

Twitter and traumatic brain injury: A content and sentiment analysis of tweets pertaining to sport-related brain injury

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Abstract

Objectives: Sport-related traumatic brain injuries are a significant public health burden, with hundreds of thousands sustained annually in North America. While sports offer numerous physical and social health benefits, traumatic brain injuries such as concussion can seriously impact a player's life, athletic career, and sport enjoyment. The culture in many sports encourages winning at all costs, placing athletes at risk for traumatic brain injuries. As social media has become a central part of everyday life, the content of users' messages often reflects the prevailing culture related to a particular event or health issue.

Methods: We hypothesized that Twitter data might be useful for understanding public perceptions and misperceptions of sport-related traumatic brain injuries. We performed a content and sentiment analysis of 7483 Twitter® tweets related to traumatic brain injuries in sports collected during June and July 2013.

Results: We identified five major themes. Users tweeted about personal traumatic brain injuries experiences, reported traumatic brain injuries in professional athletes, shared research about sport-related concussions, and discussed policy and safety in injury prevention, such as helmet use. We identified mixed perceptions of and sentiment toward traumatic brain injuries in sports: both an understanding that brain injuries are serious and disregard for activities that might reduce the public burden of traumatic brain injuries were prevalent in our Twitter analysis.

Conclusion: While the scientific and medical community considers a concussion a form of traumatic brain injuries, our study demonstrates a misunderstanding of this fact among the public. In our current digital age, social media can provide useful insight into the culture around a health issue, facilitating implementation of prevention and treatment strategies.

Keywords

Concussion, traumatic brain injury, sport-related traumatic brain injuries, Twitter, social media

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Introduction

The Centers for Disease Control and Prevention (CDC) estimate that approximately 2.5 million traumatic brain injuries (TBIs) were sustained in the United States in 2010 either as isolated head injuries or concurrent with another injury, resulting in emergency department (ED) visits, hospitalizations, or death.¹ These numbers are likely underestimations given the under-reporting of TBIs by those who have sustained them.^{2,3} Moreover, between 2001 and 2012, about 3.42 million ED visits were made for sports or recreation-related TBIs,⁴ and between 2001 and 2009, there was a 62% increase in ED visits by children for sports and recreation-related TBIs.⁵ Given the incidence of TBI and the potentially long-lasting consequences in terms of health

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and social functioning, it has become a public health problem of major concern.⁶

While there is an increasing appreciation among health professionals, public health organizations, and legislative bodies that TBI in sports is a public health concern,⁶ the extent to which our society promotes practices that propagate the problem or diminish the problem is less clear. Understanding the culture around TBI may shed light on the broader societal perspective and understanding that perspective might facilitate specific interventions to diminish the problem. Improving our understanding could help direct future efforts at prevention in fields like sport-related TBI, a major cause of TBI, particularly in youth and childhood. Gaining this level of understanding would mean improving our knowledge related to TBI, as well as the practices and behaviors carried out in response to TBIs as a society. Opinions and reactions toward TBI, as reflected in the discourse between people, reflect the culture surrounding TBI in fields like sports. These opinions and reactions can be disseminated rapidly and widely through a variety of means that include social media.

Online communication media, like social media, encompass largely limitless tools for communication of information and personal perspectives. Because of their ubiquitous availability, the public is both subject to and can influence each other's opinions, including those on health-related subjects. Modern society is living in a digital age,⁷ and social media platforms can serve as useful avenues for understanding today's culture. Therefore, studying social media content has the potential to elucidate general attitudes toward brain injuries in sports. Consequently, understanding the public perception of sport-related TBI through social media can provide better insight into the concussion culture in sports and can inform prevention and treatment policies and practices.

Twitter[®] is a social networking site that provides users with real-time information about current events, news, opinions, and ideas in the form of a 140-character piece of text called a "tweet."⁸ It is free and public, allowing anyone with Internet access to create a Twitter account for seeing and sending "tweets." Information can be communicated over Twitter in multiple forms aside from original messages. A "retweet" (RT) is when a user's original content is being tweeted by another user (e.g. RT [original tweet content]).⁸ A "modified tweet" (MT) means the original content is retweeted with added or altered content (e.g. MT [comment] [original tweet content]). Tweets can also be directed at specific Twitter users with the "@" symbol (e.g. @[user]) and a "hashtag" (#) can be used in front of a word or phrase with the purpose identifying tweets by content and theme (e.g. #[phrase]).

