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Do Climate and Environmental Characteristics Influence Concussion Incidence in Outdoor Contact Sports? A Systematic Review

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Objective: To obtain a comprehensive understanding of the implications of environmental and climate factors on sport-related concussion incidence in outdoor contact sports.

Data Sources: MEDLINE (via Ovid), Embase (via Elsevier), CINAHL Complete (via EBSCOhost), SPORTDiscus (via EBSCOhost), and Scopus (via Elsevier).

Study Selection: Studies that report incidence of sport-related concussion, assess data from athletes participating in outdoor contact sports, report on 1 or more climate or environmental factors, and report a diagnosis of concussion performed by a licensed medical professional were included. Reasons for exclusion included no report on extrinsic or environmental factors, no data on sport-related concussion incidence, and self-report of concussion diagnosis.

Data Extraction: This systematic review was conducted using Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines using 2 reviewers at each phase and a third reviewer for conflict resolution.

Data Synthesis: A total of 7558 articles were reviewed, and 20 met the inclusion criteria. There was moderate to strong strength of evidence concluding no difference between surface type (grass versus artificial) on sport-related concussion risk. Moderate to strong strength of evidence was found supporting no difference in sport-related concussion incidence based on game location (home versus away). There was no consensus on the effects of altitude or temperature on sport-related concussion incidence. One high-quality study found a decreased risk of sport-related concussion when playing in wet versus dry conditions. Heterogenous populations and data collection methods prevented extraction and meta-analysis.

Conclusions: Although a consensus on specific environmental and climate factors that influence sport-related concussion incidence was limited, the majority of studies were of high quality and gave insight into opportunities for future investigation. Administrators of large injury surveillance databases should consider including specific environmental and climate factors to provide investigators with robust data sets to better understand potential associations with sport-related concussion.

Key Words: sport-related concussion, environment

Key Points

- There is a general lack of consensus on specific climate and environmental factors that influence sport-related concussion incidence in outdoor contact sports, and current injury reporting systems do not routinely document the environmental or climate factors that may be related to concussion injuries.
- Nationwide injury surveillance systems may provide an opportunity to further investigate this relationship, as simple environmental and climate data could be added, such as field type, temperature, humidity, field conditions, location, and altitude.
- Having a better understanding of this relationship will inform future decision-making and allow for improved preparation in environmental conditions that may be related to increased risk of concussion.

Sport-related concussion is a prevalent sports-related injury with rates as high as 0.47 per 1000 National Collegiate Athletic Association (NCAA) athlete-exposures[1] and 0.51 per 1000 high school athlete-exposures.[2] However, according to the Centers for Disease Control and Prevention National Concussion Surveillance System, only 1 out of every 9 sport-related concussions is identified,[3] possibly because of underreporting or a poor understanding of symptoms by athletes. Studies have found that over the course of a collegiate sports career, 12% of athletes did not report sustaining a concussion, and 26% sustained an unrecognized sport-related concussion.[4] Additionally, up to 50% of high school athletes sustain an unreported concussion.[5,6] Immediate recognition and diagnosis is imperative for the long-term health and well-being of athletes. Risk factors that influence sport-related concussion incidence have been studied to facilitate improved awareness and diagnosis. Most commonly, these risk factors are intrinsic in nature, such

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as sport played, previous history of concussion, and gender, or are related to match play versus practice.[4,7,8] The 2017 Berlin consensus statement found minimal evidence for effective injury prevention strategies that can address these intrinsic factors[6]; however, authors highlight the need for a clearer understanding of potentially modifiable factors to design prevention strategies and reduce the risk of sport-related concussion. To date, there is minimal research investigating extrinsic factors in relation to sport-related concussion incidence. However, there is evidence that factors such as weather, surface type, and altitude influence sport-related injury.[9–12]

Weather and temperature are nonmodifiable elements faced by athletes who play outdoor sports that can affect injury rates. Tobías et al assessed the possible effect of ambient temperature on emergency department visits resulting from sports injury and found a higher risk of emergency visits (orthopedic, neurologic, and internal diagnoses) when the weather was cold (5°C) and hot (28°C), which represent the 5th and 95th percentiles of the annual temperature range for that location, respectively.[9] Orchard et al found that in American football, there was a lower risk of knee and ankle injury when playing in cold weather.[10] However, Chalmers et al did not find an association between injury rate and temperature in rugby union football.[13] In professional soccer players, Aoki et al conducted a 15-year prospective epidemiological study and found a lower injury rate on rainy days than on cloudy and sunny days.[12] As demonstrated, most research has primarily focused on musculoskeletal injury, leaving a gap in our understanding of how weather may impact sport-related concussion incidence in this population.

This systematic review is relevant to sports medicine professionals working in outdoor environments and variable climate conditions, as no previous literature reviews have synthesized current research on these factors related to sport-related concussion incidence. We chose to focus this systematic review on climate-related factors specific to competitive contact sports with known increases in sport-related concussion risk to provide medical professionals with valuable insight to enable more informed clinical decision-making for possible sport-related concussion prevention. Our purpose was to enhance our understanding of the implications that climate and environmental characteristics may have on sport-related concussion incidence in outdoor contact sports to enable more informed clinical decision-making by sports medicine teams. Thus, the aim of this study was to systematically review the literature to identify whether a relationship exists between environmental and climate factors and sport-related concussion incidence.

METHODS

This review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines and was recorded in PROSPERO (international prospective register of systematic reviews), a registry of systematic reviews under registration number (CRD42022302464).

Search Strategy

A comprehensive search was conducted by a professional medical librarian within MEDLINE (via Ovid), Embase (via Elsevier), CINAHL Complete (via EBSCOhost), SPORTDiscus (via EBSCOhost), and Scopus (via Elsevier) from inception to December 22, 2021. Each search involved keywords and subject headings for the concepts of outdoor sports and sport-related concussions. Case reports, editorials, newsletters, conference abstracts, books, and book chapters were removed via search filters. Full search strategies are available in Appendix 1. The search identified a total of 16 281 references that were imported and uploaded into Covidence (www.covidence.org), a systematic review screening tool, for automatic deduplication. The duplicate citations (n = 8719) were removed in this manner before screening. In addition, a manual search of reference lists of the articles screened for inclusion was performed to find relevant articles not identified in the initial search.

Study Selection

Two independent reviewers screened all titles and abstracts. Conflicts were resolved by a third reviewer. The same process was repeated for full text review. Studies were included if they reported sport-related concussion incidence for an outdoor contact sport and included an environmental factor, such as surface type, game location, field condition, temperature, or altitude. The diagnosis of sport-related concussion must have been made by a licensed medical provider such as a physician or athletic trainer. Studies were excluded if no environmental factor(s) were reported, the study design was inappropriate, or concussions were self-reported.

