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# Participation in Professional American-Style Football and Suicide Mortality: 1979–2019

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## Abstract

Despite strong associations established between head injury and mental health, studies of professional athletes exposed to head injury show reduced risk of suicide compared with general populations. We compared the risk of suicide among National Football League (NFL) players to Major League Baseball (MLB) and National Basketball Association (NBA) players. Death data from 1979 to 2019 were obtained from the National Death Index for 20,765 NFL, 9,684 MLB, and 3,564 NBA players whose careers began after 1919. We calculated hazard ratios (HRs) and 95% confidence intervals (CIs) for suicide for NFL players compared with a combined MLB + NBA reference group, adjusted for age at career end, race, and career body mass index. We additionally stratified follow-up time at 2011, when attention on the long-term effects of head injury and chronic traumatic encephalopathy increased. Between 1979 and 2019, 101 suicides occurred among 34,013 participants with mean ± standard deviation (SD) age at career end of 28.3 ± 4.2, and among whom 13,677 (40.2%) were Black. Overall, the NFL suicide rate was similar to the MLB + NBA (HR = 1.20, 95% CI = 0.71–2.01, $p = 0.50$). When stratified at 2011, no difference was found through 2010 (HR = 0.91, 95% CI = 0.49–1.71, $p = 0.78$), while the suicide rate post-2010 was higher among NFL players (HR = 2.64, 95% CI = 1.04–6.84, $p = 0.04$). We have identified a twofold higher incidence of recent suicide within the at-risk group of former NFL players. These findings underscore the need for more intensive post-career guidance pathways and enhanced, proactive screening measures.

**Keywords:** chronic traumatic encephalopathy; concussion; football; neurological disorders; suicide; sports; traumatic brain injury

## Introduction

Death by suicide is ranked as one of the leading causes of death among Americans under the age of 55, and as the 11th leading cause among all age groups.[1,2] Known predictors of suicide include depression, suicidal ideation, hopelessness, and sleep disturbances,[3–6] with recent studies identifying head injury as an additional risk factor for death by suicide.[7–9] Former professional American-style football (ASF) players are exposed to repetitive head injury (RHI), which has also been strongly tied to depression.[10–13] However, previous mortality studies conducted among ASF players have found lower rates of suicide when compared with general populations.[14,15] This may be due to substantive differences that exist between elite athletes and the general public making the latter a problematic reference group.[16–18] A more appropriate comparison would be professional athletes from sports that experience fewer head injuries. To date, such a study has

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yet to be conducted on a sufficiently large dataset. Accordingly, debate remains about whether participation in professional contact sports places athletes at relatively greater risk of suicide.[19,20]

Associations between RHI and chronic traumatic encephalopathy (CTE; a neuropathological finding determined at autopsy[21]) have raised concern among ASF players. In 2010, two case studies described autopsy identification of CTE among four former National Football League (NFL) players who died by suicide, suggesting suicidality as a consequence of RHI and a clinical feature of CTE.[22,23] In 2011, public sources reported that a former NFL player died by suicide with the intent to donate his brain to research.[24] Since that time, other high-profile players have left similar autopsy instructions after deaths by suicide. While the relationship between autopsy findings and antemortem phenotyping is still debated,[25] associations between head injury, suicidality, and CTE continue to be raised in both public and medical domains.[26] Two separate studies of former professional ASF players found that more than one-third of former ASF players reported CTE concerns,[27,28] with one finding additional associations with frequent thoughts of suicide.[27]

To determine whether participation in professional ASF is associated with increased suicide, we compared suicide rates among former NFL players to those from Major League Baseball (MLB) and the National Basketball Association (NBA) in a large dataset of complete historical data. We hypothesized that NFL players would have an elevated rate of suicide across all years studied compared with MLB or NBA players, two sports in which the risk of head injury is much lower.[29] We additionally evaluated the suicide rate before and after 2011, a period marked by: (1) increased scientific publications about CTE; (2) changes in how suicide was presented in public media; (3) increased discussion of links between head injury, football, and CTE;[26,30] (4) death by suicide among a number of high profile NFL players; and (5) increased awareness of efforts to minimize the association between ASF exposure and CTE.[31]

## Methods
### Study population
Sports Reference (SR), LLC[32] maintains a database of living and deceased professional athletes from the National Football League (NFL; or the American Football League prior to 1966), MLB, and the NBA ($n = 49,260$). SR provides biographical data (name, date and place of birth, date of death if relevant, colleges attended, playing height and weight), overall sports data (e.g., first and last career year), and game-level sports-specific data (e.g., teams, player performance). All MLB, NBA, and NFL athletes who played at least one professional game are included. As a result, practice players were not included in the dataset.

