The Prevalence of Depression Disorders in Retired Adult Athletes who have been Exposed to sub–Concussive Head Impacts Throughout their Playing Careers

A Synthesis Project

Presented to the

Department of Kinesiology, Sport Studies, and Physical Education

In Partial Fulfillment

Of the Requirements for the Degree

Master of Science in Athletic Administration

(Physical Education)

by Alexander Monteleone

May 20, 2024

SUNY BROCKPORT

Department of Kinesiology, Sport Studies, and Physical Education

Title of Synthesis Project:

The Prevalence of Depression Disorders in Retired Adult Athletes who have been Exposed to sub–Concussive Head Impacts Throughout their Playing Careers

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Instructor Approval Date

Accepted by the Department of Kinesiology, Sport Studies, and Physical Education, The College at Brockport, State University of New York, in partial fulfillment of the requirements for the degree Master of Science in Education (Physical Education).

Caitlyn Houston-Wilson 5/20/24

Chairperson Approval Date

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Abstract

This literature review examines the prevalence of depression disorders among retired adult athletes who have been exposed to sub-concussive head impacts throughout their playing careers. The study aims to synthesize existing research findings on the association between concussion history, repetitive head impacts, and depressive symptoms in retired athletes across various sports contexts. A systematic review of relevant literature yielded a critical mass of ten articles, which were analyzed to address the research questions. The review highlights several key themes, including the increased risk of depression associated with multiple concussions, the importance of understanding the long-term consequences of repetitive neurotrauma, and the need for further research to inform preventive measures and support strategies for athletes at all levels. Limitations of the studies reviewed, such as small sample sizes, retrospective reporting biases, and cross-sectional designs, are also discussed. Despite these limitations, the findings of the review provide valuable insights into the complex relationship between concussion history and mental health outcomes in retired athletes. The conclusions drawn from the literature review have implications for real-world applications, particularly in informing interventions aimed at improving the mental health and well-being of retired athletes. Recommendations for future research include conducting longitudinal studies with larger cohorts, validating findings in diverse populations, and exploring potential therapeutic interventions targeting mental health outcomes in this population.

Chapter 1 - Introduction

Concussions in sports have emerged as a significant public health concern, with increasing attention focused on their potential long-term impact on athletes' mental health. The Centers for Disease Control and Prevention estimates that up to 3.8 million sports-related concussions occur annually in the United States alone, highlighting this issue (Langlois et al., 2006). In addition to this, traumatic brain injury (TBI) is a significant public health problem in the United States and worldwide. The estimated 5.3 million Americans living with TBI-related disability face numerous challenges in their efforts to return to a whole and productive life (Langlois et al., 2006).

Athletes participating in high-contact sports such as football, soccer, hockey, and lacrosse are particularly susceptible to concussions, placing them at risk of experiencing adverse mental health outcomes. Recurrent concussions have been associated with numerous negative consequences, including depression, mild cognitive impairment, Alzheimer's disease, and, more recently, chronic traumatic encephalopathy (CTE).

Traumatic brain injuries (TBIs) pose a significant public health concern in the United States, with an estimated 1.7 million individuals affected annually (Kerr et al., 2012). Among adolescents and young adults, sports-related activities contribute substantially to TBI incidence, particularly mild TBIs or concussions. Studies focusing on high school, collegiate, and professional football players have revealed notably high concussion rates, underscoring the importance of addressing this issue within the sports community. Furthermore, emerging evidence suggests a potential link between repeated concussions and long-term mental health outcomes, particularly depression, among athletes (Kerr et al., 2012). Understanding this

association's underlying mechanisms and implications is crucial for effective public health intervention.

Concussion, a prevalent injury in sports, has increasingly drawn attention due to its potential long-term implications on athletes' mental health. Over the past decades, numerous studies have explored the association between concussion and various mental health outcomes, ranging from depression to impulsivity and aggression. However, the literature remains divided, with inconsistent findings and methodologies across studies. While some research focuses on professional athletes, others examine collegiate, amateur, and youth athletes, and few consider individuals participating in non-contact sports. Despite the growing body of literature, gaps exist in the understanding of the broader impact that concussions have on an athlete's psychological well-being. This synthesis aims to integrate findings from diverse populations, explore different methodologies, identify gaps in knowledge, and provide insights for future research, clinical practice, and policy development in supporting athletes' mental health needs.