Quality Assessment

The risk of bias was determined independently by 2 reviewers using a modified version of a tool created and validated by Hoy et al.[14] The original described tool has a total of 10 items. One item was removed after a preliminary review of the literature found that this item lacked relevance to the types of studies meeting our inclusion criteria. This evaluation checklist contains 9 items pertaining to methodology of studies reporting on prevalence (Table 1). Items were scored as *yes* (0) or *no* (1). A total of 0 to 3 points indicated a *low* risk of bias, 4 to 6 points indicated a *moderate* risk of bias, and 7 to

Table 1. Risk of Bias Tool

	Yes = 0 points	No = 1 point
1.	Was the study's target population a close representation of the national population in relation to relevant variables (eg, age, sex, and occupation)?	
2.	Was the sampling frame a true or close representation of the target population?	
3.	Was some form of random selection used to select the sample OR was a census undertaken?	
4.	Was the likelihood of nonresponse bias minimal?	
5.	Were data collected directly from the subjects (as opposed to a proxy)?	
6.	Was an acceptable case definition used in the study?	
7.	Was the study instrument that measured the parameter of interest (incidence of sport-related concussion) shown to have reliability and validity (if necessary)?	
8.	Was the same mode of data collection used for all subjects?	
9.	Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	

Summary of risk of bias:
0 to 3 points = low
4 to 6 points = moderate
7 to 9 points = high

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Table 2. Characteristics of Included Studies Continued on Next page

Authors, Year	Title	Study Design	Level of Evidence	Population, Level of Competition	Method of Data Collection	Environmental/Climate Factor(s)	Findings	Risk of Bias
Alles et al,[36] 1979	The National Athletic Injury/Illness Reporting System 3-year findings of high school and college football injuries	Epidemiological	2c	Males, football, high school and collegiate	NAIRS	Surface	No significant difference in sport-related concussion rates found between natural grass and AstroTurf. Somewhat higher risk on Tartan Turf but not a significant difference.	Low
Caswell et al,[26] 2012	Video incident analysis of head injuries in high school girls' lacrosse	Epidemiological	2c	Females, lacrosse, high school	ATC	Surface, field condition	Half of head injuries occurred in the first quarter of the season. Increased incidence of sport-related concussions on natural grass surface compared with artificial turf.	Moderate
Connolly et al,[21] 2018	Effect of playing and training at altitude on sport-related concussion incidence in professional football	Epidemiological	2c	Males, football, professional	*FRONTLINE* Sport-Related Concussion Watch	Altitude, location	No significant difference found when comparing altitude quartiles, but teams that both train and play at high altitudes have decreased sport-related concussion rates; also found increased rate of head injuries in away teams versus home teams.	Moderate
Dai et al,[32] 2018	Effects of game characteristics and player positions on sport-related concussion incidence and severity in professional football	Epidemiological	2c	Males, football, professional	*FRONTLINE* Sport-Related Concussion Watch	Location	Away teams had a significantly greater number of sport-related concussions than home teams.	Moderate
Ekstrand et al,[27] 2011	Comparison of injuries sustained on artificial turf and grass by male and female elite football players	Prospective cohort	1b	Males and females, soccer, professional	Medical professional/team physician	Surface	No significant difference in sport-related concussion rates found between artificial turf and natural grass.	Low
Fuller et al,[28] 2007	Comparison of the incidence, nature, and cause of injuries sustained on grass and new generation artificial turf by male and female football players. Part 1: match injuries.	Prospective cohort	1b	Males and females, soccer, collegiate	NCAA ISP	Surface	Significantly higher incidence of head injuries on artificial turf than on natural grass.	Moderate
Fuller et al,[37] 2010	Risk of injury associated with rugby union played on artificial turf	Prospective cohort	1b	Males, rugby, professional	Physiotherapist	Surface	No significant difference in sport-related concussion rates found between artificial turf and natural grass.	Low
Gardner et al,[38] 2019	National Rugby League match scheduling and rate of sport-related concussion	Descriptive, observational	2b	Males, rugby, professional	Physician	Location	No significant difference in sport-related concussion rates found between home and away teams.	Low
Gibbs et al,[39] 2017	Sport-related concussion incidence and recurrence in professional Australian football match-play: a 14-year analysis	Prospective	1b	Males, football, professional	Physician	Field condition	Decrease in sport-related concussion rates found with wet weather conditions compared with dry weather conditions. No difference found when comparing time of day (day versus night).	Low
Haider et al,[40] 2018	Does the environment influence the frequency of sport-related concussion incidence in professional football?	Retrospective	2b	Males, football, professional	*FRONTLINE* Sport-Related Concussion Watch	Temperature, humidity, barometric pressure, dew point	Significant decrease in sport-related concussion rates both with higher temperatures and with dew points above 60°F.	Moderate
Lawrence et al,[41] 2016	Influence of extrinsic risk factors on National Football League injury rates	Case control	3b	Males, football, professional	Physician	Temperature	Increased risk of sport-related concussions found with decreasing game-day temperatures. No difference in sport-related concussion rates found with varying altitude or among various playing surfaces.	Low
Lempke et al,[29] 2021	The effects of on-field heat index and altitude on sport-related concussion assessments and recovery among NCAA athletes	Retrospective	2b	Males and females; football, lacrosse, soccer; collegiate	CARE Consortium	Location	No significant difference in sport-related concussion rates found in areas of higher or lower altitudes or in areas with a higher or lower heat index.	Low
Lynall et al,[24] 2016	Division I college football sport-related concussion rates are higher at higher altitudes	Retrospective	2b	Males, football, collegiate	ATC, NCAA ISP	Altitude	Increased sport-related concussion rates found at higher altitude compared with lower altitude. Also, longer recovery rates were found with sport-related concussions sustained at higher altitudes.	Low
Meyers et al,[42] 2019	Incidence, mechanisms, and severity of game-related high school football injuries across artificial turf systems of various infill weights	Cohort	2b	Males, football, high school	ATC, physician	Turf weight	Decrease in sport-related concussion rates with lighter infill.	Low

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Table 2. Continued From Previous Page