SR determined career height and weight using team media guides, League publications, and/or team rosters. Race and ethnicity data were licensed from Hidden Game Sports, LLC.[33]

The U.S. National Death Index (NDI) electronic data starts on January 1, 1979. We excluded individuals born before 1899 ($N = 5,715$) or after 1995 ($N = 120$), or those with an SR-recorded death prior to 1979 ($N = 2,382$). We excluded active players ($N = 3,384$), those lacking birth information ($N = 526$), and those who would have been over 108 years of age at the time of censoring ($N = 20$). Due to the small number of Latino, Asian, Pacific Islander, and Alaskan Native or Native American players in the NFL[34] and evidence of race and ethnicity differences in suicide rates,[35] we restricted our analyses to White and Black former players only and excluded other race and ethnicities ($N = 2,490$). Since the NFL was created in 1920, we included only players whose careers ended on or after that year through 2017 for MLB (last available) and 2018 for NFL and NBA ($N = 444$). We excluded deaths reported by SR that occurred outside of the United States ($N = 166$). The final analytic cohort included 34,013 players (Fig. 1). This study was approved by the Harvard T. H. Chan School of Public Health institutional review board.
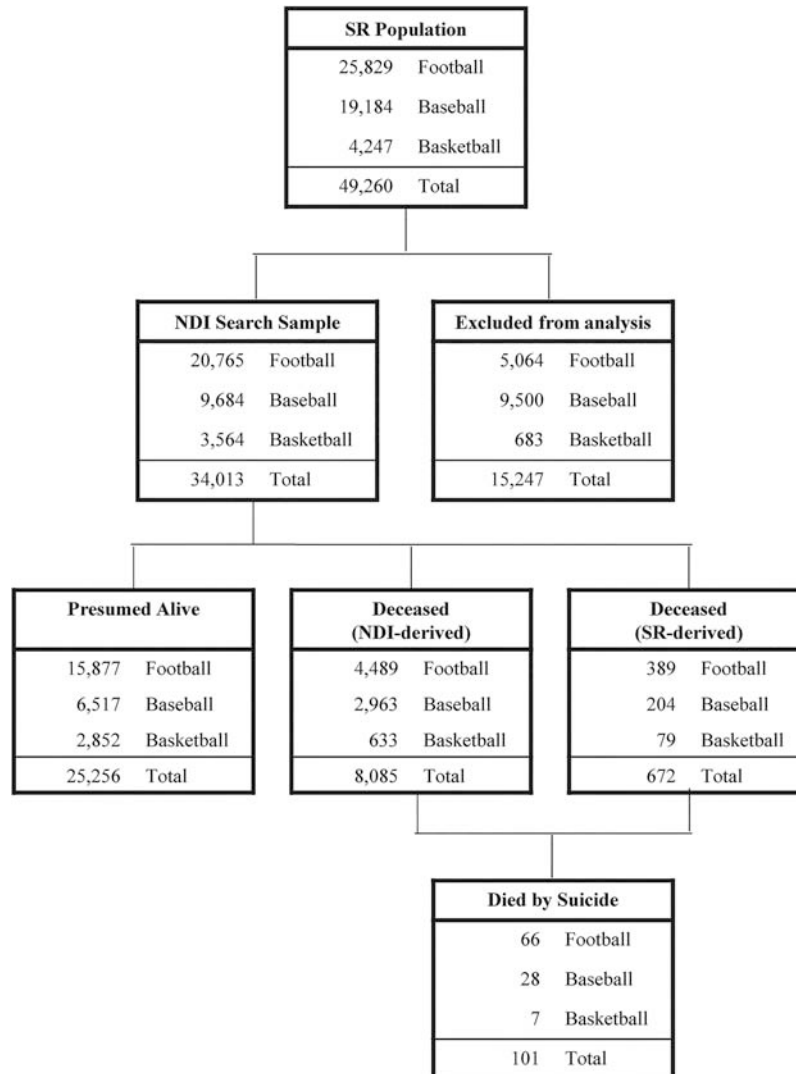
### NDI matching algorithm
All cause-of-death data for our analyses came from the NDI. We followed the NDI algorithm for identifying correct matches between submitted demographic data and NDI data.[36] Based on seven SR-derived characteristics provided (first name, middle initial, surname, and day, month, year, and state of birth), 6,828 exact matches were found. An additional 1,102 matches met NDI-specified match quality criterion, and 155 more matched on name and birth data within a ± 5-year window.