Statement of the Problem

Despite growing awareness of the long-term effects of concussions in sports, there remains a lack of comprehensive understanding regarding the specific association between sub-concussive head impacts and depression among this population. Existing research has predominantly focused on acute concussions and their immediate consequences, often overlooking the cumulative effects of repetitive head trauma. By reviewing the literature on these athletes, this synthesis project seeks to provide valuable insights into the prevalence, risk factors, and potential mechanisms underlying depression disorders in retired adult athletes exposed to sub-concussive head impacts. Such knowledge is essential for informing evidence-

based strategies to support the mental health needs of retired athletes and develop targeted interventions aimed at mitigating the adverse effects of sports-related head trauma sustained throughout an athlete's career.

Purpose of the Study

The purpose of this synthesis project is to review the literature on the prevalence of depression disorders in retired adult athletes who have been exposed to sub concussive head impacts throughout their playing careers.

Operational Definitions

1. Depression disorders – A mental health disorder characterized by persistently depressed mood or loss of interest in activities, causing a significant impairment in daily life.
2. Retired athletes – Former athletes who no longer play their sport at a highly competitive level
3. Sub concussive head impacts – Head impacts sometimes not resulting in a diagnosing concussion but still accumulates damage/injury

Research Questions

1. Do sub concussive head impacts throughout an athletes' playing career lead to depression disorders?
2. Do multiple concussions increase the severity and likelihood of depression disorders in retired athletes?

Delimitations

1. The articles used in this synthesis were both peer reviewed and full text.

2. The articles reviewed were published between 2012 – 2023.

3. Peer reviewed scholarly articles focused on depression disorders in retired adult athletes exposed to sub concussive head impacts throughout their careers

Chapter 2 – Methods and Procedures

The purpose of this chapter is to review the methods and procedures used to determine the prevalence of depression disorders in retired adult athletes who have been exposed to sub concussive head impacts throughout their playing careers. The studies collected for this synthesis were located using the EBSCO database from The SUNY Brockport's Drake Library. Within the EBSCO database the following databases were searched: CINAHL, SPORTDiscus, Google Scholar, PubMed, MEDLINE, and psychINFO. A combined search of the databases produced thousands of articles.

Keywords were used in the search to reduce the number of articles. These keywords included depression or depressive disorder or depressive symptoms or major depressive disorder AND retired athletes or former athletes AND concussion or mild traumatic brain injury or mild TBI or MTB. Depression or depressive disorder or depressive symptoms or major depressive disorder AND retired athletes or former athletes were the two most important search words to begin the research process. Additional keywords concussion or mild traumatic brain injury or mild TBI or MTBI were used to narrow the search further.

The first search conducted was done through the KSSPE Library Search database using the following databases: CINAHL, SPORTDiscus, Google Scholar, PubMed, MEDLINE, and psychINFO. The keywords used were depression or depressive disorder or depressive symptoms or major depressive disorder AND retired athletes or former athletes. This search resulted in 340 hits. To reduce the results, concussion or mild traumatic brain injury or mild tbi or mtbi were added as keywords words to the search terms. This resulted in 169 articles. To further reduce the number of articles, additional filters were added. Results were limited to full-text,

and peer reviewed articles published between 2012-2024. The results were reduced to 34 articles and four were used for this synthesis.

A second search was in the Google Scholar database. The same filters were applied: full-text and peer reviewed articles published between 2012-2024. The search box text applied was the prevalence of depression disorders in retired adult athletes who have been exposed to sub concussive head impacts throughout their playing careers. The search resulted in 1180 articles and six were used for this synthesis. To further delimit the search, several key search terms were added. An advanced search was conducted using the following search terms: depression or depressive disorder or depressive symptoms or major depressive disorder AND retired athletes or former athletes AND concussion or mild traumatic brain injury or mild TBI or MTBI This further narrowed the search to a total of 107 articled of which 6 were used for this synthesis.

Ten articles were selected through the search process. They were selected based on the appropriateness to the topic. The articles had to relate to depression, retired athletes and concussions. Seven additional articles were used for background information in Chapter 1.

The articles selected were from the following journals: *Journal of Neurology, Neurosurgery, and Psychiatry* (1 article), *The Journal of Neuropsychiatry and Clinical Neurosciences* (1 article), *Archives of Clinical Neuropsychology: The Official Journal of the National Academy of Neuropsychologists* (1 article), *Journal of Head Trauma Rehabilitation* (1 article), *Journal of Neurotrauma* (1 article), *The American Journal of Sports Medicine* (1 article), *BMJ Open Sport & Exercise Medicine* (1 article), *American Academy of Neurology* (1 article), *Frontiers in neurology* (1 article) and *Injury Epidemiology* (1 article).