Authors, Year	Title	Study Design	Level of Evidence	Population, Level of Competition	Method of Data Collection	Environmental/Climate Factor(s)	Findings	Risk of Bias
Meyers et al,[43] 2021	Surface-related high school football game injuries on pad and no-pad fields	Cohort	2b	Males, football, high school	ATC, physician	Turf pad	No significant difference in sport-related concussion rates found between surfaces with underlayer pad compared with those without an underlayer pad after head-to-surface impacts.	Low
Myer et al,[20] 2014	Rates of sport-related concussion are lower in National Football League games played at higher altitudes	Epidemiological	2c	Males, football, professional	*FRONTLINE* Sport-Related Concussion Watch	Altitude	Significant decrease in sport-related concussion rates at higher altitude compared with lower altitude.	Moderate
Ranson et al,[44] 2018	Playing surface and UK professional rugby union injury risk	Prospective	1b	Males, rugby, professional	Physiotherapist	Surface	Increased risk of sport-related concussions on natural grass compared with artificial surfaces.	Moderate
Smith et al,[33] 2013	Altitude modulates sport-related concussion incidence: implications for optimizing brain compliance to prevent brain injury in athletes	Cohort	2b	Males, football, high school	HS RIO	Altitude	Decrease in sport-related concussion rates at increased altitude compared with at lower altitudes.	Low
Smoliga et al,[31] 2017	Team logo predicts sport-related concussion risk: lessons in protecting a vulnerable sports community from misconceived, but highly publicized epidemiologic research	Retrospective	2b	Males, football, professional	*FRONTLINE* Sport-Related Concussion Watch	Altitude	No association found between higher altitude and decreased incidence of sport-related concussions.	Moderate
Teramoto et al,[30] 2017	Game schedules and rate of sport-related concussions in the National Football League	Epidemiological	2b	Males, football, professional	*FRONTLINE* Sport-Related Concussion Watch	Location	No significant association found between sport-related concussion rates and game location.	Moderate

Abbreviations: ATC, certified athletic trainer; CARE Consortium, Concussion Assessment, Research and Education Consortium; HS, high school; ISP, Injury Surveillance Program; NAIRS, National Athletic Injury Reporting System; NCAA, National Collegiate Athletic Association; RIO, Reporting Information Online.

9 points indicated a *high* risk of bias. Two raters independently scored each study, and a third rater resolved conflicts. The level of agreeability of the risk of bias between the 2 reviewers was calculated using the Cohen κ.

Data Extraction and Analysis

The primary outcome of interest was the reported incidence rates of sport-related concussion in athletes participating in outdoor contact sports. Data and key findings regarding sport-related concussion incidence across different sports, surface types (grass versus artificial), game locations (home versus away), altitudes, temperatures, and wet versus dry conditions were recorded and qualitatively categorized by 2 independent reviewers. Sample size, level of play, type of medical professional making the sport-related concussion diagnosis, and method of data collection (ie, use of an injury reporting surveillance system) were also recorded and considered in the qualitative analysis. Both the study design and level of evidence according to the Oxford Centre for Evidence-Based Medicine are included to further describe the quality of findings (Table 2). Heterogenous populations and data collection methods prevented extraction and analysis of data via meta-analysis.

RESULTS

A total of 7558 articles were initially reviewed, and 20 met the inclusion criteria (Figure). The level of agreeability of the risk of bias between the 2 reviewers was 0.89, with 55% (11/20) of articles having a low risk of bias and 45% (9/20) having a moderate risk of bias (Table 3). A description of the study results can be found in Table 2. Football followed by rugby, soccer, and lacrosse were the most common sports investigated by authors (14, 3, 3, and 2 studies, respectively). There was moderate to strong strength of evidence concluding no difference between surface type (grass versus artificial) on sport-related concussion risk. Moderate to strong strength of evidence was found supporting no difference in sport-related concussion incidence based on game location (home versus away). There was no consensus on the effects of altitude or temperature on sport-related concussion incidence. One high-quality study found a decreased risk of sport-related concussion when playing in wet conditions versus dry conditions.

DISCUSSION

Overall, we found a general lack of consensus on specific weather and environmental factors that influence sport-related concussion incidence in outdoor contact sports. Often, these factors are not documented after injury intake and warrant consideration by medical personnel working with athletes who play outdoors. Unique to outdoor contact sports is exposure to variable weather, temperatures, and surface types, and although these are often nonmodifiable, understanding risk factors can facilitate more appropriate and efficient diagnosis of sport-related concussion. This information may not influence teams and organizations to cancel games or practices; however, it may better inform decisions on scheduling, location selection, and facility design to better mitigate injury.

There has been an increase in the use of artificial grass, with almost half of the National Football League (NFL) stadiums being turf,[15] and with that, a growing amount of evidence identifying an altered risk of sport-related injury depending

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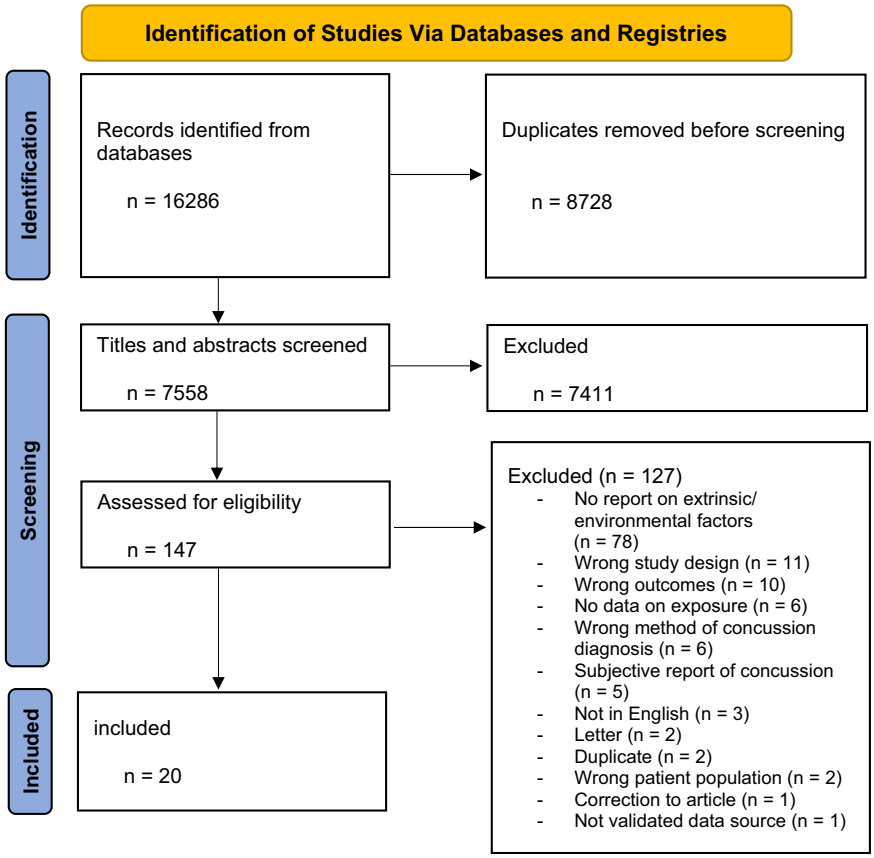