We matched 374 additional deceased players by further considering SR day, month, year, and state of death data when available. Of these, one matched on 10 of 11 characteristics, 230 matched on 9, 102 on 8, 24 on 7, and 17 on 6. Those with fewer than six matching criteria were considered alive.

### Outcome ascertainment and historical stratification
Deaths from suicide were the outcome of interest and identified using the International Classification of Diseases (ICD), Ninth Revision (ICD-9) and ICD, Tenth Revision (ICD-10), codes E950–E959, and X60–X84 and Y870, respectively, as underlying or contributing cause of death.

In addition to full follow-up analyses, we also stratified follow-up time as through 2010 versus in 2011 and after, based on a number of changing factors. These include indications that scientific and public awareness of concussion in sport and impact-related brain disease (e.g.,

**SR Population**

| | |
|---|---|
| 25,829 | Football |
| 19,184 | Baseball |
| 4,247 | Basketball |
| 49,260 | Total |

**NDI Search Sample**

| | |
|---|---|
| 20,765 | Football |
| 9,684 | Baseball |
| 3,564 | Basketball |
| 34,013 | Total |

**Excluded from analysis**

| | |
|---|---|
| 5,064 | Football |
| 9,500 | Baseball |
| 683 | Basketball |
| 15,247 | Total |

**Presumed Alive**

| | |
|---|---|
| 15,877 | Football |
| 6,517 | Baseball |
| 2,852 | Basketball |
| 25,256 | Total |

**Deceased (NDI-derived)**

| | |
|---|---|
| 4,489 | Football |
| 2,963 | Baseball |
| 633 | Basketball |
| 8,085 | Total |

**Deceased (SR-derived)**

| | |
|---|---|
| 389 | Football |
| 204 | Baseball |
| 79 | Basketball |
| 672 | Total |

**Died by Suicide**

| | |
|---|---|
| 66 | Football |
| 28 | Baseball |
| 7 | Basketball |
| 101 | Total |

**FIG. 1.** Flowchart of matching and excluded National Football League (NFL), Major League Baseball (MLB), and National Basketball Association (NBA) players and suicide occurrence for the National Death Index (NDI) dataset using Sports Reference (SR) data. Players were excluded if they were more than 108 at the time of censoring ($N = 20$) or born before 1899 ($N = 5,835$), finished playing before 1920 ($N = 444$), were currently listed as active players ($N = 3,384$), were missing biographical data needed for NDI matching ($N = 526$), died before 1979 ($N = 2,382$) or outside the United States ($N = 166$), lacked birth information, or were of Latino, Asian, Pacific Islander, and Alaskan Native or Native American descent ($N = 2,490$). COD, cause of death.

CTE) had notably shifted. First, PubMed by Year[37] (a tool that calculates the annual proportion of peer-reviewed PubMed studies containing specified terms) showed increased use of "CTE" around 2010 (Supplementary Fig. S1). Second, a study of internet searches for CTE, concussion, and TBI appeared to increase around 2010, especially for concussion.[26] In addition, a number of publicized suicides among former players occurred in or after 2011, some of whom left specific instructions for autopsy.[24] We also conducted additional sensitivity analyses that split the data at follow-up through 2009 or 2011.

