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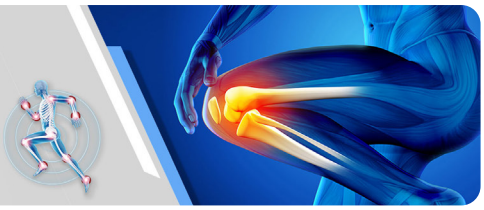

Epidemiology of Injuries in High School Football Players: A Prospective Cohort Study

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Abstract

Objective: To estimate the incidence and severity of injuries sustained by a group of high-school football players and to identify risk factors associated with these injuries

Design: Observational cohort study

Settings: High school football programs in Quebec, Canada

Participants: 707 male high-school football players were recruited and entered the study. They had to come from one of four participating high schools to be included in the study. All players completed the survey

Interventions: Participants filled out a questionnaire about sociodemographic data, football experience, and life habits. They were observed throughout a football season and any injury was entered into a database by the team's trainer

Main outcome measures: Participants were divided into "injured" or "non-injured" at the end of the observation period. Each injury was analyzed independently. Incidence rates of injury were calculated per 1000 Athlete-Exposures (AEs) and potential risk factors were assessed

Results: 294 players sustained 413 injuries (11.67 per 1000 AEs; 95% Confidence Interval (CI) 11.63-11.7). Injuries were more frequent in game than practice (Relative Risk (RR) 41.67, CI 30.5-56.9). The most frequent injuries were concussions (3.11 per 1000 AEs; CI 3.09-3.13). The presence of a previous injury was associated with significantly more subsequent injuries ($p=0.0006$). Other significant associations were the presence of another active injury, tobacco use, and a higher BMI ($p<0.05$)

Conclusion: Injuries are frequent in high-school football players. Future prevention strategies should focus on athletes with a previous history of injury. Reducing concussion rate is also necessary in this growing population

Keywords: High-school students; Football players; Injuries; BMI

Introduction

In the United States, over 7 million high-school students take part in their school's athletics [1]. Of that number, about 1.5 million play football [2]. Approximately 300 000 to 1.2 million high school football players sustain an injury each year [3,4]. According to the National Federation of State High School Associations, high school athletes have fewer school absences, better grades at graduation, fewer disciplinary sanctions, and a better chance of success in future studies when compared to their classmates [4,5]. The

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quest for excellence often leads to more difficult practice sessions and tougher competition [6]. Sports injuries are responsible for about 23% of traumatic pediatric consults in the ER [7]. Football is the sport with the highest rate of injury [8]. Furthermore, growing athletes are likely to experience injuries that affect their growth [5].

The identification of risk factors for football-related injuries has been studied for over 3 decades [9]. Previous injuries and as well as a player's age have been identified as risk factors for injuries [10]. A recent systematic review identified some risk factors for concussions in youth football (high-school level or younger) such as grass instead of turf; game situations; and positions at risk for head impact [11]. There has been a lot of interest towards concussion prevention in recent years although risk factors for musculoskeletal injuries still have not been clearly identified. Most studies on the subject are over 15 years old, and very few apply to patients under 18 years old. They are often not prospective, follow small cohorts over a short period, and their definition of injuries is variable, which makes external validity hard to assess. The objectives of this study are to assess the rate of injury in a unique cohort of Canadian high-school football players; to identify which types of injuries are most prevalent; and to identify potential risk factors for these injuries.

Methods

A prospective cohort design conducted throughout one complete football season (2015-2016) was used for this study. Recruitment of participants was achieved through approaching directors of four high-school high-level football programs in Quebec City, Canada. The only inclusion criterion was to be a football player enrolled in one of the participating football teams. Consent of players and their parents was obtained by one investigator (MB) before the beginning of data collection. All players and parents signed the consent forms. The school board approved the study.

Players compete in four distinct categories based on age (12-13, 13-14, 14-15, and 15-17-year-olds). Participants filled out a questionnaire about for sociodemographic data, football-specific data, and nutritional and life habits. Nutritional habits were included in the original questionnaire although results were not analyzed as part of this project, except for water consumption.

