General Brief Report

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Trends of public interest in chronic traumatic encephalopathy (CTE) from 2004 to 2022

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Abstract

Context: Public interest in sport-related medical conditions is known to be affected by social media and pop cultural coverage. The purpose of this project was to assess the relationship between popular culture concerning chronic traumatic encephalopathy (CTE) and analyze of how often this topic was searched on the internet.

Objectives: The objective of this study was to investigate deviations in public interest following player incidents of CTE and the effects that the media has had on public interest in CTE.

Methods: To determine our primary objective, we utilized Google Trends to extract the monthly relative search interest (RSI) in CTE between January 2002 and October 2022. To assess the increase in RSI following a major event, an autoregressive integrated moving average (ARIMA) to predict RSI from March 2012 was created through the end of the period, and calculated the differences between the actual and forecasted values.

Results: Data indicate that RSI increased over time, specifically following the release of the movie *Concussion*. The peak in RSI (100) over this timespan was following the release of Aaron Hernandez's autopsy results in 2017, which was 87.8 (95 % CI: 8.7–15.7) higher than forecasted, showing a 720.3 % increase in RSI. While research was published regarding CTE in 2005, the first major spike in search interest occurred after Junior Seau died in 2012. Increasing public interest in CTE continued when media exposure conveyed autopsies of former NFL players, the movie *Concussion*, and the release of *The Killer Inside: The Mind of Aaron Hernandez*. Given this increased interest in CTE, we recommend that media broadcasters become more educated on brain injuries, as well as the movement of Brain Injury Awareness Month and Concussion Awareness Day.

Conclusions: There has been an increase in public interest in CTE from 2004 through 2022 with surges following media releases of events involving NFL players. Therefore, physicians and media broadcasters must create partnerships to better educate the public about head injuries and the effects of CTE.

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Public awareness of various medical topics has been explored utilizing infodemiology [1–4]. Infodemiology focuses on studying the distributions, determinants, and characteristics of information from an electronic medium such as the Internet, with the primary purpose of informing public health and public policy [5, 6]. Google Trends is one of the major infodemiology tools that has been utilized [7]. Google Trends can be utilized in public health and healthcare studies to assess the public interest and awareness of medical topics as they relate to popular and nationally publicized events including athletics [3]. One study investigating public interest following NFL injuries among six popular, first-string NFL quarterbacks found that search interest in all six quarterbacks increased following their injuries [8]. Interestingly, their study demonstrated a

consistent pattern of increased search engine activity – having increased queries during the 3 days following the reported injury – marking the influential time frame of public engagement and media presence [8]. Additionally, a NBA Finals study showed similar results of increased search interest following injury reports that would be of potential interest to orthopedic surgeons [9].

Our interest is the evaluation of the relationship between public interest and chronic traumatic encephalopathy (CTE). CTE is a progressive neurodegenerative brain disorder that is thought to be caused by numerous forceful blows to the head and is frequently associated with repeated sports-related concussions [10]. Additionally, it is a diagnosis that can only be made postmortem through the evaluation of hyperphosphorylated tau proteins. CTE is most commonly diagnosed in individuals who participate in contact sports for extended periods – including athletes playing in the National Football League (NFL) because over 500 former football players have been diagnosed with CTE [10]. In a 2017 study, CTE was present in the brains of 111 out of 202 former NFL players. This study was conducted on players from all positions and found that linemen have the greatest affected rate of CTE (44/202) [11]. According to data released by the NFL, there were 187 reported concussions during the 2021 professional football season, including preseason practice and games [12].

Traumatic encephalopathy syndrome (TES) is the premortem clinical syndrome of CTE, involves repeated brain trauma and cognitive deficits and neurobehavioral dysregulation with progression that are not completely explained by other mental or biological medical conditions, and may often be the clinical term describing what current and former NFL players are experiencing [13]. Sports media coverage often struggles with the distinction between the postmorbid pathological diagnosis of CTE and the proposed clinical syndrome TES. For instance, during the 2022 football season, the increased discussion of the potential long-term effects of traumatic brain injury (TBI) and concussions, including CTE, became apparent in public conversation following Tua Tagovailoa's concussion reaction that was broadcast on national television. Tagovailoa experienced a fencing response on the field as a result of receiving consecutive concussions within a short period [14]. A "fencing" response is the tonic posturing of contralateral limbs, including flexion and extension in an unnatural manner following head impact [15].