Figure. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram.

on surface type. Several studies have found an increase in knee ligamentous injury and foot and ankle injuries when playing on artificial surfaces compared with natural grass in football and rugby.[11,16,17] Balazs et al conducted a systematic review to determine the risk of anterior cruciate ligament rupture on natural grass versus artificial turf and found an increased risk of anterior cruciate ligament injuries on synthetic playing surfaces in football but not in soccer.[18] Unfortunately, many studies did not report on turf generation or age of the turf used for training and games. Unlike weather, there have been studies looking at the relationship between surface type and sport-related concussion injury risk. O'Leary et al conducted a systematic review and found no association between incidence of sport-related concussion and playing on artificial turf in soccer.[19] However, this review only included soccer as well as studies that reported "head/neck" injuries without defining concussion, which may have skewed their results There is a lack of confidence in our understanding of whether surface type may influence sport-related concussion incidence, necessitating further investigation.

Altitude is one of the few environmental factors that has been studied in relation to sport-related concussion incidence in sport; however, the body of literature is conflicting. Some authors have found a reduction in sport-related concussion injury risk when playing at a higher altitude,[20–22] but other studies have found no association between the two.[23–25] Lack of consistency in population and methodology still leaves this question up for debate. Other factors, including game location and field condition, warrant further investigation as these are unique to outdoor sports, and the environment can be much more variable and inconsistent than environments within stadiums or inside. This also warrants investigation to determine if there is a relationship between these factors and sport-related concussion.

There were limitations to our study, which should be noted. Only 4 of the articles that met the inclusion criteria included female athletes[26–29] participating in soccer and lacrosse. American football was the most common (14 studies) sport assessed. This limits the generalizability of the results to other sports and female athletes. Several studies used NFL concussion incidence data from the *FRONTLINE* "Concussion Watch,"[20,21,30–32] which has not been validated as a reliable injury surveillance database. Some injury epidemiology studies, such as, for example, articles using NFL data, did not identify or differentiate domed/indoor stadiums versus outdoor stadiums in their analysis when reporting other environmental variables of interest. Lastly, the methodology for collecting environmental and climate-specific factors was not homogenous across studies. Different ranges for altitude and what was high versus low altitude varied.[20,21,24,31,33] Binney et al recently published a study challenging the "statistical flaw" of studies creating categories of altitude as seen in the studies included in our systematic review.[34] The authors analyzed concussion rate data from the NFL during the season from 2012 to 2019 and assessed the relationship between altitude and concussion rates continuously as well as categorically as previously done to compare results. They found that the continuous plots did not demonstrate any association between sport-related concussion rate and altitude. However, when using a cutoff point (644 feet, as used in Myer et al[20]), a significant difference in sport-related concussion rate was observed. These limitations may elucidate why we were unable to find specific trends in

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Table 3. Risk of Bias Assessment of Included Studies

Component Study	Fuller et al 2010	Ekstrand et al 2011	Fuller et al 2007	Teramoto et al 2017	Smoliga et al 2017	Smith et al 2013	Ranson et al 2018	Myer et al 2014	Meyers et al 2021	Meyers et al 2019	Lynall et al 2016	Lempke et al 2021	Lawrence et al 2016	Haider et al 2018	Gibbs et al 2017	Gardner et al 2019	Dai et al 2018	Connolly et al 2018	Caswell et al 2012	Alles et al 1979
Was the study's target population a close representation of the national population in relation to relevant variables (eg, age, sex, and occupation)?	High	High	Low	High	High	Low	High	High	Low	Low	Low	Low	High	High	High	Low	High	High	High	Low
Was the sampling frame a true or close representation of the target population?	High	Low	Low	Low	Low	Low	Low	Low	Low	High	Low	High	Low	Low	High	Low	Low	Low	Low	Low
Was some form of random selection used to select the sample OR was a census undertaken?	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Was the likelihood of nonresponse bias minimal?	Low	Low	Low	High	High	Low	Low	High	Low	Low	Low	Low	Low	High	Low	Low	High	High	High	Low
Were data collected directly from the subjects (as opposed to a proxy)?	Low	Low	Low	High	High	Low	High	High	Low	Low	Low	Low	High	High	Low	Low	High	High	Low	Low
Was an acceptable case definition used in the study?	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High
Was the study instrument that measured the parameter of interest (incidence of concussion) shown to have reliability and validity (if necessary)?	High	Low	Low	High	High	Low	Low	High	Low	Low	Low	Low	Low	High	Low	Low	High	High	High	Low
Was the same mode of data collection used for all subjects?	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	Low	Low	Low	High	High	Low	Low	High	Low	Low	Low	Low	Low	High	Low	Low	High	High	Low	Low
Summary item on the overall risk of study bias	Moderate	Low	Low	Moderate	Moderate	Low	Moderate	Moderate	Low	Low	Low	Low	Low	Moderate	Low	Low	Moderate	Moderate	Moderate	Low

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sport-related concussion incidence and identify the need for consistency when defining environmental characteristics to understand their influence more accurately on sport-related concussion incidence.

Due to the lack of consensus on the influence of environmental factors on sport-related concussion incidence revealed by this systematic review, there is an opportunity to better use injury reporting systems by adding simple environment-specific data. Sport-related concussion diagnosis is challenging in the athletic environment, and understanding all potential factors that influence concussion incidence opens the door to develop more comprehensive and effective clinical decision-making for medical professionals. Nationwide injury surveillance systems may provide a fruitful opportunity to further investigate this relationship, as simple environmental and climate data could be included, such as field type, temperature, humidity, field conditions, location, and altitude. Participation in injury surveillance systems can result in a substantial sample of data to better identify trends in injury incidence in sports.[35] Further study of environmental and climate factors may motivate sports medicine decision-makers to consider changes to modifiable factors related to games and practices to improve safety and mitigate injury risk in this population.