Teams' athletic trainers collected information on each injury that happened throughout the season (type, body part, treatment, and consequences on the remaining of the season), regardless of the setting (game, practice, or training). All injuries were reported and validated by the team's physiotherapist. Head coaches were not involved in collecting data to reduce the risk of reporting bias. Return to play was authorized by the physiotherapist. Concussions were diagnosed and need for rehabilitation protocol was based on teams' physical trainers experience and judgment of medical teams when necessary.

At the end of the season, participants took part in an online survey to report all the injuries sustained during the season. The compiled answers were compared to the initial injuries and any additional injury was validated by the physiotherapists before being considered in the analyses.

A strict definition of an injury is used in this study [8]: an event that results in the termination of the current session, or that prevents the next session. An athlete was analyzed as an "injured" athlete if he had sustained one or more injuries throughout the season. Each injury was then analyzed independently to reduce bias from re-injuries. Injuries were divided into two categories: musculoskeletal (axial skeleton) and head/spine injuries (concussions, skeletal spine injuries).

Discrete data were presented as frequency and proportion (%), and continuous data were presented as mean with Standard Deviation (SD). Incidence rates of injury were calculated per 1000 Athlete-Exposures (A-Es) where exposure is defined as one practice or one game. Frequency of injuries was presented with a 95% confidence interval. Risk factors were identified using one-way ANOVA and multivariate analyses with odds ratios and 95% confidence levels (α=0.05). Odds ratio >1 signified an increased risk of injury for in the presence of said factor. Only variables which were identified as statistically significant in a univariate model were entered in the multivariate model [1]. Subgroup analyses were performed as well as clustering for each age group. Statistical analysis was performed using JMP version 14.3 (SAS, Cary, NC, USA). P-values are two-sided, and a 0.05 significance threshold was used. A pilot study (n-=165) was done the season before the project started to calculate sample size and identify important covariables. We established that a sample size of 400 players was needed to demonstrate a significant difference of 10% between injured and non-injured players.

Results

A total of 707 athletes were included in the study. The cohort was composed of 137 "12-13" (19.38%), 161 "13-14" (22.77%), 175 "14-15" (24,75%), and 234 "15-17" (33.1%). Table 1 resumes the main characteristics of the population. Most players had a history of previous injury (403; 64.38%) Most players reported light or moderate sport-related stress levels (514; 81,81%%). Nutritional habits are available in Supplemental Files.

Over the course of this study, 13-year-old players compiled a total of 5691 exposures; 6845 exposures for 14-year-old players; 8074 exposures for 15-year-olds and 14 088 exposures for 16-17-year-olds. 294 players sustained a total of 413 injuries during the observation period (11.76

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per 1000 AEs). 15-17 reported nearly half of the events (169, 40.69%). Injuries were more common during games than practice (369; 89.35%; 62,5 per 1000 AEs vs. 44; 10.65%; 1,5 per 1000 AEs; RR 41.67, 95%CI 30.5-56.9). Musculoskeletal injuries were the most common across all levels of play (305; 73.85%) followed by head injuries (108; 26.15%). Injuries were more frequent as players got older. Table 2 presents types of injuries by category and by level of play.

The most common site of injury was the head with over a quarter of all injuries (111; 26.94%). Head injuries were more frequent in games than in practices (16.94 per 1000 A-Es vs. 0.17 per 1000 A-Es, respectively). Most cases were concussions requiring a full specific rehabilitation protocol before returning to play (108; 26.15%, 3.18 per 1000 AEs). Other head injuries included face cuts and teeth injuries. Thighs (57; 13.83%), knees (52; 12.62%), and shoulders and arms (50; 12.14%) were also frequently injured (Table 3).

The most frequently injured players played at the position of DB (24.83%), wide receiver and DL (14.63%), and LB (13.61%).

Table 4 presents the statistical association between each characteristic/nutritional habit and the occurrence of injury in the cohort. Among the potential risk factors identified, the ones with statistical significance were weight (OR 0.98; p = 0.0003); height (OR 0.14; p = 0.0043); BMI (OR 0.94; p = 0.0008); years of experience (p=0.0073); the presence of one or more previous injuries (p<0.0001); and presence of a current injury (p=0.0005). Occasional tobacco use was also associated with a higher rate of injury (OR 6.22; 95% CI 1.33-29.03; p=0.0098), although "occasional" was not defined in original study so this result was not included in multivariate analysis to reduce risk of bias. The most significant risk factor was the presence of a previous injury (RR=2.25; 95% CI 1.977-2.56).