An increasing number of individuals across various demographics are using Twitter, including 23% of the Internet-using adult population.⁷ Generating approximately 200 million tweets per day,⁹ Twitter is a global tool for communication and content sharing. Previous studies using Twitter centered around its potential use as an educational tool,^{10,11} while other

research has been conducted on the content of information disseminated over Twitter on a variety of health topics.¹²⁻¹⁶

The analyses presented in this article used Twitter as a source of publicly disseminated information to gauge the current culture of TBI in sports. Qualitative analysis of tweets pertaining to sport-related TBI with the purpose of discerning themes in content and sentiment toward TBI sustained by athletes was carried out. Our goal was to gain an understanding of the culture surrounding TBI and concussion in sports.

Methods

Search strategy and data collection

We carried out a qualitative analysis of publicly available tweets on Twitter. Tweets were collected electronically using NVivo by QSR International[®], a computer program developed for qualitative research.¹⁰ In order to acquire the tweets, we first searched keywords using the Twitter search engine and then downloaded the results through NCapture, an NVivo plugin. Both scientific and colloquial terms were searched because as Twitter users vary in age, professional, and cultural backgrounds, both are likely to be used by tweeters. Scientific terms included words used by medical professionals or in medical fields to describe TBI (e.g. "traumatic brain injury"), while colloquial terms comprised words used to refer to TBI in an informal conversation setting among the general population (e.g. "banged up"). Search terms were chosen and agreed upon by first author (A.M.W.) and second author (M.C.M.) after reviewing tweets collected from preliminary searches of scientific and colloquial brain injury terminology.

Because the Twitter search engine does not have a truncation function, derivatives of certain terms were searched individually. The following 18 scientific search terms were used: "concussion," "concussions," "brain injury," "brain injuries," "head injury," "head injuries," "brain trauma," "brain traumas," "head trauma," "head traumas," "knocked unconscious," "loss of consciousness," "lost consciousness," "concuss," "concussed," "concussive," "MTBI," and "TBI." The following 23 colloquial search terms were used: "into the boards," "puck to the head," "shot to the head," "shoulder to the head," "stick to the head," "pancaked," "stinger," "ball to the head," "banged up," "blow to the head," "check to the head," "clock cleaned," "drop the gloves," "elbow to the head," "get nailed," "get dinged," "head butt," "bell rung," "hit to the head," "out cold," "sacked," "knocked out," and "table-topped." The "hash tagged" forms of these terms (e.g. #concussion, #outcold) were also searched.

We collected tweets daily from 9 June to 9 July 2013. Given the goal to represent all age groups, societal, and occupational statuses, Twitter users were not limited in any way. However, tweets that did not refer to brain injury in sport, were not written in English, or used the search terms out of study context (e.g. misspelled "confusion" as "concussion") were eliminated. Tweets containing colloquial search terms

Table 1. Definition of terms used to code tweet sentiment toward brain injury.

Sentiment	Definition	Example tweet
Recognition	Demonstrates an understanding that TBI is a serious health condition	RT@[user]: Playing on with a concussion isn't big or brave, it's sheer stupidity. (#lions)
Neglect	Disregard for, lack of concern for, or lack of understanding of TBI	I'm so glad Silva got his bell rung
Neutrality	Indifferent or impartial attitude toward TBI, or no clear affect regarding TBI in sports	Toews is definitely concussed

TBI: traumatic brain injury.

such as “banged up” or “stinger” that were referring to an injury other than a head injury were eliminated. If it was unclear whether the tweet was referring to a head injury, it was eliminated.

Coding strategy

Tweets mined with scientific and colloquial search terms were exported into separate Microsoft® Office Excel 2011 spreadsheets for analysis and coded for two variables: user sentiment and tweet content. Tweets were coded as portraying one of three sentiments toward brain injury: “Recognition,” “Neglect,” or “Neutrality” toward TBI in sports. Each sentiment is defined in Table 1.

The tweets (n=7483) were analyzed using a grounded-theory framework in which subthemes and themes were allowed to organically emerge from the data, rather than be directed by a pre-determined hypothesis.¹⁷ Following this framework, a piece of text is evaluated for a meaningful unit or code: information that describes and summarizes the key content of that text.¹⁸ These units are applied to subsequent pieces of text to describe, or “code,” their content.¹⁹ Analyzing tweet content began with both coders (A.M.W. and M.C.M.) independently summarizing the main intent or message conveyed by each tweet from the same sample of 200 randomly selected tweets from both scientific and colloquial data sets. This process allowed each coder to separately generate a preliminary set of content codes. The coders subsequently compared their respective lists and revised them into codes with mutual phrasing, developing a standardized list of content codes. Both members independently coded the remaining tweets using this list. The content codes were organized into categories, which were sorted into subthemes and larger themes.