**Statistical analysis.** We estimated hazard ratios (HR) and 95% confidence intervals (CIs) using multivariable Cox proportional hazards models with years since career end as the time scale to determine relative rates of suicide. In sensitivity analyses, we used age as the time metameter for Cox models. In analyses that included all years of electronic NDI data, players contributed follow-up time starting on the date of their career end or, for those whose careers ended before 1979, on January 1, 1979, the onset of electronic NDI data. Players contributed follow-up time until censoring (death by suicide or any competing

cause), or end of follow-up (December 31, 2019), whichever came first. The only difference for pre-2011 analyses was that end of follow-up was considered December 31, 2010. For analyses of 2011 and later, follow-up time started on January 1, 2011 or date of their career end if after that (those who died prior to 2011 contributed no follow-up) and ended on December 31, 2019. To check on possible change in the reference group post-2010, we also estimated HR among MLB + NBA players in post-2010 follow-up compared with earlier.

If a participant's death occurred in the same year as their final career year, the end of career was assigned as the day before date of death (MLB/NBA/NFL $n = 8/10/10$). NDI state-specific privacy restrictions prevented release of cause of death for 33 decedents (18 matched by the NDI-only algorithm and 15 with additional SR data). These decedents, as well as 298 players identified as deceased by SR, but not matched with NDI, were censored the day before their death. To avoid the possibility of SR death identification being biased by sport and cause of death, we conducted sensitivity analyses only considering deaths identified without the additional SR death information. To avoid differences in playing years contributing to relative rates, we conducted sensitivity analyses that excluded players whose careers started before 1954, the earliest career start among those who died by suicide after 2010. Main analyses combined MLB and NBA as reference, due to a similarly reduced risk of RHI. Secondary analyses treated MLB as a reference in comparison to NFL and NBA. Models were adjusted for age at career end, race (Black/White), and body mass index (BMI; kg/m$^2$) during professional career. We imputed mean BMI by sport, position, and debut year for players missing BMI (MLB/NBA/NFL $n = 0/2/55$).

Analyzing players whose careers ended before 1979 conditions on them surviving to 1979, which could bias overall results if associations are different in earlier follow-up years. Thus, we first examined players for whom we had complete post-career follow-up (those whose careers ended in 1979 or later). We examined HR for increasing 5-year follow-up increments to determine how missing follow-up would impact HR when we included all players.

All hypothesis tests were two-sided and assessed at $p < 0.05$ level of significance. Analyses were conducted using R Statistical Software,[38] version 4.4.1. The R package "Survival" was used to calculate parameter estimates and test the proportional hazards assumption using Schoenfeld tests. All sport-related terms satisfied the proportional hazards assumption.

## Results

The mean ± SD ages at career end for MLB, NBA, and NFL players were $29.8 \pm 4.7$, $28.3 \pm 4.4$ and $27.6 \pm 3.7$, respectively. A majority of NFL (50.4%) and NBA (62.8%) players were Black, compared with 11.1% from the MLB (Table 1). Across all sports, 101 suicides occurred between 1979 and 2019. Among these, 66 NFL players died by suicide over 469,892 total years of follow-up, 28 MLB players died by suicide over 221,761 years of follow-up, and 7 NBA players died by suicide over 83,095 years of follow-up (Table 1).

When only considering players with complete post-career follow-up (i.e., those whose careers ended in 1979 or later), the HR across all follow-up time was 1.25 (95% CI: 0.56–2.78; Fig. 2A). Among this group, HRs for increasing 5-year follow-up periods were nonsignificantly lower in earlier postcareer periods, but otherwise generally similar by post-career follow-up years (Supplementary Table S1). Thus, missing earlier post-career years of players whose careers ended earlier should not miss important risk periods. When we considered all players with careers that ended between 1920 and 2019 and who died after 1979, NFL players showed a slightly elevated, but not significant HR for suicide compared with MLB + NBA similar to the analysis among only those with complete follow-up (HR = 1.20, 95% CI: 0.71–2.01; Fig. 2A). In analyses that stratified follow-up time at 2010, there was no difference in suicide rate by