In a multivariate model, the statistically significant variables were the presence of one or more previous injuries (OR 2.30; 95% CI 1.56-3.39) and the presence of a current injury (2.09; 1.24-3.51). BMI, weight, height, as well as years of experience were not associated with a significantly increased risk of sustaining an injury in our cohort.

Table 1: Characteristics of the population.

Age (years)	13	14	15	16-17	Total
	(N=137)	(N=161)	(N=175)	(N=234)	(N=707)
Mean weight (kg) (SD)	49.48 (12.71)	57.28 (13.35)	65.86 (13.44)	76.11 (15.57)	64.14 (17.26)
Mean height (cm) (SD)	155 (9)	164 (9)	1.71 (8)	178 (7)	169 (12)
Mean BMI (kg/cm^2) (SD)	20.3 (3.66)	21.04 (4.21)	22.34 (3.69)	24.01 (4.31)	22.20 (4.27)
Median years of experience (range)	2 (0-6)	2 (0-8)	3 (0-8)	5 (1-8)	3 (0-8)
Previous injury (%)	118 (18.85)	151 (24.12)	141 (22.52)	216 (34.50)	626 (89)
High stress level					
Yes (%)	1 (0.73)	7 (4.35)	17 (9.71)	17 (7.26)	42 (6.70)
No (%)	117 (85.4)	146 (90.68)	124 (70.86)	208 (88.89)	585 (93.30)
Sleep hours					
< 8 (%)	11 (8.03)	23 (14.29)	29 (16.57)	56 (29.93)	119 (16.83)
≥ 8 (%)	110 (80.29)	130 (80.75)	112 (64)	161 (68.80)	513 (72.56)
Tobacco use (%)	1 (0.73)	0 (0.00)	1 (0.57)	12 (5.13)	14 (1.98)
Alcohol consumption (%)	0 (0.00)	7 (4.35)	19 (10.86)	108 (46.15)	134 (18.95)
Drug use (%)	0 (0.00)	0 (0.00)	2 (1.14)	7 (2.99)	9 (1.27)

Table 2: Types of injuries across categories.

	Head injuries		Musculoskeletal		Total N	Total %
Level	N	%	N	%		
Dec-13	19	4.60%	38	9.20%	**57**	**13.80%**
13-14	25	6.05%	59	14.29%	**84**	**20.34%**
14-15	31	7.51%	72	17.43%	**103**	**24.94%**
15-17	33	7.99%	136	32.93%	**169**	**40.92%**
Total	**108**	**26.15%**	**305**	**73.85%**	**413**	**100.00%**

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Table 3: Sites of injuries.

Site	N (%)	Site	N (%)
Head	111 (26.88)	Thigh	57 (13.80)
Concussion	108	Strain	50
Other	3	Contusion	7
Trunk	33 (7.99)	Knee	52 (12.59)
Contracture	11	Strain	1
Contusion	9	Contusion	14
Sprain	11	Sprain	21
Fracture	2	Fracture	1
Shoulder and arm	50 (12.11)	Tendinitis	15
Strain	1	Leg	28 (6.78)
Contracture	1	Strain	12
Contusion	18	Contusion	10
Sprain	10	Tendinitis	6
Fracture	2	Foot and ankle	49 (11.86)
Dislocation	1	Contusion	3
Tendinitis	17	Sprain	40
Hand & wrist	33 (7.99)	Fracture	3
Contusion	3	Tendinitis	3
Sprain	15		
Fracture	14		
Dislocation	1		

Discussion

Rate of injury

The main finding of this study is a high rate of injury per 1000 A-Es (11.76). This finding is even more important during game situations (62.5 injuries per 1000 A-Es.) These rates of injury are higher than those published by other authors in a similar population. Hammer et al. [12] reported a game rate of 12.04 injuries per 1000 A-Es, for a total rate of injury of 3. Shankar et al. [1] found a total rate of 12.04 injuries per 1000 A-Es in game situations in a cohort of high-school football players. Both studies used a stricter definition of an injury than used in this trial (medical professional diagnosis required and at least one to two days play restriction); this probably underestimates the rate of injury, as an injury conducting to the immediate end of play will not always require a medical diagnosis. Differences in injury surveillance methodology can also explain discrepancy between study results. Turbeville et al. [13] reported a game injury rate of 13.12 (10.4-16.0) in a cohort of 717 high school football players between 1998 and 1999. Injuries were reported only by coaches; they are however not trained for diagnosis and might have overlooked many injuries.