REFERENCES

1. Zuckerman SL, Kerr ZY, Yengo-Kahn A, Wasserman E, Covassin T, Solomon GS. Epidemiology of sports-related concussion in NCAA athletes from 2009–2010 to 2013–2014: incidence, recurrence, and mechanisms. *Am J Sports Med.* 2015;43(11):2654–2662. doi:10.1177/0363546515599634
2. Rosenthal JA, Foraker RE, Collins CL, Comstock RD. National high school athlete concussion rates from 2005–2006 to 2011–2012. *Am J Sports Med.* 2014;42(7):1710–1715. doi:10.1177/0363546514530091
3. National Concussion Surveillance System. Centers for Disease Control and Prevention. Accessed August 2, 2023. https://www.cdc.gov/traumaticbraininjury/research-programs/ncss/index.html
4. Abrahams S, Fie SM, Patricios J, Posthumus M, September AV. Risk factors for sports concussion: an evidence-based systematic review. *Br J Sports Med.* 2014;48(2):91–97. doi:10.1136/bjsports-2013-092734
5. Llewellyn T, Burdette GT, Joyner AB, Buckley TA. Concussion reporting rates at the conclusion of an intercollegiate athletic career. *Clin J Sport Med.* 2014;24(1):76–79. doi:10.1097/01.jsm.0000432853.77520.3d
6. Wallace J, Covassin T, Nogle S, Gould D, Kovan J. Knowledge of concussion and reporting behaviors in high school athletes with or without access to an athletic trainer. *J Athl Train.* 2017;52(3):228–235. doi:10.4085/1062-6050-52.1.07
7. McCrory P, Meeuwisse W, Dvořák J, et al. Consensus statement on concussion in sport—the 5th International Conference on Concussion in Sport held in Berlin, October 2016. *Br J Sports Med.* 2017;51(11):838–847. doi:10.1136/bjsports-2017-097699
8. Koerte IK, Schultz V, Sydnor VJ, et al. Sex-related differences in the effects of sports-related concussion: a review. *J Neuroimaging.* 2020;30(4):387–409. doi:10.1111/jon.12726
9. Tobías A, Casals M, Saez M, Kamada M, Kim Y. Impacts of ambient temperature and seasonal changes on sports injuries in Madrid, Spain: a time-series regression analysis. *BMJ Open Sport Exerc Med.* 2021;7(4):e001205. doi:10.1136/bmjsem-2021-001205
10. Orchard JW, Powell JW. Risk of knee and ankle sprains under various weather conditions in American football. *Med Sci Sports Exerc.* 2003;35(7):1118–1123. doi:10.1249/01.MSS.0000074563.61975.9B
11. Robertson CM, Williams S, West SW, et al. Influence of playing surface on match injury risk in men's professional rugby union in England (2013–2019). *Scand J Med Sci Sports.* 2022;32(11):1615–1624. doi:10.1111/sms.14226
12. Aoki H, O'Hata N, Kohno T, Morikawa T, Seki J. A 15-year prospective epidemiological account of acute traumatic injuries during official professional soccer league matches in Japan. *Am J Sports Med.* 2012;40(5):1006–1014. doi:10.1177/0363546512438695
13. Chalmers DJ, Samaranayaka A, Gulliver P, McNoe B. Risk factors for injury in rugby union football in New Zealand: a cohort study. *Br J Sports Med.* 2012;46(2):95–102. doi:10.1136/bjsports-2011-090272
14. Hoy D, Brooks P, Woolf A, et al. Assessing risk of bias in prevalence studies: modification of an existing tool and evidence of interrater agreement. *J Clin Epidemiol.* 2012;65(9):934–939. doi:10.1016/j.jclinepi.2011.11.014
15. Molski M. Which NFL stadiums have artificial turf vs. real grass? NBC Sports Washington. Published December 20, 2021. Accessed August 2, 2023. www.nbcsports.com/washington/football-team/which-nfl-stadiums-have-artificial-turf-vs-real-grass
16. Williams S, Hume PA, Kara S. A review of football injuries on third and fourth generation artificial turfs compared with natural turf. *Sports Med.* 2011;41(11):903–923. doi:10.2165/11593190-000000000-00000
17. Loughran GJ, Vulpis CT, Murphy JP, et al. Incidence of knee injuries on artificial turf versus natural grass in National Collegiate Athletic Association American football: 2004–2005 through 2013–2014 seasons. *Am J Sports Med.* 2019;47(6):1294–1301. doi:10.1177/0363546519833925
18. Balazs GC, Pavey GJ, Brelin AM, Pickett A, Keblish DJ, Rue JP. Risk of anterior cruciate ligament injury in athletes on synthetic playing surfaces: a systematic review. *Am J Sports Med.* 2015;43(7):1798–1804. doi:10.1177/0363546514545864
19. O'Leary F, Acampora N, Hand F, O'Donovan J. Association of artificial turf and concussion in competitive contact sports: a systematic review and meta-analysis. *BMJ Open Sport Exerc Med.* 2020;6(1):e000695. doi:10.1136/bmjsem-2019-000695
20. Myer GD, Smith D, Barber Foss KD, et al. Rates of concussion are lower in National Football League games played at higher altitudes. *J Orthop Sports Phys Ther.* 2014;44(3):164–172. doi:10.2519/jospt.2014.5298
21. Connolly JG, Nathanson JT, Sobotka S, et al. Effect of playing and training at altitude on concussion incidence in professional football. *Orthop J Sports Med.* 2018;6(12):2325967118794928. doi:10.1177/2325967118794928
22. Adams R, Kaye-Kauderer HP, Haider S, Maniya AY, Sobotka S, Choudhri TF. The effects of altitude on concussion incidence in the 2013–2017 National Hockey League seasons. *Cureus.* 2018;10(5):e2681. doi:10.7759/cureus.2681
23. Li AY, Durbin JR, Hannah TC, et al. High altitude modulates concussion incidence, severity, and recovery in young athletes. *Brain Inj.* 2022;36(6):733–739. doi:10.1080/02699052.2022.2035435
24. Lynall RC, Kerr Z, Parr MS, Hackney AC, Mihalik JP. Division I college football concussion rates are higher at higher altitudes. *J Orthop Sports Phys Ther.* 2016;46(2):96–103. doi:10.2519/jospt.2016.6315
25. Zavorsky GS, Smoliga JM. Correct data and meta-analytic approaches show the reduced risk of concussion for athletes playing at higher altitudes-reply. *JAMA Neurol.* 2017;74(4):485–486. doi:10.1001/jamaneurol.2016.6068
26. Caswell SV, Lincoln AE, Almquist JL, Dunn RE, Hinton RY. Video incident analysis of head injuries in high school girls' lacrosse. *Am J Sports Med.* 2012;40(4):756–762. doi:10.1177/0363546512436647
27. Ekstrand J, Hägglund M, Fuller CW. Comparison of injuries sustained on artificial turf and grass by male and female elite football players. *Scand J Med Sci Sports.* 2011;21(6):824–832. doi:10.1111/j.1600-0838.2010.01118.x
28. Fuller CW, Dick RW, Corlette J, Schmalz R. Comparison of the incidence, nature and cause of injuries sustained on grass and new generation artificial turf by male and female football players. Part 1: match injuries. *Br J Sports Med.* 2007;41(suppl 1):i20–i26. doi:10.1136/bjsm.2007.037267
29. Lempke LB, Lynall RC, Le RK, McCrea M, McAllister T, Schmidt JD; CARE Consortium Investigators. Correction to: The effects of on-field heat index and altitude on concussion assessments and recovery