**Table 1.  Demographic Distributions and Suicide Occurrence Among Professional Athletes from Major League Baseball (MLB; Career End from 1920 to 2017), National Basketball Association (NBA; Career End from 1920 to 2018), and National Football League (NFL; Career End from 1920 to 2018)**

|  | Total (N = 34,013) | MLB (N = 9,684) | NBA (N = 3,564) | NFL (N = 20,765) |
|---|---|---|---|---|
| Suicide occurrence, N (%) | 101 (0.3%) | 28 (0.3%) | 7 (0.2%) | 66 (0.3%) |
| Age at suicide, mean (SD) | 53.4 (18.2) | 59.8 (17.1) | 42.2 (16.6) | 51.9 (18.1) |
| Person-years of follow-up, N | 774,748 | 221,761 | 83,095 | 469,892 |
| Race, N (%) |  |  |  |  |
| Black | 13,677 (40.2%) | 1,076 (11.1%) | 2,237 (62.8%) | 10,364 (50.4%) |
| White | 20,336 (59.8%) | 8,608 (88.9%) | 1,327 (37.2%) | 10,401 (50.1%) |
| Age at career end, mean (SD) | 28.3 (4.2) | 29.8 (4.7) | 28.3 (4.4) | 27.6 (3.7) |
| Professional BMI, mean (SD) | 27.6 (3.9) | 25.1 (1.9) | 24.0 (1.7) | 29.4 (3.8) |
| Missing, N | 57 | 0 | 2 | 55 |
| Years of follow-up per player, mean (SD) | 30.1 (17.9) | 32.7 (18.1) | 27.9 (17.2) | 29.2 (17.8) |

BMI, body mass index; SD, standard deviation.
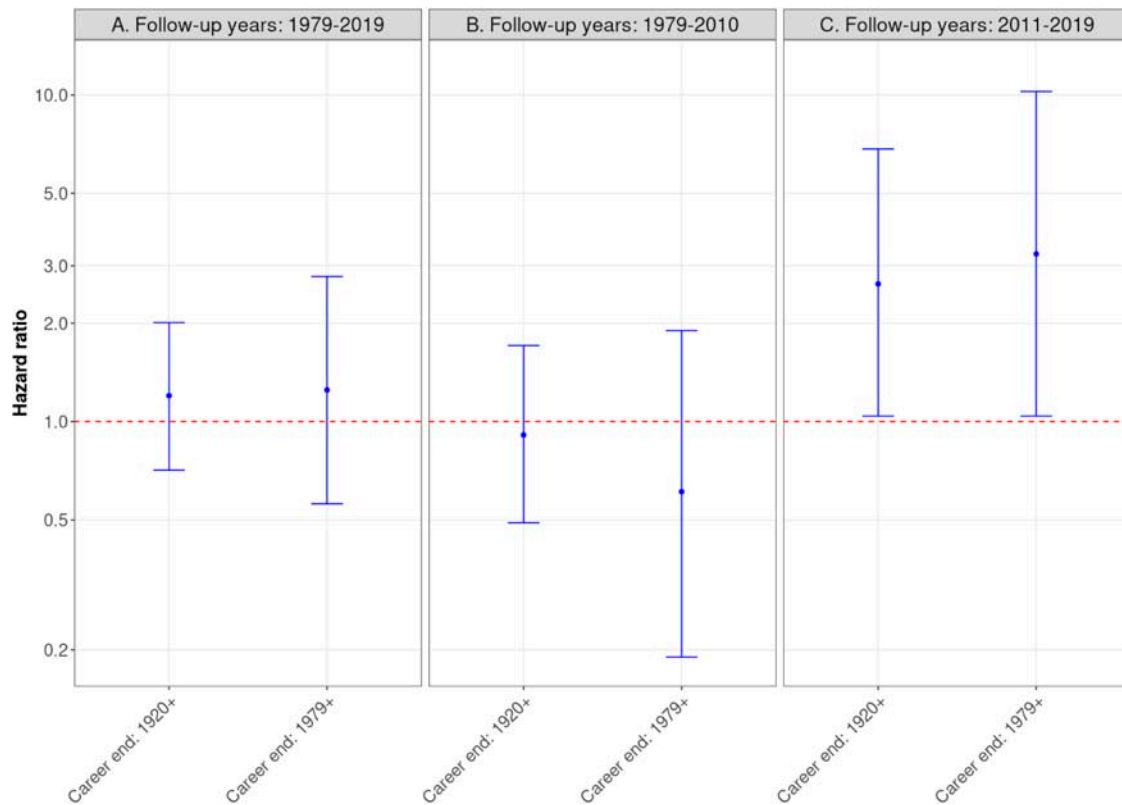
**FIG. 2.** Hazard ratios[a] (HRs) and 95% confidence intervals (CIs) for suicide among all National Football League (NFL) athletes compared with all Major League Baseball (MLB) combined with National Basketball Association (NBA) players as reference. Analyses use calendar year as the time metamer, and were conducted across **(A)** the entire follow-up period from 1920 to 2019; **(B)** during follow-up restricted to 1979–2010; and **(C)** during follow-up restricted to 2011–2019. All analyses were conducted in participants whose career ended after 1920, and restricted to those with career end after 1979. Note: [a]Models were adjusted for age, race, and career BMI.