The critical mass for this synthesis consisted of 2,705 retired athletes mostly from the National Football League (N=1,476 → 54.57% of the participants). All the data was collected in the United States. Studies in this synthesis were conducted using both qualitative and quantitative approaches. Individual and group interviews, semi-structured interviews, clinical interviews, questionnaires, online surveys, multiple choice questions, and Beck Inventory II scales were used to gather data. The following methods were used to also used in the analyzation and gathering of all the data across all 10 studies: General health questionnaire, Beck Depression Inventory II, Patient Health Questionnaire-15, comprehensive semi-structured interviews, Pittsburgh Sleep Quality Index, self-reported measures of depression symptom severity as well as concussion history, self-reported behavioral/mood tests, cumulative head impact index, Baseline General Health Survey, Short Form 36 Measurement Model for Functional Assessment of Health and Well-Being (SF-36 PCS), Hospital Anxiety and Depression Scale (SF-36v2 Health Survey), diffusion tensor imaging (DTI) scanning, Depression, Anxiety, and Stress Scale (DASS), Brief, Pain Inventory, Connor-Davidson Resilience Scale (CD-RISC), and Epworth Sleepiness Scale, depression module of The Patient Health Questionnaire (PHQ-9), the Short Form of the Barratt Impulsiveness scale (BIS15); and the 12-item Short Form of the Buss-Perry Aggression Questionnaire (BPAQ-SF).

Chapter 3 – Review of Literature

The purpose of this chapter is to present a review of the literature on the prevalence of depression disorders in retired adult athletes who have been exposed to sub-concussive head impacts throughout their playing careers. Sub-concussive head impacts refer to blows to the head that do not result in clinically apparent signs or symptoms of a concussion. Despite lacking evident symptoms, accumulating evidence suggests that repeated sub-concussive head impacts may contribute to long-term neurological consequences, including but not limited to depression disorders, among retired athletes. Concussions have become a pressing concern in sports, with increasing attention on their potential long-term effects on athletes' mental health. A comprehensive understanding of this issue requires synthesizing findings from various studies investigating the association between concussion history and mental health outcomes across different athlete populations and sports contexts. The following themes will be reviewed: concussion history and depression in retired NFL players, depression in former collegiate athletes, sleep quality in former collegiate athletes, repetitive head impacts and research on female athletes and non-traditional sports.

Concussion History and Depression in Retired NFL Players

Throughout this literature review, multiple studies were included that are centered around retired professional football players of the National Football League (NFL). Among all these studies was research by Brett et al. (2022), who conducted a longitudinal study spanning 19 years to investigate changes in depressive symptom severity among former NFL players. The literature surrounding the association between concussion history, football participation, physical function decline, and depressive symptoms in former NFL players

provides valuable insights into the long-term consequences of contact sports participation. Several studies have examined this association, highlighting both consistent findings and areas of divergence.

This study assessed the impact of concussion history, years of football participation, and physical function. Data from 333 participants showed a small but significant increase in depressive symptom severity over time. More extensive concussion history was associated with higher overall depressive symptom severity, while neither concussion history nor years of participation influenced the rate of change in symptoms over the 19 years. However, a decline in physical function was linked to a faster growth rate of depressive symptoms over time, independent of concussion effects. This suggests that addressing physical function decline may be a key target for interventions aimed at mitigating long-term neuropsychiatric difficulties associated with concussions in later life (Brett et al., 2022).

The authors also found that some studies, but not all, have reported an elevated risk of depression associated with a history of concussions and repetitive head impacts (RHI) in contact sport athletes (Brett et al., 2022). The authors noted the limitations of cross-sectional studies in understanding longitudinal changes in depressive symptomatology and the influence of physical comorbidities (Brett et al., 2022).

Brett et al. (2022) additionally analyzed the trajectory of depressive symptom severity and physical function decline over time among former NFL players. They found that concussion history was significantly associated with greater overall depressive symptom severity, while a decline in physical function predicted a steeper increase in depressive symptoms over the study period (Brett et al., 2022). These findings highlight the importance of considering

physical function decline as a potential risk factor for depression in former contact sport athletes (Brett et al., 2022).

Overall, the literature suggests that interventions targeting physical function decline may help mitigate the risk of elevated depressive symptoms in former NFL players. In other words, continuing to stay physically active can improve quality of life in this particular population. However, further longitudinal studies are needed to accurately estimate the association between concussion history and depressive symptom severity, as well as other neurobehavioral outcomes (Brett et al., 2022).