Coders regularly met to evaluate coding discrepancies. On occasions where tweets did not fit under any of the established codes, both coders agreed upon a new code, which was incorporated into the appropriate subtheme and theme by comparing it to previously sorted codes. Coder agreement

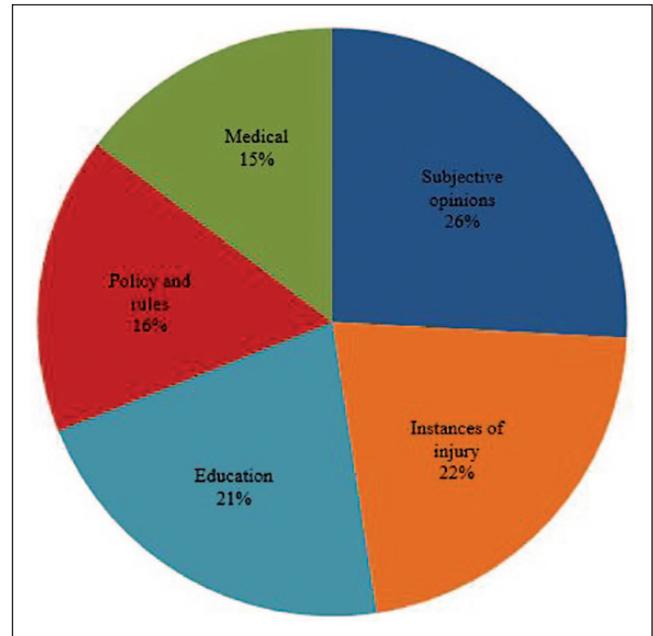


Figure 1. Percentage of total tweets classified in each of the 5 emerged themes.

was confirmed by determining inter-rater reliability across each variable (chance-corrected Cohen's kappa scores were 0.93 and 0.91 for sentiment and content, respectively).

Results

Using 41 search terms, 291,806 tweets were generated. For feasibility, a 25% sample of tweets was selected using a random number generator for a sample of 72,952 tweets. Tweets were manually filtered to select only those including the specific mention of a head injury occurring in a sport, leaving 7483 tweets as the final study cohort. Scientific and colloquial search terms generated 6215 and 1268 tweets, respectively. A total of 110 content codes were applied to the tweets. The codes were each categorized into subthemes (n=13), which were subsequently classified under broader themes (n=5) (Figure 1, Table 2).

Content analysis

The following five themes and corresponding subthemes emerged from our content analysis.

Subjective opinions. The predominant theme to emerge was “Subjective opinions” (25.8%, n=1934) (Table 2). This theme encompassed tweets in which the primary content was an explicit or very clear expression of the user's personal opinion on head injury in sports.

Of these tweets, 63.1% (n=1221) were classified under the subtheme “Demonstrates awareness of brain injury severity.” Tweets in this subtheme expressed clearly or explicitly that

Table 2. Themes and their respective subthemes, identified during the coding process.

Theme (n)	Subtheme (n)	Description	Example tweets
Subjective opinions (1934)	Demonstrates awareness of brain injury severity (1221)	Condemning violence in sports and concussions as a factor in an athlete's career	How much violence are we willing to put up with, how many concussed children are worth it for a sport? [link]
	"Part of the game" attitude toward brain injury (713)	Encouraging an athlete to play through a head injury, condoning hits to the head as part of the sport	@[user] is seriously concussed. But he's playing!! (#becauseitsthecup)
Instances of injury (1627)	Reporting occurrence of brain injury (1521)	Reporting brain injuries sustained personally or by other athletes	@[user] Went up to intercept the ball wasn't looking, caught a shoulder to the head. Knocked out unconscious for a few seconds
	Mechanism of brain injury (106)	Illegal and accidental causes of brain injuries	Alex Cobb Sustains Scary Head Injury After Being hit with Line Drive [link]. (#MLB #BreakingNews)
Education (1600)	Brain injury research (767)	Causes, long-term effects, and prevention of brain injury	Pittsburgh #concussion study indicates it's better to teach safe tackling in practice rather than limit contact [link]
	Providing information about brain injury (363)	Informal information about head injuries, queries, and statistics on TBI occurrence	Keeping our parents informed and our student-athletes safe! A Parent's Guide to Concussion [link]. (#DCAthletesRock!)
	Increasing public awareness of brain injury severity (470)	Raising TBI awareness (e.g. by describing an injured athlete's experience with concussion)	If Chris Stewart doesn't have a concussion I'd be surprised. Concussions for catchers need to get more attention. Like they do in the NFL
Policy and rules (1223)	Consequence of inflicting brain injury (62)	Play suspensions, fines, and bans enforced for inflicting a head injury	Well boychuk will get fined for that hit to the head
	Legal action surrounding brain injury (145)	Law suits, monetary compensation for concussed athletes	Judge Orders Mediation Between NFL, Players Suing Over Head Injuries. #Seahawks [link]
	Safety and law enforcement during play (1016)	Concussion guidelines, following injury prevention protocol (e.g. helmet use) during play, treatment protocol	New rules coming this fall to the @NFL in regards to #concussion #prevention
Medical (1099)	Brain injury treatment (149)	Emergency department visits, rehabilitation, or hospitalization for concussion treatment	Bergie went to the hospital. For observation. Concussed? I hope not soooo much
	Brain injury diagnosis and detection (716)	Concussion tests or technology to diagnose athletes of concussion	Included among unnecessary CT scans are those for sport-related concussion, yet ordered by 72% of neurologists! [link]
	Brain injury symptoms (234)	Mild to severe symptoms of head injury (e.g. headaches, seizures) and behavioral changes	That injury to Perk really worries me. The way he stumbled and fell over when he tried to get up makes it look like a concussion