sport among players who contributed follow-up time up to and including 2010 (NFL HR = 0.91; 95% CI = 0.49–1.71, $p = 0.78$; Fig. 2B). However, there was a significantly elevated HR after 2010 (NFL HR = 2.64; 95% CI = 1.04–6.84; $p = 0.04$; Fig. 2C). The HR after 2010 was greater when restricted to those with complete follow-up (career end in 1979 or later), among whom the HR for suicide for NFL players compared with MLB + NBA players was 3.26 (95% CI: 1.04, 10.25; $p = 0.04$; Fig. 2C), in contrast to the period prior to 2011 (NFL HR = 0.61; 95% CI = 0.19–1.90; $p = 0.39$; Fig. 2B). Stratifying the follow-up time after 2009 slightly weakened the HR, while results stratifying after 2011 were similar (Supplementary Table S2). Analyses that used only MLB players as the reference group were similar in all cases (Supplementary Tables S3 and S4). Results were essentially the same in analyses that did not use deaths identified only by SR (Supplementary Table S5). Analyses that used age as the time metameter yielded similar

results (Supplementary Table S6). The HR for post-2011 compared with prior to 2011 among MLB + NBA was 0.93 (95% CI: 0.43–2.00; $p = 0.85$).

## Discussion

Previous studies have shown reduced suicide mortality in elite athletes when compared with general populations,[15,39–41] but many differences between elite athletes and general populations (e.g., history of exercise and training, access to health care, salary discrepancies) complicate efforts to identify specific aspects of sport that affect suicide risk. To address these differences, our study compared NFL players with MLB and NBA players over follow-up from 1979 to 2019 and found no significant difference in the rate of suicide overall. However, we identified a large difference when we compared suicide rates up through 2010 to years after. Specifically, we found equivalent suicide risk by sport through 2010, but a more than twofold significant increase in rate of deaths by

suicide among former NFL players after 2010. Further, sensitivity analyses found that the HR in later years was similar when we split follow-up time after 2011 and weaker when split after 2009 (which added a "lower risk year" to the high-risk period if we assume increased risk began in 2011). These findings align with a prior study on suicide among former NFL players between 1920 and 2015, which found that a disproportionate number of suicides (42.3%) occurred after 2009.[30]

Like our study, two prior investigations of suicide among NFL athletes used other elite athletes as comparators. One found an elevated, but not significant, HR of 1.59 (95% CI: 0.54–4.69) for NFL players compared with MLB players from 1979 to 2013, although that study only included players who played at least five seasons.[42] The other compared contract NFL players with replacement players who participated during the 1987 NFL strike with follow-up from 1979 to 2013 and found that contract NFL players had a lower proportion of self-harm and interpersonal violence-related deaths,[43] although the specific numbers of self-harm or interpersonal violence deaths and HR were not indicated. Importantly, neither prior study isolated the post-2010 time period nor had as large a sample size as the current study.