Over the past 2 decades, many NFL players who have been involved in highly publicized, tragic events, such as committing suicide and homicide, were found to have CTE. While this prompts public conversation regarding CTE, other psychiatric symptomatology may have been present earlier in these individuals. The heightened media coverage of CTE during these unfortunate events likely had a similar effect on public interest, thus our objective was to investigate the reach that media coverage of player incidents and deaths has had on public interest in CTE over time. Our main hypotheses were that: (1) there would be an increased trend of public interest since the time CTE appeared in scientific literature; (2) we would see spikes in search volume following media publications mentioning CTE or former NFL players' deaths; and (3) we would see increased search volume when information is released about current NFL players sustaining a concussion. Our secondary objective was to assess whether the public interest in CTE during the NFL's offseason months – which includes brain injury awareness month in March – differs from the NFL season. Our findings will provide insight into the sources of public awareness regarding what CTE is and events that inform the public about this condition.

Methods

To assess public interest and awareness, we conducted a temporal cross-sectional analysis utilizing data from Google Trends from January 1, 2004 through October 31, 2022. As previously mentioned, Google Trends has been utilized to document the public interest in medical topics, such as vaccinations [16], COVID-19 predictability [2], and cancer screening [17].

To identify search interest in CTE, we extracted search interest of the *disease* 'chronic traumatic encephalopathy,' and *injuries* of 'traumatic brain injury' and 'concussion.' Within Google Trends, 'traumatic encephalopathy syndrome' was not a recognized searchable disease and the search term did not return discernible results. Google Trends assesses the relative search interest (RSI) as a percentage (0–100) of all searches within a set time period. To determine the impact that media publicity had on the search history, we researched the release of several publications on CTE and NFL players' injuries or deaths, such as when Junior Seau committed suicide. All events and dates are shown in Table 1.

Statistical analysis

To analyze the change of RSI in CTE over time, we constructed linear regression models for each of the terms queried. Additionally, we compared the mean RSI in 'CTE' and 'concussion' during the NFL season from September to February each year to the offseason months – because Brain Injury Awareness Month is in March. Finally, we utilized

Table 1: Major media events resulting in increased public interest in CTE.

Date	Event
07-2005	Dr. Omalu Bennet publishes initial CTE research
05-2012	Junior Seau commits suicide
01-2013	Autopsy confirms J. Seau's CTE diagnosis
11-2013	Tony Dorsett: Documented symptoms indicative of CTE
02-2016	'Concussion' movie popularity rises
09-2017	Aaron Hernandez's autopsy gains media attention
09-2018	Daniel Te'o-Nesheim's autopsy gains media attention
09-2019	Increased exposure for CTE within the NFL
01-2020	'Killer inside: The mind of Aaron Hernandez' is released on netflix
04-2021	Autopsy: Phillip Adams' CTE diagnosis, stage II
01-2022	Demaryius Thomas dies from neurological complications
07-2022	Autopsy confirms Demaryius Thomas' CTE diagnosis
10-2022	Tia Tagovailoa's consecutive concussions

an autoregressive integrated moving average (ARIMA) model to forecast RSI immediately following the first publicized incident involving an NFL player with CTE (2012) – and then compared the highest actual peak in RSI to the forecasted value and determined the coinciding event. This study does meet the requirements for human subjects research as defined by 45 CFR 46.102(d) and (f) of the Department of Health and Human Services' Code of Federal Regulations and was not submitted to an Institutional Review Board for review.

Results

The regression analysis assessing trends in monthly RSI for 'chronic traumatic encephalopathy' showed a statistically significant increase from January of 2004 through October 2022 (Coef. = 0.14, standard error [SE]=0.01; t=14.93, p<0.001; Figure 1). 'Concussions' also had a significant increase during this time (Coef.=0.19, SE=0 0.01; t=17.26, p<0.001), as did 'traumatic brain injury' (Coef.=0.02, SE=0.01; t=3.41, p=0.001), although TBI had a much lower monthly increase (Figure 2).

From our mean comparison of RSI of 'chronic traumatic encephalopathy' during the football season months (September through February) vs. the offseason months (March through August), we found that the mean RSI during the season was 18.71 (standard deviation [SD]=15.92) and during the offseason was 15.48 (SD=9.18) – a nonstatistically significant difference (t=1.87, p<0.06). However, the mean RSI for the term 'concussion' was 37.26 (SD=17.99) during the football season months, whereas it was 29.21 (SD=12.91) during the offseason months – which was statistically significant (t=3.86, p=0.0001).

The peak RSI (100) occurred in 2017 following the release of Aaron Hernandez's autopsy results, which was 87.81 (95 % Cl: 8.72–15.66) points higher than the forecasted value from the ARIMA model, showing a 720.3 % increase in RSI. Other significant peaks occurred after the release of the documentary 'The Killer Inside: The Mind of Aaron Hernandez' in 2020, with a RSI of 92, compared to the forecasted value of 13.35, as well as the death of Demaryius Thomas due to seizure complications, with a RSI of 68 and forecasted value of 14.34.