Number of tweets per theme and subtheme and descriptions that classified them. All tweets (n=7483) were assigned a code (n=110), which were each sorted into one of the above themes.

brain injuries are severe, often stating concern and support for concussed athletes or condemning injured athletes who continued to play through their injuries:

#winitforshaw RT @[user]: Be careful out there, Shaw. Head injuries are nothing to mess with. (#blackhawks)

@[user] like Toews getting his "bell rung" and staying on the bench? We all admire the courage but the NHL needs to get serious soon.

Tweets within this subtheme also highlighted the impact of brain injuries as a factor in an athlete's career:

@[user] I'd never sign a player with a back or head injury history.

@[user] Scrivins is 27, Reimer is one hit to the head away from retirement. Good move leafs.

The other 713 (36.9%) of tweets fit under the subtheme "Part of the game" attitude toward brain injury," downplaying

TBI severity and often viewing brain injuries as a normal feature in sports or encouraging head injuries in game strategy:

It's [hockey]. People get hurt. Sometime bones break, sometimes concussed, sometimes you bleed. Play on.

I've had a mild concussion alex cobb is gonna be fine.

I would thoroughly enjoy seeing #Marchand getting elbowed in the head and being knocked out cold! (#63 #rat)

The majority of tweets within the "Subjective opinions" theme demonstrated a recognition of brain injury severity (47.2%, n=914):

Also: I hate cutesy discussion of brain injuries. "Bell rung." "Eggs scrambled." Seriously. It's a BRAIN INJURY. (#hockey #StanleyCup)

I've read that 90% of Boxers suffer brain injury. If that's even close to accurate UFC should be stopped immediately.

However, a large number demonstrated (37.5%, n=726) showed disregard for head injury severity:

It p****me off when peopl tell usto be carefulwhen playing footballBecause of concussions theydont understand itsa risk forthe game we love.

Instances of brain injury. The second most common theme was "Instances of brain injury" (21.7%, n=1627). This theme comprised tweets which reported and discussed injuries sustained by athletes, Twitter users' personally sustained injuries, and the means by which these head injuries occurred. Within this theme, 93.5% (n=1521) of tweets were categorized into the subtheme "Reporting occurrence of brain injury." Users reported the incidence of personal head injuries, concussed professional or youth athletes, individual athletes with multiple head injuries, and loss of consciousness as a result of TBI:

But I think I might actually have a concussion.

Brian Toomey is feared to have suffered serious head injuries in a crashing fall at Perth—[link]. (#horseracing)

The other 6.5% (n=106) of tweets fell under the subtheme "Mechanism of brain injury," whereby users primarily reported a means by which brain injuries are sustained:

Worried for Cobb from Tampa Bay. Took a shot to the head off a hit from his pitch. (#royals #tampabay #cobb)

Got a slapshot to the head with no helmet, got the biggest headache.

Of the tweets in this theme, 15.4% (n=250) showed recognition of brain injury severity:

Lealiifano out cold and being stretchered off the field. Unfortunate way to make your debut. Hope he's ok.

About 12.0% (n=195) showed neglect for brain injury severity:

High chance that I'm concussed after that game getting 3 foul balls off the face. (#ohwell)

Education. The third theme was "Education" (21.4%, n=1600) and comprised tweets that shared knowledge or attempted to inform others about brain injuries. The subtheme "Brain injury research" comprised 47.9% (n=767) tweets. These tweets commented on or shared links to research regarding the causes and occurrence of TBI, long-term effects and recovery time, and research supporting prevention guideline improvements:

Brain abnormalities, memory loss found among sports players who head-butt ball: [link].