Some studies looked at the rate of injuries in youth football players cohorts. Dompier et al. [14] reported an overall injury rate of 17.8 (95% CI 16.3-19.4) per 1000 A-Es in players aged 9 to 14 with a game injury rate of 30.5 (25.6-35.4). Stuart et al. [15] reported a game injury rate of 8.47 A-Es in players aged 9 to 13. Youth football players might sustain fewer injuries due to different rules, a slower pace of play, and smaller and/or weaker players.

Types of injury

The most frequent injuries in this cohort were concussions (26.88%; 3.11 per 1000 AE, 16.94 per 1000 AE in game situations.) This is similar to a recent study by Hammer and al. [12] who reported that 21.1% of all injuries were concussions in their cohort of high school football players. Kerr et al. [16] showed a concussion rate of 3.32 to 3.9 per 1000 AE in game situation. O'Connor et al. [17] showed that concussions had about 2 per1000 AEs in a cohort followed over the 2011 to 2014 seasons. Pankow et al. [11] found a lower concussion rate in their systematic review on the subject (1.15 per 1000AEs in game situations). Their systematic review included studies which had many different definitions for concussions. Our rigorous protocol for head injuries might explain why our numbers are higher than those of other studies. Stockwell et al. [18] recently reported that most players drop their heads when tackling and showed that several high school football coaches still teach at-risk tackling techniques to their players.

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Prevention and education are the cornerstones to reduce concussions in high school football players.

Other frequently injured sites were thigh (57; 13.80%), knee (52; 12.59%), and shoulder and arm (50; 12.11%.). These results are similar to other studies [19,20]. Hammer et al. [12] reported knees and hips/legs being the most frequently injured body parts in football players (15.2% and 12.3% respectively), with knees suffering the highest number of severe injuries (26.6%). The rigorous injury detection protocol used in this trial illustrates a more complete picture of the extent and prevalence of the musculoskeletal injuries in high football athletes.

Risk factors

The presence of a previous injury was the most influential factor in the occurrence of subsequent injuries. The presence of an active injury also predisposed to sustaining another injury (RR = 2.25 [1.98-2.56]; p=0.00425). Knowles et al. [10] found that previous injuries doubled the risk of subsequent injuries. Turbeville et al. [13] assessed the history of injury in their cohort of 646 middle school football players but did not find it to be a significant risk factor for injuries (p=0.7). Their cohort was however younger (median = 13.5 years old). Although they did not analyze for the presence of previous injuries, Ramirez et al. [2] have mentioned the importance of being aware of reinjuries in young football players. A significant attention should be paid to players with active or previous injury to prevent reinjuries; modified and/or adapted training protocols and delayed return to play (not favored by coaches) to achieve better healing should be considered.

Heavier players sustained more injuries Turbeville et al. [13] also found that injured players were significantly bigger than non-injured players.13 A recent systematic review by Pankow et al. [11] found that positions which experience head impacts more frequently – such as linemen – were at significantly higher risk for concussions. Shanker et al. [1] showed that linemen, both offensive and defensive, as well as linebackers were the most frequently injured players. At a high-school age, our hypothesis is that heavier players are less muscular and fit than heavy players at college or professional levels. This can explain why players with a higher BMI were more at risk for injuries in this cohort (p=0.0006).

Tobacco use was also associated with the occurrence of injuries (OR 6.22; 95% CI 1.33-29.03; p=0.0098). Volpi et al. [21] had already identified smoking, drinking, and diet as potential lifestyle factors that could increase the occurrence of injuries in professional soccer players. We however did not define "occasional" smoking to players when they completed the survey. Low fluid intake during games also seemed to increase the number of injuries (p=0.0431). Other sports played as well as hours of sleep per night were not associated with an increased risk of injury in our cohort.