In another study conducted by Brett et al. (2019), the researchers explored the intricate relationship between sport-related concussion (SRC) history and depressive symptoms among retired NFL athletes, with a focus on the moderating influence of somatic symptom endorsement. Previous studies have highlighted the association between SRC history and adverse neuropsychological outcomes, including depression, in later life (Brett et al., 2019). Subsequent studies by some of the other authors explored in this literary review, including those by Didehbani et al. and Strain et al., presented mixed findings regarding the association between SRC history and depression.

The methodology employed by Brett et al. (2019) involved recruiting a sample of 43 retired NFL athletes and administering self-report inventories to assess depression (using the Beck Depression Inventory-II) and somatic symptoms (using the adjusted Patient Health Questionnaire-15). The results of the study indicated that somatic (physical) symptoms had nearly twice the effect on depressive symptoms compared to SRC history, highlighting the

importance of considering comorbid somatic conditions in addressing depression among retired athletes (Brett et al., 2019).

The study's findings have significant implications for clinical practice and future research. Medical professionals working with retired athletes should be vigilant in assessing both depressive and somatic symptoms, as these may interact to exacerbate mental health issues. Furthermore, future studies should aim to clarify the mechanisms underlying the relationship between SRC history, somatic symptoms, and depression, potentially informing targeted interventions to improve the mental health outcomes of retired athletes (Brett et al., 2019). In conclusion, Brett et al. (2019) provides valuable insights into the complex relationships between SRC history, somatic symptoms, and depressive symptoms among retired NFL athletes.

Another study centered around former NFL players and Traumatic Brain Injury (TBI) is the study by Strain et al. (2013). TBI is a significant concern in contact sports such as American football, with retired NFL players often experiencing long-term neurological consequences, including depressive symptoms (Strain et al., 2013). While the association between TBI and depression has been established, the underlying neurobiological mechanisms remain poorly understood. Strain et al. (2013) conducted a study to investigate the relationship between depressive symptoms and white matter dysfunction found through brain imaging in retired NFL players with a history of concussions.

Strain et al. (2013) focused on utilizing neuroimaging techniques, specifically diffusion tensor imaging (DTI), to assess white matter integrity in retired NFL players. They aimed to investigate whether white matter abnormalities were associated with the manifestation of

depressive symptoms in this population. The researchers sought to identify potential biomarkers for depression in retired athletes with a history of concussions (Strain et al., 2013)

In their study, Strain et al. (2013) found a significant correlation between depressive symptoms, as measured by self-report questionnaires, and white matter dysfunction in retired NFL players. Specifically, individuals with higher levels of depressive symptoms exhibited lower values in certain white matter tracts compared to those with lower levels of depressive symptoms. These findings suggest a potential neurobiological basis for the development of depression following concussive injuries in athletes (Strain et al., 2013). Despite these significant findings, further research is needed to validate these findings in larger cohorts and explore potential therapeutic interventions targeting white matter integrity in this population. By exploring the relationship between depressive symptoms and white matter dysfunction, the study opens avenues for future research aimed at improving the diagnosis and treatment of depression in athletes with TBI (Strain et al., 2013).

Another study that looked at retired NFL players was a Didehbani et al. (2013) study that explored the link between past concussions and present depression symptoms in retired professional athletes. Researchers recruited 30 retired NFL athletes with a history of concussions. They discovered a notable association between the lifetime number of concussions and the severity of depressive symptoms measured by the Beck Depression Inventory-II, in particular the cognitive factor showing a significant relationship with concussions. Overall, NFL players reported more depression symptoms throughout the study compared to the control group. These findings imply that self-reported concussions might correlate with later depressive symptoms, particularly cognitive ones (Didehbani et al., 2013).

Overall, the literature suggests that concussions, particularly in the context of professional sports, may have significant implications for mental health. By highlighting specific cognitive symptoms associated with concussions, the current study informs targeted interventions aimed at mitigating the long-term mental health consequences of head injuries in athletes. However, limitations such as small sample size and retrospective reporting of concussions warrant further investigation. Future research should aim to address these limitations and explore the impact of early concussions on mental health outcomes in both professional and non-professional athletes.