Did you know? 39% of catastrophic head injuries happen to kids playing with concussion. (#LearnTheRisks)

A second subtheme, "Increasing public awareness of brain injury severity," consisted of 29.4% (n=470) of tweets. Tweets reflecting increased awareness of TBI by stressing the importance of safety during sports and providing profiles of professional athletes with life-changing concussions reflect this subtheme:

@[user] @[user] They seem 2 avoid using the word concussion at all costs now. It sucks to stand down players but safety is key.

Clinton Portis Says He Played Through Concussions "All the Time" During #NFL Career [link].

The remaining 22.7% (n=363) were included in the subtheme "Providing information about brain injury." This information included prevention and management techniques:

Getting your "bell rung"=concussion. (#HockeyTerm)

To prevent brain damage, soccer players should keep "head counts"—Los Angeles Times [link].

The majority of tweets in this theme demonstrated recognition of brain injury severity (76.4%, n=1222):

Did you know that approximately 50,000 brain injuries are reported each year in Canada? (#stopconcussions #playsafe)

Only 0.8% (n=13) of tweets in this theme showed disregard for brain injury severity:

Lolll heading a ball in soccer is said to give you the same effect as a concussion lol if they take it out of the game i will reallly lol.

Policy and rules. Tweets pertaining to the theme "Policy and rules" (16.3%, n=1223) were concerned with sport protocols and guidelines relating to TBI prevention and management.

Most tweets were classified within the subtheme “Safety and law enforcement during play” (83.1%, n=1016). Users reported improvements in TBI prevention policy, enforcement of concussion-prevention protocol during play, and the use of protective gear such as helmets:

Oregon passes new law protecting child athletes from #concussions #TBI #PlayerMD [link].

Godsaake Shaw! Put your helmet back on! Did you not learn after getting knocked out from a puck to the head!? (#StanleyCup #Game6 #NHL)

The subtheme “Legal action surrounding brain injury” included 11.9% (n=145) of tweets in which users discussed compensation provided to concussed athletes, predominantly for retired professional American football players suing the National Football League (NFL) over concussions sustained during their careers:

Thousands of Former NFL players Sue League over Brain Injuries [link].

Jury Verdict of the Week: \$11.5M awarded to player for head injury during high school football practice [link].

The remaining 5.1% (n=62) of tweets were part of the subtheme “Consequence of inflicting brain injury.” These tweets suggested that there should be some form of punishment for inflicting injury including fines, play suspensions, and in-game penalties, such as yellow cards:

If the @NHLBlackhawks withheld Toews from going in the “quiet room” to rule out a diagnosis of a concussion there will be hefty fines to pay.

After re-watching that hit on Toews, #NHL needs to suspend Boychuk for that obvious elbow to the head.

Most tweets pertaining to “Policy and rules” demonstrated recognition of brain injury severity (48.8%, n=597):

After re-watching that hit on Tows, #NHL needs to suspend Boychuck for that obvious elbow to the head.

“if in doubt, sit it out!” New guidelines for sports #concussions [link].

About 105 (8.6%) tweets within this theme showed disregard for injury severity:

I have a concussion. Not supposed to b riding my horse. But I am! Wutever. (#idc)

Medical. The final theme was “Medical” (14.7%, n=1099) and incorporated tweets relating to the healthcare of head injuries. The majority of tweets in this theme were part of the

subtheme “Brain injury diagnosis and detection” (65.2%, n=716). They reported new diagnostic techniques such as helmet sensors for injury detection, the performance of concussion tests for clearance of head injury, or discussed head injury diagnosis and clearance to play by a medical professional:

A Wearable Alert to Head Injuries in Sports [link].

New devices can warn the sidelines when an athlete has taken a potentially serious hit to the head [link].

Red Sox catcher David Ross to see concussion specialist [link] via @[user].

The “Brain injury symptoms” subtheme included 21.3% (n=234) of tweets and reported clinical indications of TBI ranging in severity from bruising and headaches to death:

Head is still pounding from hitting it against the goal post while diving during yesterday’s game. Feeling all the symptoms of a concussion.

Brandon McCarthy suffers seizure related to last season’s head injury [link].

Finally, the remaining 13.6% (n=149) of tweets were part of the subtheme “Brain injury treatment” and included tweets about hospitalizations or emergency room visits for TBI:

Female boxer Frida Wallberg hospitalized following brutal KO loss to Diana Prazak [link].