It is important to note that our findings do not imply that ASF-related exposures have benign effects on brain health, as many acute and chronic adverse effects of head injuries have been well-documented.[10,11,13,44] RHI in football players has been strongly tied to depression,[10–13] and severe depression remains the strongest contributor to suicidality.[45,46] Our data are consistent with some change around 2011, accounting for an increased rate of death certificate-identified suicides among NFL players relative to the MLB + NBA reference group, which could be explained by a number of possible reasons. First, the increase in NFL player suicide after 2010 could relate to the emerging widespread awareness of concussion and CTE in the NFL.[20] Such increased awareness could have led to a higher rate of suicide as captured by death certificates in different ways. For example, there could be an increased recording of suicide on death certificates by medical examiners since 2011. If that increase is from incorrectly attributed suicides, that would show an increase in the suicide rate. Such an increase could also have occurred, for example, if greater awareness of concussion effects and CTE led to reduced stigmatization of suicide and so greater recognition by families and medical examiners that a given death was in fact by suicide. This explanation would imply that former ASF players do indeed have a higher rate of suicide than former MLB and NBA athletes—possibly from RHI, but that difference was masked prior to 2011 by under-reporting among former ASF players because of stigma.

Other mechanisms may also have contributed to a higher recording of suicide among NFL players after 2011. A number of well-publicized NFL deaths by suicide starting in 2011 could have motivated additional suicides through copycat behavior, known as the Werther Effect.[47] Notably, the 2011 suicide and several subsequent ones were among NFL players who died of self-inflicted gunshot wounds to the chest with specific instructions to preserve their brains for CTE studies.[24] Second, it is possible that the higher rate of suicide could result from exposure to a colleague who died with CTE. It has been found that compensation and retirement decisions of ASF players are affected by a teammate dying with CTE.[48] It is therefore possible that players' decisions are highly responsive to the health status of peers, and could contribute to suicidality.

In addition, diagnosed incurable neurodegenerative illness has generally been associated with depression and risk of suicide,[49] which may also apply to CTE. Thus, even if the underlying biological consequences of playing football remained the same, increased feelings of despair and demoralization associated with putative neurodegenerative disease (e.g., CTE) could have independently contributed to the increase in deaths by suicide found in this study. Alongside increased awareness of the relationship between RHI exposure and CTE starting around 2011, there was prominent scrutiny of institutional responses that minimized these associations.[31] Publicity surrounding these efforts may have resulted in protest-related motivations to demonstrate the pathological effects of RHI in the setting of institutional inaction, especially relevant given the aforementioned efforts by some decedents to preserve their brains for study.

It is also possible that other factors contributed to our results. Equipment, rule-based, or policy changes implemented before 2011, as well as earlier participation in football beginning in the 1980s, could possibly have affected the later risk of suicide. However, such changes would have had to have occurred a while before 2011 since our population was followed for many years after playing, and given such an interval, such changes would likely lead to more gradual changes in suicide risk over time than what we observed. Investigations into ASF-specific factors that may have changed before or during 2011 are warranted. It is also important to note that a reduction in risk of suicide post-2010 among MLB and NBA players could also contribute to our findings. The slightly lower HR for post-2010 follow-up among MLB + NBA players suggests that some contribution from this could be occurring. However, this must be interpreted with caution since the distribution of follow-up times before and after 2010 differs and that can affect HR,[50] and there were very few cases of suicide after 2010 among MLB + NBA

making further exploration of HR in specific follow-up time windows unstable.

Regardless of the contributors to mental health symptoms that increase risk of death by suicide, clinicians should prioritize screening for and treating treatable conditions with symptoms that may result in suicidality. At present, CTE can only be identified on autopsy based on patterns of phosphorylated tau aggregation in neurons at the depths of cortical sulci,[21] although efforts to identify CTE-related tau deposition patterns among living players are ongoing.[51–54] While an antemortem diagnosis of CTE is not yet possible, concern about having CTE has been documented in approximately one-third of former players,[27,28] and was associated with increased thoughts of self-harm.[27] Among former professional football players, a common clinical phenotype has been associated with (1) CTE concerns[27]; (2) meeting research criteria for traumatic encephalopathy syndrome[55]; and (3) reporting being told they have CTE by a medical care provider.[56,57] Specifically, players with CTE concerns or those who have been told they have CTE were more likely to report treatable conditions (sleep apnea, chronic pain, hypertension, low testosterone, etc.)[27,57] that have been linked to incident psychiatric symptoms in populations without brain injury.[58–60] In addition to proactively treating these medical issues, NFL players with these conditions and others who are concerned that they have CTE should be surveilled and treated for thoughts of self-harm using psychotherapy, pharmacotherapy, or other interventions that reduce suicidality. Finally, reporting in public media may also be used to positively counteract the Werther effect. Known as the Papageno effect, following death by suicide, coverage of positive coping in adverse circumstances that did not result in suicide has been found to prevent contagion effects.[47]