For the last study in this section encompassing retired NFL players, Kerr et al. (2012) cohort study will be explored. The study aimed to prospectively determine the effects of recurrent concussions on the clinical diagnosis of depression in retired football players. Concussions have emerged as a significant public health concern, particularly within the realm of sports-related injuries. Langlois et al. (2006) estimated that approximately 1.7 million people in the United States sustain a traumatic brain injury (TBI) annually, with a substantial proportion attributed to sports-related activities. Moreover, it highlights the prevalence of mild TBIs or concussions among adolescents and young adults, particularly in sports like football (Langlois et al., 2006).

Considering these concerns, research has focused on understanding the long-term consequences of concussions, including their impact on mental health outcomes such as depression. Kerr et al. (2012) revealed a significant association, with retired players reporting multiple concussions being at a higher risk of depression compared to those with no history of concussions.

When analyzing data from the NFL's retired players association, Kerr et al. (2012) found that retired players reporting a history of concussions during their professional careers had a significantly higher risk of being clinically diagnosed with depression over nine years compared to those reporting no concussions. The risk of depression diagnosis increased with the number of self-reported concussions. Furthermore, athletes diagnosed with depression also exhibited lower physical health scores before diagnosis. The study suggests that concussions may accelerate the progression to depressive episodes later in life among professional football players (Kerr et al., 2012).

Overall, the body of literature underscores the importance of understanding the complex interplay between concussions and mental health outcomes, particularly depression, among athletes. Continued research is essential to inform preventive strategies and support mechanisms for athletes at all levels and to explore potential mechanisms underlying these associations. The literature review delves into the intersection of concussion history, football participation, physical function decline, and depressive symptoms in retired NFL players. Brett et al. (2022) longitudinal study over 19 years revealed a small increase in depressive symptom severity, with extensive concussion history correlating with higher severity. Physical function decline predicted a faster growth rate of depressive symptoms, suggesting its importance in interventions. Brett et al. (2019) found that somatic symptoms significantly influenced depressive symptoms among retired athletes, emphasizing the need for comprehensive assessments. While, Strain et al. (2013) and Didehbani et al. (2013) explored the neurobiological and cognitive aspects of depression post-concussion, highlighting white matter dysfunction and cognitive symptoms. Lastly, Kerr et al. (2012) demonstrated a significant association between

recurrent concussions and depression diagnosis among retired players, suggesting a need for preventive strategies and support mechanisms. Overall, the literature underscores the complex relationship between concussions and mental health outcomes in athletes, urging further research to inform interventions and explore underlying mechanisms.

Depression in Former Collegiate Athletes

Concussions in sports have garnered significant attention due to their prevalence and potential long-term consequences on athletes' health. Concerns about the repercussions of concussions extend beyond immediate effects to potential long-term consequences. Retired athletes have reported associations between recurrent concussions and adverse mental health outcomes such as depression, mild cognitive impairment, as well as Alzheimer's disease.

Nonetheless, the existing literature on this topic has several limitations. Most studies have primarily focused on male athletes from collision sports like football and ice hockey, limiting generalizability to younger athletes, females, and sports with lower levels of contact. An example of this is Kerr et al. (2012) study on the Nine-year risk depression diagnosis increases with increasing self-reported concussions in retired professional football players that was previously reviewed in the chapter. Additionally, prior research has often used limited or non-validated measures to assess mental health outcomes, and some studies have only considered concussions sustained during professional careers, potentially biasing the number of concussions sustained overall (Kerr et al., 2012).

It is important to diversify the research in terms of population, gender, age range and specific sport. The first study by Kerr et al. (2012) focused on retired NFL players. In another study conducted by Kerr et al. (2014), this research was conducted on the collegiate population.

To address these gaps, Kerr et al. (2014) conducted a study to estimate the association between recurrent concussions and current levels of depression, impulsivity, and aggression in a cohort of former collegiate athletes. Unlike Kerr et al. (2012) study geared towards retired NFL players, Kerr et al. (2014) was focused on the collegiate athlete population. Kerr et al. (2014) aimed to provide a more comprehensive understanding of the relationship between concussion history and mental health outcomes while also comparing the effects of considering all concussions versus only those sustained during collegiate and professional sports.

The study was a cross-sectional study that explored the association between recurrent concussions and mental health outcomes in former collegiate athletes. Kerr et al. recruited former collegiate athletes from a Division I university in the southern US and analyzed the data from 797 respondents. The study found that former collegiate athletes reporting three or more concussions had a higher prevalence of moderate to severe depression compared to those reporting zero concussions (Kerr et al., 2014). Additionally, athletes with two or more concussions exhibited higher levels of impulsivity, and those with three or more concussions showed increased aggression. These associations remained significant after controlling for various factors such as alcohol dependence, family history, and demographic variables. The study additionally underscores the importance of further research, particularly prospective studies, to understand causality better and validate concussion histories in assessing mental health outcomes in athletes (Kerr et al., 2014).