Seven stitches for Oburu: Wilson Oburu has been released from hospital after suffering a concussion on Sunday ... [link].

While most tweets in the “Medical” theme showed neutral sentiment toward brain injury in sport (59.1%, n=650), 39.2% (n=431) showed an appreciation for brain injury severity:

Back to the doctor, hoping she clears me to play from my concussion! (#ivebeenplaying #andlifting #hardo)

@[user] It is proved that a head injury can cause epilepsy. You may want to speak to your doctor before continuing with this sport.

A minority of tweets in this theme (1.6%, n=18) demonstrated disregard for brain injury severity:

RT @[user]: Alex Cobb’s doctors say tests came back normal. Just a mild concussion? Dude’s tough enough to play hockey. (#rays #lightning)

Overall, of the 7483 tweets in the total study cohort, 40.3% (n=3012) were devoid of sentiment toward sport-related TBI (“Neutrality”), 46.6% (n=3360) of tweets were coded under the “Recognition” sentiment, displaying the

Table 3. Comparison of number of tweets per sentiment between tweets using scientific compared to colloquial terminology to refer to brain injury (N=7483).

Search term category	Recognition	Neutrality	Disregard
Colloquial	376	633	259
Scientific	3038	2379	798

All tweets were generated using colloquial search terms (n = 1268) and scientific search terms (n = 6215) were coded under one of the above sentiments ($\chi^2 = 163.72$, $p < 0.001$).

Table 4. Comparison of number of tweets per sentiment among scientific search terms (N = 6215).

Scientific search term	Recognition	Neutrality	Disregard
Brain or head injury or injuries	1130	635	90
Brain or head trauma or traumas	60	52	10
Concussion or concussions	1592	1484	570
Concussed or concussive or concuss	136	102	116
Knocked unconscious or loss of consciousness or lost consciousness	28	65	11
TBI or MTBI	92	41	1

TBI: traumatic brain injury; MTBI: mild traumatic brain injury. ($\chi^2 = 386.17$, $p < 0.001$).

view that TBI is serious, and 14.1% (n = 1057) tweets were coded under the “Neglect” sentiment, showing a lack of concern for TBI (Table 3) ($\chi^2 = 163.72$, $p < 0.001$).

Of the tweets using scientific terminology to refer to head injury (n = 6215), 48.9% (n = 3038) were coded under the “Recognition” sentiment, expressing the opinion that brain injuries are serious, and 12.8% (n = 798) of tweets were coded under “Neglect,” showing disregard for head injuries. Conversely, among tweets using colloquialisms (n = 1268), 29.7% (n = 376) exhibited an appreciation for TBI severity, while 20.4% (n = 259) showed neglect for TBI. Of the 1855 tweets using the words “brain injury,” “brain injuries,” “head injury,” or “head injuries” to refer to TBI, 60.9% (n = 1130) were coded under “Recognition” (Table 4). Of the 3646 tweets using the word “concussion” or “concussions,” significantly fewer (43.8%, n = 1592) were coded under “Recognition” ($\chi^2 = 386.17$, $p < 0.001$).

Discussion

Through qualitative tweet analysis, we identified five consistent content themes as well as noteworthy differences in sentiment toward brain injury. The five content themes were as follows: “Subjective opinions,” “Instances of injury,” “Education,” “Policy and rules,” and “Medical.” Users predominantly

provided personal commentary about personal or professional athlete concussions, shared concussion knowledge relating to symptoms and medical treatment, and disseminated information about research and tools for concussion prevention. With regard to tweet sentiment, more tweets reflecting “Recognition” rather than “Neglect” toward brain injury were evident for each theme, indicating a perception of the seriousness of TBI versus disregard. Altogether, these findings indicate a discordant opinion of sport-related TBI among the public: there is both an understanding that brain injuries are serious and disregard for activities that might reduce the public burden of TBI. This needs to be addressed in order to improve the culture of concussion.

Misinformation and mixed sentiment toward brain injury on Twitter

Our findings are consistent with previous studies that illustrated the sharing of incorrect and inconsistent concussion information on Twitter and other media platforms.^{16,20} For instance, users often recommended that injured athletes discontinue play and discussed concussion as a factor in an athlete’s career, resulting in decreased demand for “less valuable” concussed athletes. In contrast, users also depicted a “part of the game” attitude, encouraging athletes to play through injuries—praising them as “tough”—and suggesting that athletes use violence to inflict injuries instead of using skill to win a game. Others implied that personally sustaining an injury was worth it if it meant winning a game, emphasized with “hashtags” such as “#becauseisthecup.”