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among NCAA athletes. *Sports Med*. 2021;51(4):837. doi:10.1007/s40279-020-01425-2.
30. Teramoto M, Cushman DM, Cross CL, Curtiss HM, Willick SE. Game schedules and rate of concussions in the National Football League. *Orthop J Sports Med.* 2017;5(11):2325967117740862. doi:10.1177/2325967117740862
31. Smoliga JM, Zavorsky GS. Team logo predicts concussion risk: lessons in protecting a vulnerable sports community from misconceived, but highly publicized epidemiologic research. *Epidemiology.* 2017;28(5):753–757. doi:10.1097/EDE.0000000000000694
32. Dai JB, Li AY, Haider SF, et al. Effects of game characteristics and player positions on concussion incidence and severity in professional football. *Orthop J Sports Med.* 2018;6(12):2325967118815448. doi:10.1177/2325967118815448
33. Smith DW, Myer GD, Currie DW, Comstock RD, Clark JF, Bailes JE. Altitude modulates concussion incidence: implications for optimizing brain compliance to prevent brain injury in athletes. *Orthop J Sports Med.* 2013;1(6):2325967113511588. doi:10.1177/2325967113511588
34. Binney ZO, Smoliga JM. Bad altitude: categorizing elevation produces spurious association with concussions in the National Football League (NFL). *J Orthop Sports Phys Ther.* 2022;52(10):694–701. doi:10.2519/jospt.2022.11220
35. Chandran A, Morris SN, Wasserman EB, Boltz AJ, Collins CL. Methods of the National Collegiate Athletic Association Injury Surveillance Program, 2014–2015 through 2018–2019. *J Athl Train.* 2021;56(7):616–621. doi:10.4085/1062-6050-406-20
36. Alles WF, Powell JW, Buckley W, Hunt EE. The National Athletic Injury/Illness Reporting System 3-year findings of high school and college football injuries. *J Orthop Sports Phys Ther.* 1979;1(2):103–108. doi:10.2519/jospt.1979.1.2.103
37. Fuller CW, Clarke L, Molloy MG. Risk of injury associated with rugby union played on artif icial turf. *J Sports Sci.* 2010;28(5):563–570. doi:10.1080/02640411003629681
38. Gardner AJ, Howell DR, Iverson GL. National Rugby League match scheduling and rate of concussion. *J Sci Med Sport.* 2019;22(7):780–783. doi:10.1016/j.jsams.2019.02.003
39. Gibbs N, Watsford M. Concussion incidence and recurrence in professional Australian football match-play: a 14-year analysis. *J Sports Med (Hindawi Publ Corp).* 2017;2017:2831751. doi:10.1155/2017/2831751
40. Haider S, Kaye-Kauderer HP, Maniya AY, et al. Does the environment influence the frequency of concussion incidence in professional football? *Cureus.* 2018;10(11):e3627. doi:10.7759/cureus.3627
41. Lawrence DW, Comper P, Hutchison MG. Influence of extrinsic risk factors on National Football League injury rates. *Orthop J Sports Med.* 2016;4(3):2325967116639222. doi:10.1177/2325967116639222
42. Meyers MC. Incidence, Mechanisms, and severity of game-related high school football injuries across artificial turf systems of various infill weights. *Orthop J Sports Med.* 2019;7(3):2325967119832878. doi:10.1177/2325967119832878
43. Meyers MC. Surface-related high school football game injuries on pad and no-pad fields. *Am J Sports Med.* 2021;49(9):2489–2497. doi:10.1177/0363546521990780
44. Ranson C, George J, Rafferty J, Miles J, Moore I. Playing surface and UK professional rugby union injury risk. *J Sports Sci.* 2018;36(21):2393–2398. doi:10.1080/02640414.2018.1458588

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Appendix 1. Search Strategy

Search Strategy Report

Date of completed search: December 22, 2021.
Total number of articles (before deduplication): 16 281.
Total number of articles (after deduplication): 7562.
Database: MEDLINE (OVID)

	Search Parameters	Number
1.	(((exp Sports/ OR exp Athletes/ OR exp Athletic Injuries/ OR exp Athletic Performance/) AND (contact OR contacts OR outdoor OR outdoors OR collision OR collisions).ti,ab) OR ((athlete OR athletes OR athletic OR player OR players OR play OR sport OR sports OR competition OR competitions OR competitive OR competitively OR "physical activity" OR "physical activities") adj3 (contact OR contacts OR outdoor OR outdoors OR collision OR collisions)).ti,ab. OR (exp Baseball/ OR exp Cricket Sport/ OR exp Football/ OR exp Marathon Running/ OR exp Mountaineering/ OR exp Racquet Sports/ OR exp Running/ OR exp Skating/ OR exp Skiing/ OR exp Snow Sports/ OR exp Soccer/ OR exp Tennis/ OR exp Team Sports/ OR exp Track and Field/ OR exp Volleyball/) OR (baseball OR cheerleading OR cheerleader OR cheerleaders OR climbing OR climber OR climbers OR cricket OR football OR handball OR hockey OR lacrosse OR marathon OR marathons OR marathoner OR marathoners OR mountaineering OR mountaineer OR mountaineers OR multisport OR pentathlon OR pentathlons OR pentathloner OR pentathloners OR rugby OR skating OR skater OR skaters OR skiing OR skier OR skiers OR snowboarding OR snowboarder OR snowboarders OR soccer OR softball OR squash OR surfing OR surfer OR surfers OR tennis OR triathlon OR triathlons OR triathloner OR triathloners OR volleyball OR NCAA OR NFL OR FIFA OR NBL OR NICA OR USASA OR NVA OR NBA OR Olympic OR Olympics OR superbowl OR superbowls OR "world cup" OR "world cups").ti,ab.)	77 873
2.	exp Brain Concussion/ OR brain injuries/ OR brain injuries, traumatic/ OR (concussion OR concussions OR concussed OR "mild traumatic brain injury" OR "mild traumatic brain injuries" OR MTBI OR MTBIs OR "head injury" OR "head injuries" OR "brain injury" OR "brain injuries").ti,ab	121 952
3.	1 AND 2	3808
4.	3 not (case reports OR editorial OR letter).pt.	3546

Database: Embase (Elsevier)
Note: all searches were conducted in the "results" tab.

