder	2 (1.5)	10 (5.1)
Arm/elbow	18 (13.5)	18 (9.2)
Hand/wrist/fingers	24 (18.0)	29 (14.8)
Trunk	23 (17.3)	26 (13.3)
Lower extremity	39 (29.3)	67 (34.2)
Hip/groin	9 (6.8)	5 (2.6)
Thigh/upper leg	4 (3.0)	7 (3.6)
Knee	10 (7.5)	21 (10.7)
Lower leg	5 (3.8)	10 (5.1)
Ankle	10 (7.5)	15 (7.7)
Foot/toes	1 (0.8)	9 (4.6)
Other	5 (3.8)	8 (4.1)
Total	133 (100.0)	196 (100.0)

[a] Median = 296.5 plays per season.

can only be used for leagues whose governing bodies actually provide them.[43,44] Developing best-practice guidelines for all youth football leagues, regardless of affiliation, should be considered.

Age Comparisons for Injury Risk and Rates

Injuries, particularly severe injuries, concern all involved in youth football. We estimated that 1 in 9 athletes was expected to sustain a game injury (risk = 11.15%); however, the 1-year risk decreased to 3.48% when considering TL injuries only. These data suggest that injuries may be less common than generally thought. This relatively low incidence was further illustrated by the

Table 6. Distributions of Injuries by Diagnosis and Number of Plays per Season in Youth Football Players During Games in the 2013 Season

	Plays Per Season, No. (%)	
Diagnosis	Below-Median[a] Group	Above-Median[a] Group
Abrasion	4 (3.0)	9 (4.6)
Concussion	12 (9.0)	20 (10.2)
Contusion[b]	54 (40.6)	57 (29.1)
Dislocation	0 (0.0)	1 (0.5)
Fracture	3 (2.3)	4 (2.0)
Heat-related event	2 (1.5)	9 (4.6)
Inflammatory condition	0 (0.0)	5 (2.6)
Laceration	1 (0.8)	1 (0.5)
Nervous system	4 (3.0)	9 (4.6)
Respiratory	1 (0.8)	2 (1.0)
Spasm	12 (9.0)	12 (6.1)
Sprain	21 (15.8)	33 (16.8)
Strain	11 (8.3)	17 (8.7)
Subluxation	0 (0.0)	2 (1.0)
Other	8 (6.0)	15 (7.7)
Total	133 (100.0)	196 (100.0)

[a] Median = 296.5 plays per season.
[b] Indicates difference (ie, injury proportion ratio did not equal 1.0).

athlete-play–based all-injury rate (4.70/10 000 athlete-plays). Nevertheless, the presence of such injuries merits the development of prevention programming in youth football to further reduce the incidence and severity of injuries.

When measured via injury risk, AE-based injury rates, or athlete-play–based injury rates, injury incidence in youth football was greater among older than younger players (Tables 1 and 2). This parallels previously reported findings[45,46] and may highlight the varying components of gameplay that exist across the age span of youth players (eg, younger players have less contact exposure). In addition, the resulting RRs and IRRs generated from these estimates were similar in magnitude, which may be due to the average number of games per season not differing between younger and older players. National organizations have recommended scheduling only 7 to 9 games during the regular season for their membership leagues, thereby placing safe game limits on season-long players.[43,44] In such cases, researchers may benefit from calculating injury-incidence measures, such as injury risk or AE-based injury rates, to reduce the burden of reporting for data collectors; in our study, we relied on the assistance of coaches and parents to collect athlete-play counts. However, when the number of athlete-plays per game or season or the number of games per season may differ between groups, research is needed to determine the usefulness of athlete-play–based injury rates.

Athlete-Plays per Season Comparisons in Injury Risk and Rates

Aside from reporter burden and potential entry error, athlete-play–based injury rates may also yield biased effect estimates compared with injury risk or AE-based injury rates (Tables 3 and 4). We found that injury risk and AE-based injury rates were greater in the above-median group than in the below-median group. However, athlete-plays–based injury rates provided a contrasting result (Table 4). Youth players who do not receive playing time may be less athletic (eg, slower, weaker) and at greater risk for injury. On the other hand, the findings may also stem from players sitting out for a number of plays after injury and not contributing athlete-play–count data to the at-risk denominator in the athlete-plays–based injury rates. In the most extreme example, athletes who were injured on the first play and did not participate for the remainder of the game would inherently yield greater athlete-plays–based injury rates than athletes who were uninjured or injured on the final play. This "healthy-athlete bias" exists when injury rates use athlete-plays–based or time-based measures. The healthy-athlete bias may also occur with AE-based injury rates, such as when examining only severe injuries that limit participation across multiple games. Although we recommend using AE-based injury rates that minimize the healthy-athlete bias, we also advocate for further research into how growth maturity and other measures of athleticism may be associated with playing time and injury incidence.

Limitations

As noted, our study was a secondary data analysis. More importantly, our examination of athlete-plays was exploratory; we excluded the first year in which data collection was pilot tested, but we were unable to account for potential variations in data collection at the league, team, and data-collector levels. We advocate for more research on identifying valid and reliable measures of athlete-plays to validate our findings. Our athlete-play counts were aggregated on a seasonal basis and did not account for the specific number of plays in each game in which each athlete participated. Such information would allow researchers to analyze the association of injury incidence and the number of athlete-plays within specific games but would require substantial data-collection efforts. Athlete-play counts also did not account for the types of plays (eg, offense, defense, special plays) or the positions played. Using mean and median cutoffs in the analyses minimized our ability to detect variability across the sample. However, these allow for easy interpretations of the findings. Nonetheless, researchers should attempt to collect more in-depth data across a longer time frame to allow for longitudinal analyses.

Furthermore, given that we focused on examining athlete-play counts and their association with injury incidence, we were limited in our analyses of other potential risk factors, including variations that may occur by time or at the league or team level (eg, injury-prevention programming, policy related to minimal plays per game), game level (eg, weather, playing surface, time per game), or player level (eg, previous injury history, height, mass, playing experience). In addition, although we analyzed the data by NTL and TL injuries, we did not examine the severity distribution of TL injuries by the number of games missed, as scheduling may vary on a league-by-league basis. Finally, our data originated from 2098 youth football players from 105 teams in 12 recreational leagues across 6 states, yet our findings may not be generalizable to other youth football leagues that were not included in the study or football programs at other competition levels (eg, high school, collegiate, professional). Such research is warranted because differences may exist at higher levels of competition due to specialization by position and between starters and nonstarters.

CONCLUSIONS

We found that youth football players participated in approximately 44 plays per game and 334 plays per season. A proportion of players had large numbers of athlete-plays per game and per season. In the context of current concerns about subconcussive impacts, heat-illness risk, and long-term orthopaedic effects, developing appropriate athlete-play–count restrictions to protect the health and safety of players may be warranted. When considering measures of injury incidence and the circumstances of data-collection burden for ATs in youth settings, injury risk and AE-based injury rates are more feasible measures to calculate. Although such measures do not account for variations in time, they can minimize the presence of the healthy-athlete bias (ie, healthier athletes avoid being injured and stay in the game longer, consequently contributing more at-risk time and deflating the resulting injury rates). However, future research is needed not only to determine the validity of our results for other youth football settings or competition levels but also to identify the best practices for obtaining valid and reliable athlete-play data in large settings.

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