Strengths and limitations

The main strength of this study is the large number of participants. Since this study recruited all football players from the four major high-school football programs in the Quebec region, the external validity of the results is excellent. There was an excellent participation rate; trainers and PTs from all schools got rapidly involved at the beginning of the process and players were followed closely so that injury reporting was as accurate as possible. This study also used a clear, agreed-upon definition of an injury, which makes both internal and external validity better.

Limitations include the probability of having missed some injuries, especially injuries that occurred during practices as trainers were always not with the team during those sessions. Also, injury rates did not consider re-injuries or multiple injuries sustained in the same incident. One school also had a lot more players than the others; this could have diluted the rate of injury as more players are included in each practice and game but also more of them are on the bench. Other limitations include the lack of a validated surveillance system. Finally, our data was collected 6-7 years prior to analysis and publication, which could affect result interpretation. However, we chose to use and publish it as we know culture around high-school football and injury prevention strategies have not changed much, if at all, since 2016.

Conclusion

The rate of injury among high-school football players is high. Head injuries (mainly concussions) are the most common injuries. Previous or active injuries, obesity, and smoking habits have been identified as significant risk factors.

Innovative preventive and educational strategies are required in this growing population. Multidisciplinary programs including nutritionists, physiotherapists, sports psychologists, and coaching staff support (i.e. modified or adapted training programs, development of injury surveillance systems) should be developed. A specific attention to head injuries prevention through modified teaching techniques is mandatory.

New studies are required to measure the impact of these programs.

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APPENDIX

Appendix 1: Nutrition habits of cohort.

Nutrition					
Weight modification (N, %)		**Sports drinks on practice days (N, %)**		**Snacks per day (N, %)**	
Trying to lose weight	83 (13.28)	Never	63 (10.02)	1	17 (2.71)
Trying to gain weight	190 (30.40)	Rarely	177 (28.14)	2	77 (12.26)
Trying to maintain weight	214 (34.24)	Sometimes	262 (41.65)	3	185 (29.46)
Indifferent	138 (22.08)	Regular	127 (20.19)	4	180 (28.66)
				5	73 (11.62)
				6	96 (15.29)
Nutrition modification (N, %)		**Sports drinks on game days (N, %)**			
Yes, but room for improvement	306 (49.12)	Never	75 (11.92)		
Yes, follows all recommendations	40 (6.42)	Rarely	167 (26.55)	**Snack before practice (N, %)**	415 (66.40)
No, already had good nutrition	146 (23.43)	Sometimes	216 (34.34)	**Snack after practice (N, %)**	478 (76.36)
No, already had good nutrition	12 (1.93)	Regular	171 (27.19)	**Fluid intake during practice (ml) (N, %)**	
No, too difficult	83 (13.32)	**Sport bars or gels on practice days (N, %)**		0-500	75 (12.25)
No, no interest	36 (5.78)	Never	356 (56.87)	500-1000	345 (56.37)
Presence of food allergy (N, %)	102 (16.24)	Rarely	135 (21.57)	1000-1500	144 (23.53)
Veganism/vegetarianism (N,%)	1 (0.16)	Sometimes	100 (15.97)	> 1500	48 (7.84%)
Use of supplements (N,%)	122 (19.46)	Regular	35 (5.59)	**Bad sugars consumption (N, %)**	
Use of energy drinks on practice days (N, %)		**Sport bars or gels on game days (N, %)**		Never	6 (0.96)
Never	576 (92.31)	Never	377 (60.13)	Rarely	168 (26.84)
Rarely	36 (5.77)	Rarely	122 (19.46)	Sometimes	351 (56.07)
Sometimes	11 (1.76)	Sometimes	86 (13.72)	Regular	101 (16.13)
Regular	1 (0.16)	Regular	42 (6.70)	**Saturated fats consumption (N, %)**	
Use of energy drinks on game days (N, %)		**Meals per day (N, %)**		Never	7 (1.11)
Never	609 (97.44)	1	1 (0.16)	Rarely	223 (35.45)
Rarely	12 (1.92)	2	17 (2.71)	Sometimes	329 (52.31)
Sometimes	3 (0.48)	3	503 (80.22)	Regular	70 (11.13)
Regular	1 (0.16)	4	93 (14.83)		
		5	13 (2.07)		