Discussion

In line with our hypothesis, there was a stable increasing trend in public interest regarding CTE from 2004 through 2022. We found this trend to be statistically significant. One notable peak in our data was in 2017 when Aaron Hernandez's autopsy results were released. These results confirmed a diagnosis of severe CTE. Additionally, there were peaks with other media publications including the release of the documentary *The Killer Inside: The Mind of Aaron Hernandez* (2020), and the death of Demaryius Thomas (2021) [18]. The latest peak in our data occurred in September 2022 following the media attention surrounding Tua Tagovailoa's consecutive concussions. Similar to the previously mentioned studies [8], our results showed that the largest increases in the search volume of CTE occurred following heightened media coverage of the identified events [8]. However, due to the nature of the events, the public's view of CTE may be limited in scope – having only been reached by those negative stories, furthermore leaving the public uninformed about the different degrees of head injuries.

Implications and recommendations

The increased search interest in CTE surrounding these traumatic events may have influenced the parents' decision to allow child participation in the sport as the number of athletes aged 6–18 has dropped from 8.4 million in 2006 to 5.2 million in 2021 [19]. Further, in addition to ongoing research regarding TBI, both the NFL and National Collegiate Athletic Association (NCAA) in 2018 implemented rules to discourage helmet-to-helmet contact when players tackle [20]. The following year, the NFL announced that the number of reported concussions was down 29 % [21].

Our main recommendation is that as osteopathic physicians, we develop partnerships with newscasters and

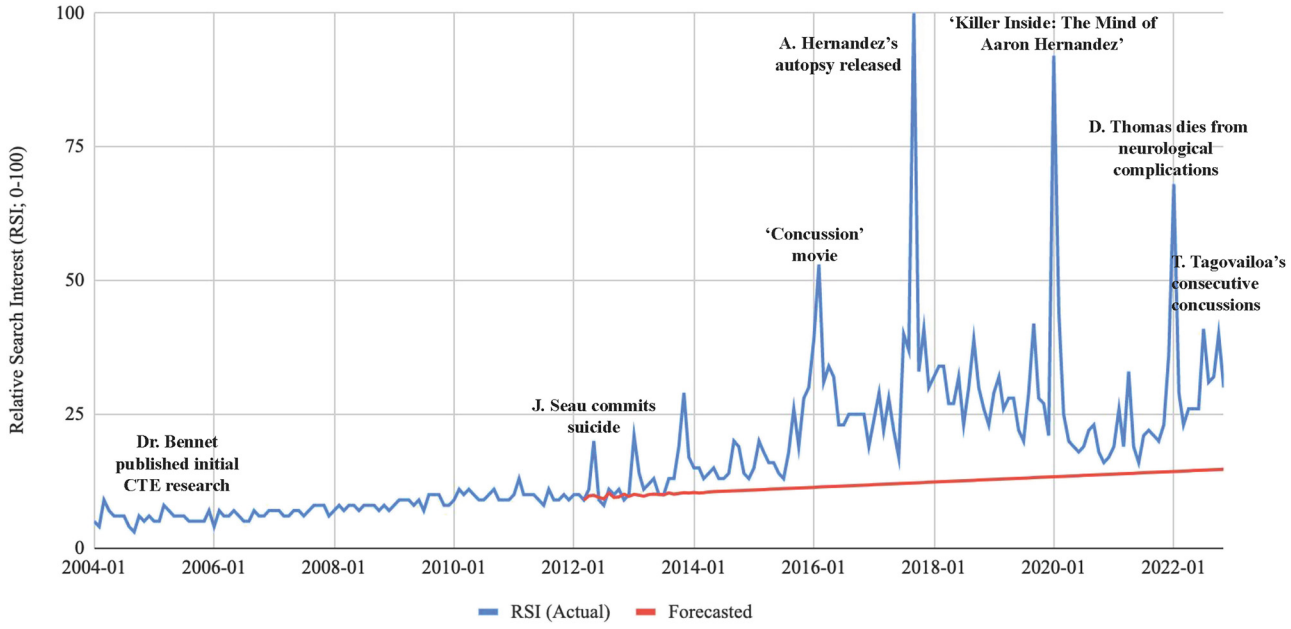

Figure 1: The relative search interest (RSI) of google trends in the topic 'chronic traumatic encephalopathy' from January 1, 2004 through October 31, 2022.