	Search Parameters	Number
1.	(('sport'/exp OR 'athlete'/exp OR 'sport injury'/exp OR 'athletic performance'/exp) AND (contact OR contacts OR outdoor OR outdoors OR collision OR collisions):ti,ab) OR ((athlete OR athletes OR athletic OR player OR players OR play OR sport OR sports OR competition OR competitions OR competitive OR competitively OR 'physical activity' OR 'physical activities') NEAR/3 (contact OR contacts OR outdoor OR outdoors OR collision OR collisions)):ti,ab OR ('baseball'/exp OR 'cricket (sport)'/exp OR 'football'/exp OR 'football player'/exp OR 'marathon running'/exp OR 'mountaineering'/exp OR 'racquet sport'/exp OR 'running'/exp OR 'skating'/exp OR 'skiing'/exp OR 'winter sport'/exp OR 'soccer'/exp OR 'soccer player'/exp OR 'tennis'/exp OR 'team sport'/exp OR 'track and field'/exp OR 'volleyball'/exp) OR (baseball OR cheerleading OR cheerleader OR cheerleaders OR climbing OR climber OR climbers OR cricket OR football OR handball OR hockey OR lacrosse OR marathon OR marathons OR marathoner OR marathoners OR mountaineering OR mountaineer OR mountaineers OR multisport OR pentathlon OR pentathlons OR pentathloner OR pentathloners OR rugby OR skating OR skater OR skaters OR skiing OR skier OR skiers OR snowboarding OR snowboarder OR snowboarders OR soccer OR softball OR squash OR surfing OR surfer OR surfers OR tennis OR triathlon OR triathlons OR triathloner OR triathloners OR volleyball OR NCAA OR NFL OR FIFA OR NBL OR NICA OR USASA OR NVA OR NBA OR Olympic OR Olympics OR superbowl OR superbowls OR 'world cup' OR 'world cups'):ti,ab	132 075
2.	'brain concussion'/exp OR 'traumatic brain injury'/de OR (concussion OR concussions OR concussed OR 'mild traumatic brain injury' OR 'mild traumatic brain injuries' OR MTBI OR MTBIs OR 'head injury' OR 'head injuries' OR 'brain injury' OR 'brain injuries'):ti,ab	150 767
3.	1 AND 2	5605
4.	3 not ('case report'/exp OR 'case study'/exp OR 'editorial'/exp OR [editorial]/lim OR 'letter'/exp OR [letter]/lim OR 'note'/exp OR [note]/lim OR [conference abstract]/lim OR 'conference abstract'/exp OR 'conference abstract'/it)	3589

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Database: CINAHL Complete (EBSCOhost)

	Search Parameters	Number
1.	(((MH "Sports+" OR MH "Athletes+" OR MH "Athletic Injuries+") AND (TI (contact OR contacts OR outdoor OR outdoors OR collision OR collisions) OR AB (contact OR contacts OR outdoor OR outdoors OR collision OR collisions))) OR ((TI (athlete OR athletes OR athletic OR player OR players OR play OR sport OR sports OR competition OR competitions OR competitive OR competitively OR "physical activity" OR "physical activities") N3 (contact OR contacts OR outdoor OR outdoors OR collision OR collisions)) OR AB (athlete OR athletes OR athletic OR player OR players OR play OR sport OR sports OR competition OR competitions OR competitive OR competitively OR "physical activity" OR "physical activities") N3 (contact OR contacts OR outdoor OR outdoors OR collision OR collisions)) OR (MH "Contact Sports" OR MH "Football" OR MH "Rugby" OR MH "Sports" OR MH "Caving" OR MH "College Sports" OR MH "Extreme Sports" OR MH "Handball" OR MH "Mountaineering" OR MH "Professional Sports" OR MH "Racquet Sports+" OR MH "Tennis" OR MH "Rock Climbing" OR MH "Skating+" OR MH "Skateboarding" OR MH "Skiing+" OR MH "Sports, Disabled+" OR MH "Sports Re-Entry" OR MH "Team Sports+" OR MH "Winter Sports+" OR MH "Hockey" OR MH "Snow Skiing+" OR MH "Snowboarding") OR TI (baseball OR cheerleading OR cheerleader OR cheerleaders OR climbing OR climber OR climbers OR cricket OR football OR handball OR hockey OR lacrosse OR marathon OR marathons OR marathoner OR marathoners OR mountaineering OR mountaineer OR mountaineers OR multisport OR pentathlon OR pentathlons OR pentathloner OR pentathloners OR rugby OR skating OR skater OR skaters OR skiing OR skier OR skiers OR snowboarding OR snowboarder OR snowboarders OR soccer OR softball OR squash OR surfing OR surfer OR surfers OR tennis OR triathlon OR triathlons OR triathloner OR triathloners OR volleyball OR NCAA OR NFL OR FIFA OR NBL OR NICA OR USASA OR NVA OR NBA OR Olympic OR Olympics OR superbowl OR superbowls OR "world cup" OR "world cups") OR AB (baseball OR cheerleading OR cheerleader OR cheerleaders OR climbing OR climber OR climbers OR cricket OR football OR handball OR hockey OR lacrosse OR marathon OR marathons OR marathoner OR marathoners OR mountaineering OR mountaineer OR mountaineers OR multisport OR pentathlon OR pentathlons OR pentathloner OR pentathloners OR rugby OR skating OR skater OR skaters OR skiing OR skier OR skiers OR snowboarding OR snowboarder OR snowboarders OR soccer OR softball OR squash OR surfing OR surfer OR surfers OR tennis OR triathlon OR triathlons OR triathloner OR triathloners OR volleyball OR NCAA OR NFL OR FIFA OR NBL OR NICA OR USASA OR NVA OR NBA OR Olympic OR Olympics OR superbowl OR superbowls OR "world cup" OR "world cups"))	59 184
2.	MH "Brain Concussion+" OR MH "Brain Injuries" OR TI(concussion OR concussions OR concussed OR "mild traumatic brain injury" OR "mild traumatic brain injuries" OR MTBI OR MTBIs OR "head injury" OR "head injuries" OR "brain injury" OR "brain injuries") OR AB(concussion OR concussions OR concussed OR "mild traumatic brain injury" OR "mild traumatic brain injuries" OR MTBI OR MTBIs OR "head injury" OR "head injuries" OR "brain injury" OR "brain injuries")	45 171
3.	1 AND 2	2983