There are limitations to note. As previously described, there may be some errors in death certificate reporting of suicides. There is little published research on how well death certificates capture suicide in the United States. One doctoral thesis has reported that of suicides captured by the U.S. National Violent Death Reporting Systems (USNVDRS), death certificates correctly identify 99.6%,[61] but this doesn't speak to any suicides possibly missed by the USNVDRS. However, the contribution of changes to the rate of underreporting of suicides before and after 2010 cannot be determined in our data. Additionally, Latino, Asian, Asian-Pacific Islander, Native Alaskan, or American populations are underrepresented in professional football,[34] so the generalizability to these populations is not known.

## Conclusions

This study suggests that ASF-specific factors emerging in or after 2011 are associated with increased suicide mortality reporting in NFL players. These findings highlight the importance of proactive surveillance and treatment of NFL players for thoughts of self-harm, which could be further aided by disentangling the factors contributing to this increase. Living former players have been found to report multiple treatable conditions that can exacerbate psychiatric symptoms, such as sleep apnea, low testosterone, hypertension, and chronic pain,[27,57,62,63] and should therefore be screened for such conditions. These findings should motivate players, family members, and clinicians to have explicit conversations with former professional athletes to reduce risk of self-harm in this population.

## Transparency, Rigor, and Reproducibility Statement

This study was not preregistered online as data collection has been ongoing for several years, but the methods have been published online in prior publications. The analysis plan was not preregistered online but was conceived and executed by the primary authors and reviewed by two secondary authors. The primary authors certify that the analysis was prespecified. The sample includes every eligible participant because it relies on government records. Data collection and analyses were performed by investigators who were aware of relevant participant characteristics. All outcome measures used are in the public domain. Due to the high-profile nature of study participants, data are not available at this time. Analytic code can be made available upon reasonable request. R was used to complete the analyses. Missing data were handled as reported in the text.

## Authors' Contributions

R.G. had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. N.K. contributed equally to this work. Concept and design: R.G., M.G.W., N.K., B.A., and R.Z. Acquisition, analysis, or interpretation of data: R.G., M.G.W., N.K., M.L., and E.N.F. Drafting of the article: R.G., N.K., B.A., W.G., R.Z., A.L.B., M.G.W., and M.L. Critical revision of the article for important intellectual content: All authors. Statistical analysis: N.K., B.A., R.G., M.G.W., and M.L. Obtained funding: R.Z., B.A., W.G., M.G.W., and R.G. Administrative, technical, or material support: E.N.F., R.G., and R.Z. Supervision: W.G., M.G.W., and R.Z.

and the American Heart Association and receives compensation for his role as team cardiologist from the U.S. Olympic Committee/US Olympic Training Centers, US Soccer, US Rowing, the New England Patriots, the Boston Bruins, the New England Revolution, and Harvard University. R.Z. reported receiving royalties from Springer/Demos publishing for serving as coeditor of the text Brain Injury Medicine; serving on the scientific advisory board of Myomo Inc., and onecare.ai Inc.; and receiving grants from the NIH. M.G.W. reported receiving grants from the NFLPA and the NIH during the conduct of the study. D.H.D. serves as an expert witness in legal cases involving brain injury and concussion; evaluates patients in the Massachusetts General Hospital Brain and Body–TRUST Program, which is funded by the NFLPA; and serves as an advisor and options holder for StataDx. R.G. received grant funding from the NFLPA.

No other disclosures were reported.

## Supplementary Material

Supplementary Data

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