The mixed sentiments toward TBI and presentation of misinformation may cause confusion as to which viewpoint to adopt and potentially compromise intervention initiatives. For example, praise for concussed athletes who play through their injury or implications that injured professional athletes are not as valuable as their uninjured counterparts (e.g. @[user] *I’d never sign a player with a back or head injury history*) may encourage others to hide concussion symptoms for fear of not being able to play or falling in athletic ranks. These are in fact some of the reasons concussions are unreported among university and high-school athletes.^{2,21,22} Glorifying athletes who hide their injuries and play on for the “love of the game” can encourage other athletes to do the same. Similarly, spreading opinions that concussed athletes are “damaged goods” risks the stigmatization of concussion which may also discourage individuals from seeking help or treatment and may pressurize concussed athletes to hide their injuries.²³ This is of particular concern in youth sports, where concussions are likely already under-reported.^{24–27} As Twitter does not censor information quality in any way, these improper standpoints can persist.

Varying sentiment based on terminology

We found that sentiment toward TBI differs depending on the terminology used. A greater percentage of tweets using scientific terminology to refer to TBI demonstrated the sentiment that

TBIs are serious health conditions (48.9%) compared to those using colloquial terminology (29.7%). Notably, a greater percentage of tweets using the terms “brain-” or “head injury” or “brain-” or “head trauma” and their plural derivatives (n=1190/1977, 60.2%), demonstrated an understanding of TBI severity when compared to those using the word “concussion” (n=1592/3646, 43.8%). As a concussion is a form of TBI,^{28–30} this suggests a possible discrepancy in understanding exactly what constitutes a concussion TBI based on the terminology used. This notion is supported by a study by Robbins et al.³¹ who found that an athlete’s understanding of concussion is not in line with the current definition. Whereas terms using “injury” or “trauma” inherently imply severity, the meaning behind the term “concussion” is less clear³² and can lead to the word being used incorrectly in sports culture, propagating a misunderstanding of its meaning. It has even been suggested that the word “concussion” be retired altogether.³³ Additionally, tweets often made the distinction between “concussion” and “mild concussion” (e.g. *It’s amazing how Cobb only got a minor concussion*). The use of “mild” in characterizing head injuries can be misleading and could lead to a misinterpretation of how serious a head injury is. Its use in association with “concussion” can diminish the perceived severity of TBI.³⁴ What appear as minor differences in phrasing may further promulgate a disregard for TBI severity, affecting the public’s perception of TBI in sport.

The term “concussion” seems to have been incorporated into the sports culture as an expected occurrence that is just as much a “part of the game” as scoring a goal. This misunderstanding presents a new direction for injury prevention efforts. If an inherent misconception of the term “concussion” exists, then it may be that this simple misunderstanding in terminology serves as a source for neglect of injury severity. Given that the symptoms and severity of TBIs occur along a spectrum of mild to severe, clearly defining what constitutes a concussion is difficult for the public,^{33,35} when engaging in injury prevention efforts, clearer terminology should be used when describing head injuries. TBI is a serious public health problem and is one of the main causes of permanent disability or death.³⁶ Replacing the use of the term “concussion” with phrases that are less open to interpretation, such as “traumatic brain injury,” may encourage the understanding that concussions and similar TBIs are serious health conditions.

Implications for brain injury prevention

The content discussed among users parallels the “Five Es” of injury prevention: education, enforcement, engineering, evaluation, and economic incentives³⁷ and are summarized in Table 5. Understanding these facets as reflected in Twitter has direct relevance for programming and policy. Despite this, current research shows that while efforts to educate athletes and the public on general concussion knowledge, prevention, and management are already underway, they are not yet entirely sufficient, as there are still significant gaps in concussion knowledge. Chrisman et al.³⁸ reported increased

Table 5. Description of the “Five Es” of injury prevention and sample tweet content corresponding to each.

Five Es	Description of E	Tweet content
Education	Raise injury awareness and promote safe behavior to minimize risk of injury ^{29,32–34}	Consequences of TBI research Raising TBI awareness by promoting safe play during sports
Enforcement	Promotes implementation of injury prevention protocols by legal bodies ^{29,32}	Punishments given to athletes who inflicted concussions Need for sport law updates for concussion prevention
Engineering	Encourages the use of technological products, such as helmets, to reduce the risk of injury ³⁵	Policies for wearing protective headgear Importance of head protection
Evaluation	Insists on surveillance of current injury prevention policies to confirm their efficacy ²⁹	Challenged sports leagues with regards to their policies on TBI management Requirement for policy improvement
Economic incentives	Stressing the financial expense of injury in an attempt to encourage prevention efforts ³⁶	*

TBI: traumatic brain injury.