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Database: SPORTDiscus (EBSCOhost)

	Search Parameters	Number
1.	((DE “SPORTS” OR DE “AERODYNAMICS in sports” OR DE “AERONAUTICAL sports” OR DE “AMATEUR sports” OR DE “BALL games” OR DE “COLLEGE sports” OR DE “COMBAT sports” OR DE “ENDURANCE sports” OR DE “EXTREME sports” DE “INDIVIDUAL sports” OR DE “MILITARY sports” OR DE “OLYMPIC Games” OR DE “SCHOOL sports” OR DE “SENIOR Olympics” OR DE “SPORTS for children” OR DE “SPORTS for girls” OR DE “SPORTS for older people” OR DE “SPORTS for people with disabilities” OR DE “SPORTS for youth” OR DE “SPORTS teams” OR DE “TEAM sports” OR DE “TEAMWORK (Sports)” OR DE “VIOLENCE in sports” OR DE “WOMEN’S sports”) AND (TI (contact OR contacts OR outdoor OR outdoors OR collision OR collisions) OR AB(contact OR contacts OR outdoor OR outdoors OR collision OR collisions))) OR TI ((athlete OR athletes OR athletic OR player OR players OR play OR sport OR sports OR competition OR competitions OR competitive OR competitively OR “physical activity” OR “physical activities”) N3 (contact OR contacts OR outdoor OR outdoors OR collision OR collisions)) OR AB((athlete OR athletes OR athletic OR player OR players OR play OR sport OR sports OR competition OR competitions OR competitive OR competitively OR “physical activity” OR “physical activities”) adj3 (contact OR contacts OR outdoor OR outdoors OR collision OR collisions)) **OR** DE “BALL games” OR DE “BASEBALL” OR DE “CONTACT sports” OR DE “EXTREME sports” DE “HOCKEY” OR DE “OLYMPIC Games” OR DE “PROFESSIONAL sports” OR DE “RACKET games” OR DE “ROLLER skating” OR DE “SENIOR Olympics” OR DE “SKATEBOARDING” OR DE “SOFTBALL” OR DE “TEAM sports” OR DE “WINTER sports” OR TI (baseball OR cheerleading OR cheerleader OR cheerleaders OR climbing OR climber OR climbers OR cricket OR football OR handball OR hockey OR lacrosse OR marathon OR marathons OR marathoner OR marathoners OR mountaineering OR mountaineer OR mountaineers OR multisport OR pentathlon OR pentathlons OR pentathloner OR pentathloners OR rugby OR skating OR skater OR skaters OR skiing OR skier OR skiers OR snowboarding OR snowboarder OR snowboarders OR soccer OR softball OR squash OR surfing OR surfer OR surfers OR tennis OR triathlon OR triathlons OR triathloner OR triathloners OR volleyball OR NCAA OR NFL OR FIFA OR NBL OR NICA OR USASA OR NVA OR NBA OR Olympic OR Olympics OR superbowl OR superbowls OR “world cup” OR “world cups”) OR AB (baseball OR cheerleading OR cheerleader OR cheerleaders OR climbing OR climber OR climbers OR cricket OR football OR handball OR hockey OR lacrosse OR marathon OR marathons OR marathoner OR marathoners OR mountaineering OR mountaineer OR mountaineers OR multisport OR pentathlon OR pentathlons OR pentathloner OR pentathloners OR rugby OR skating OR skater OR skaters OR skiing OR skier OR skiers OR snowboarding OR snowboarder OR snowboarders OR soccer OR softball OR squash OR surfing OR surfer OR surfers OR tennis OR triathlon OR triathlons OR triathloner OR triathloners OR volleyball OR NCAA OR NFL OR FIFA OR NBL OR NICA OR USASA OR NVA OR NBA OR Olympic OR Olympics OR superbowl OR superbowls OR “world cup” OR “world cups”)	497 134
2.	DE “BRAIN concussion” OR DE “POSTCONCUSSION syndrome” OR TI (concussion OR concussions OR concussed OR “mild traumatic brain injury” OR “mild traumatic brain injuries” OR MTBI OR MTBIs OR “head injury” OR “head injuries” OR “brain injury” OR “brain injuries”) OR AB (concussion OR concussions OR concussed OR “mild traumatic brain injury” OR “mild traumatic brain injuries” OR MTBI OR MTBIs OR “head injury” OR “head injuries” OR “brain injury” OR “brain injuries”)	12 134
3.	1 AND 2	2872

Database: Scopus (Elsevier)

	Search Parameters	Number
1.	TITLE-ABS((athlete OR athletes OR athletic OR player OR players OR play OR sport OR sports OR competition OR competitions OR competitive OR competitively) W/3 (contact OR contacts OR outdoor OR outdoors OR collision OR collisions)) OR TITLE-ABS(({physical activity} OR {physical activities}) AND (contact OR contacts OR outdoor OR outdoors OR collision OR collisions)) OR TITLE-ABS(baseball OR cheerleading OR cheerleader OR cheerleaders OR climbing OR climber OR climbers OR cricket OR football OR handball OR hockey OR lacrosse OR marathon OR marathons OR marathoner OR marathoners OR mountaineering OR mountaineer OR mountaineers OR multisport OR pentathlon OR pentathlons OR pentathloner OR pentathloners OR rugby OR skating OR skater OR skaters OR skiing OR skier OR skiers OR snowboarding OR snowboarder OR snowboarders OR soccer OR softball OR squash OR surfing OR surfer OR surfers OR tennis OR triathlon OR triathlons OR triathloner OR triathloners OR volleyball OR NCAA OR NFL OR FIFA OR NBL OR NICA OR USASA OR NVA OR NBA OR Olympic OR Olympics OR superbowl OR superbowls OR {world cup} OR {world cups})	195 080
2.	TITLE-ABS(concussion OR concussions OR concussed OR {mild traumatic brain injury} OR {mild traumatic brain injuries} OR MTBI OR MTBIs OR {head injury} OR {head injuries} OR {brain injury} OR {brain injuries})	116 092
3.	1 AND 2	3800
4.	Selected publication types: article, review	3291

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