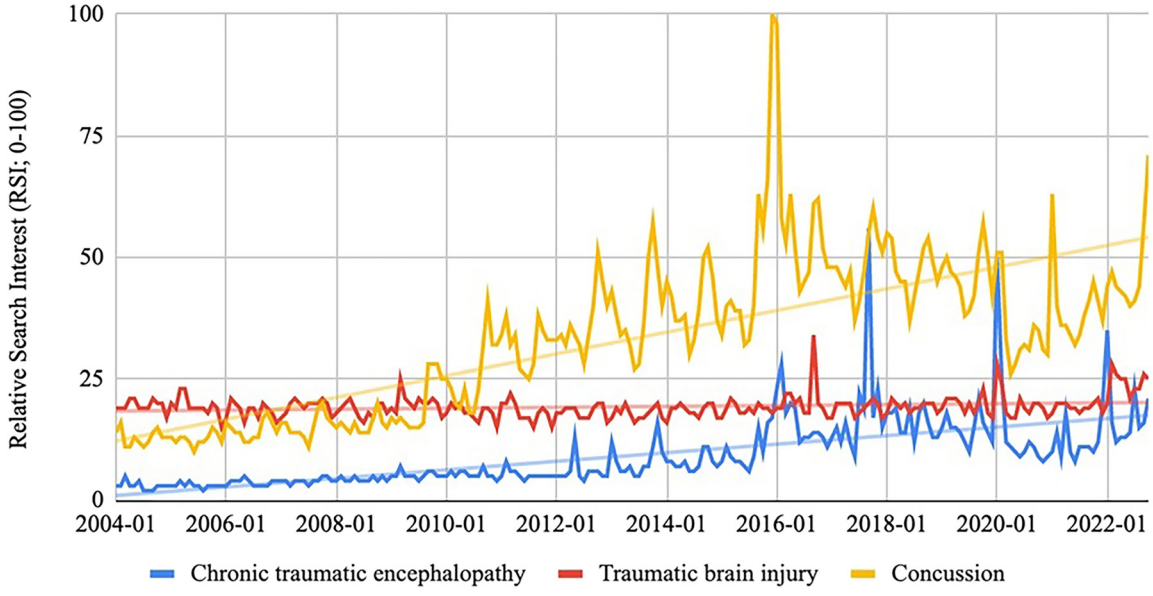

Figure 2: The relative search interest (RSI) of google trends in the topics 'CTE,' 'concussion,' and 'TBI' from January 1, 2004 through October 31, 2022.

media journalists to deliver accurate information regarding brain injuries when broadcasting sports in which traumatic head injuries may occur. Further, by creating media partnerships, we may be able to provide a more holistic context of circumstances surrounding the tragic events that peaked public interest when they are being presented in the media. Many contact sports can result in a wide range of head injuries, in addition to TBI, and all can result in long-term behavior, mood, and memory changes, which can lead the public to quickly make speculations about CTE. As such, is also important that information shared with the general public is evidence-based, and that it balances information about the possible risks of sports with accurate information concerning recovery from a single concussion or other less

threatening events. For instance, the *nocebo* effect is a well-known contributor that can negatively affect recovery post-TBI [22]. The nocebo effect focuses on when a patient experiences worsening symptoms as a result of increased negative information on a topic [22]. While it is clear that repeated concussive and nonconcussive blows are a risk for CTE pathology, the linkage to the syndrome and specific behaviors remains under investigation, thus the public must be properly informed about the progression of head injuries for which creating partnerships between the media and physicians could be a great avenue. Given that our findings show increased search interest in TBI-related terms occurring during the NFL season – specifically 'concussion' – an additional recommendation is to consider changing both Brain Injury Awareness Month, currently in March, and Concussion Awareness Day, currently in September, to November. This would coincide with not only the NFL season but also the National Hockey League season – two sports in which players experience an increase in reported head injuries. By changing the timing of these brain injury awareness initiatives to November, public awareness and access to research will coincide with several different in-season sports with players who are known to experience head injuries and may provide an opportunity for a more scientific discussion of CTE.

Strengths, limitations, and future research

In the United States, Google accounts for 61.4 % of all searches; however, despite being a widely utilized search engine, Google Trends research is limited to those who have internet access [23]. Additionally, because we focused on the NFL, which is predominantly played within the United States, we limited our searches to those that occurred within the United States for this study. Future research should focus on the full extent of media coverage for CTE, which could include social media outlets such as X (formerly known as Twitter). This could better assess the public's interest and discussions around CTE and other head injury–related topics that are occurring on these platforms. Additional research could also focus on CTE and concussions in other sports such as hockey, soccer, and rugby – including assessing prevalences in and differences between men's and women's leagues.

Conclusions

Our study found a steady increase in search interest in CTE from 2004 through 2022 – with surges following media releases and traumatic events involving former NFL athletes. Although the previous media attention surrounding these unfortunate events mostly hinged on CTE, other biopsychosocial factors may have contributed to the maladaptive phenotype. Given this increase in public interest, physicians and media personnel must work together to share correct and up-to-date research involving brain injuries such as concussions and CTE.

Research ethics: This study was determined to be non-human subjects research by the Oklahoma State University Institutional Review Board. This study adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.
Informed consent: Not applicable.
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