*Tweet content did not discuss economic incentives to encourage following TBI protocol.

concussion education and awareness among coaches, but not to the same extent among athletes and parents. Topolovec-Vranic et al.³⁹ reported that despite finding a higher general concussion knowledge among athletes, coaches, and other sport-engaged personnel, there was still a lack of awareness of mental health symptoms of concussion, such as anxiety. While traditional concussion education methods such as lecture-based classroom learning may improve concussion knowledge among athletes,⁴⁰ a failure to implement them can make them ineffective. Even implementing legislation for mandatory concussion education among collegiate athletes did not improve concussion knowledge among student athletes.^{27,41} By contrast, more novel technology-based education methods, such as online modules, have shown significant improvement in post-education concussion knowledge.⁴² By more feasibly and consistently reaching student athletes, online concussion education interventions using social media may therefore prove to be more effective.

Limitations

This study had several limitations. First, we were only able to collect publicly available tweets, limiting the

population from which data was collected to accounts who made their tweets publically available. In addition, we only studied a specific time period (June to July). Had we chosen a time when other sports were more in the public eye, such as American Football in December, the response pattern may have been different. However, our goal was to understand the public perception of TBI in sport, and as the general public would likewise not be privy to or influenced by private tweets, our sample is still representative of the public perception. Furthermore, we did not analyze the Twitter users in any way, so tweet content and sentiment were not interpreted in the context of the tweeters. A potential limitation of Twitter is the 140-character tweet length, which may restrict users from elaborating on their opinions. It would be interesting to see whether similar trends exist on other social media platforms without character limits. Furthermore, the Twitter Application Program Interface (API) is limited to a 1% sample of tweets generated randomly by Twitter. Despite not being able to access all tweets, the sample is random and therefore representative of content on Twitter. Finally, automated sentiment analysis software do exist, which are designed to determine sentiment in short lines of text. However, we felt that direct coding by the authors would better detect nuanced or sarcastic sentiments, making the results more robust and reliable.

Conclusion

In closing, our findings show that a detailed analysis of social media can provide insight into the current public perception of an important public health issue. We showed that a mixed understanding and sentiment exist among the public regarding sport-related head injuries. Our results suggest that there may be an insufficient capacity among the public to institute broad-based efforts to prevent TBI and implement the appropriate course of action following TBI. As many concussions are unreported due to insufficient concussion knowledge,^{43,44} correcting misconceptions about a health condition like TBI can aid the shift in the prevailing culture from ignoring or concealing the condition, to preventing and properly managing them.

Future directions

This largely dichotomous view of sport-related head injury on Twitter has implications for the use of social media in treatment and prevention efforts. With the goal of correcting misconceptions, treatment and injury prevention enforcers may be able to utilize the interactive sharing component of social media sites like Twitter by sharing educational materials, which can be disseminated by the users who display an appreciation for head injury severity to those who disregard it. In this way, social media can be used as a medium to educate athletes, coaches, and parents,

among other Internet users, on the serious effects of head injury. The importance of these interventions is emphasized by special funding calls to support injury prevention research—a recent grant from the CDC (RFA-CE-17-002) was released to support the development of targeted educational interventions that will prevent sport-related concussion and improve the culture and quality of knowledge around concussion in sport.

Benefits associated with the use of social media for health communication have been previously identified; however, a significant limitation has been the quality and reliability of the information.⁴⁵ This is highlighted by our findings of inconsistent information and opinions on Twitter about sport-related TBI. It may be possible to assess the validity and reliability of the information shared on Twitter through the profiles of Twitter users, where users can include their occupations and qualifications. Those reading and seeking information about head injuries on Twitter can determine the quality of the information based on who is sharing it. This may help readers determine which facts and viewpoints to accept as true among the spectrum of opinions and misinformation on Twitter. Likewise, the media may skew the reporting of sport-related concussion by emphasizing emotive content rather than empirical data, propagating a discordance between the content in media and science.⁴⁶ It is necessary then to also work toward aligning the messages reported by the media and research, to ensure correct concussion knowledge dissemination.

In our current “information age,” despite the informal nature of social media sites, they have an indispensable role in learning and education.⁴⁷ With 52% of adults using two or more social media platforms,⁷ their global impact on knowledge transfer cannot be discounted.⁴⁸ Ultimately, future work should focus on how social media can best be used to support and facilitate program and policy planning to diminish the personal and public burden of TBI and similar conditions.

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