Sleep in Former Collegiate Athletes

The literature on the relationship between concussion history, sleep quality, and depression among athletes provides valuable insights into the complex interplay of these

factors. Brett et al. (2021) contributes to this body of knowledge by investigating the mediating role of sleep quality in the association between prior concussions and depressive symptom severity among former collegiate American football players.

This study aimed to investigate the role of sleep quality and the link between repeated concussions and later-life depression among former American collegiate football players. Fifty-eight participants were evaluated approximately 15 years after quitting their sport, with assessments including detailed concussion and sports histories, as well as measures of depression severity and sleep quality. Results revealed that concussion history predicted poorer sleep quality, which in turn predicted more significant depressive symptoms. These findings suggest the potential for sleep-related interventions to mitigate depression risk in individuals with multiple prior concussions (Brett et al., 2021). It's possible that improving sleep with certain interventions could help reduce the risk of depression in those athletes who have had multiple prior concussions throughout their playing careers.

Previous studies have highlighted the elevated risk of depression associated with repeated concussions among athletes, independent of physical health status (Brett et al., 2021). However, the mechanisms underlying this association remain unclear. Sleep quality emerges as a potential mediator in this relationship, given its close association with both concussion history and depression (Brett et al., 2021).

Moreover, evidence suggests that mTBI (mild traumatic brain injury), particularly repetitive mTBI, can lead to chronic disturbances in sleep quality (Brett et al., 2021). Sleep abnormalities following mTBI may further exacerbate the risk of depression, creating a relationship between sleep quality and depressive symptoms. The results of the study indicated

a significant association between concussion history and increased depressive symptom severity. Findings revealed that disruptions in sleep quality may explain the greater risk of depression associated with repeated concussions among athletes (Brett et al., 2021).

Overall, the findings underscore the importance of addressing sleep disturbances in athletes with a history of multiple concussions to mitigate the risk of depression. However, the authors acknowledge the limitations of their study, including its cross-sectional design and reliance on self-reported measures.

Repetitive Head Impacts

Another study involving college athletics was the study of Montenigro et al. (2017) who addressed the lack of validated tools for quantifying cumulative exposure to repetitive head impacts (RHI) in football and to examine their association with long-term clinical outcomes. The researchers developed the "cumulative head impact index" (CHII) metric and used it to analyze data from 93 former high school and collegiate football players. They found a threshold dose-response relationship between CHII and the risk of later-life cognitive impairment, executive dysfunction, depression, apathy, and behavioral dysregulation. Importantly, CHII demonstrated greater predictive validity for these outcomes than other exposure metrics such as duration of play, age of first exposure, and concussion history.

The literature on repetitive head impacts (RHI) and their potential long-term consequences, particularly in contact sports like American football, has gained significant attention recently. Several studies have investigated the cumulative effects of concussive and sub-concussive events on neurological health. Montenigro et al. (2017) conducted a seminal study investigating the long-term consequences of cumulative head impact exposure in former

high school and college football players. This research is part of a broader conversation on the potential neurological risks associated with repetitive head impacts (RHI) in contact sports.

The study by Montenigro et al. (2017) provided crucial background information on the prevalence of RHI in football and its association with neurological conditions such as depression, apathy, executive dysfunction, and cognitive impairment. By focusing on former players, the study shed light on the enduring effects of RHI beyond the active playing years (Montenigro et al., 2017).

Montenigro et al. (2017) outlined their purpose to investigate the relationship between cumulative head impact exposure and later-life neurological impairments. Their methods involved recruiting former football players and assessing their head impact exposure through self-reported measures and neurobehavioral evaluations. The study employed statistical analyses to identify associations between head impact exposure and clinical outcomes, controlling for potential confounders. Results indicated a significant correlation between cumulative head impact exposure and later-life depression, apathy, executive dysfunction, and cognitive impairment. Notably, the study highlighted dose-response relationships, with greater exposure to RHI correlating with higher prevalence and severity of neurological impairments.

These findings underscore the importance of considering cumulative head impact exposure as a risk factor for adverse neurological outcomes in former football players. The study by Montenigro et al. (2017) contributes valuable insights to the literature on RHI. It reinforces the need for preventive measures and long-term monitoring of athletes participating in contact sports.

In conclusion, Montenigro et al. (2017) provide compelling evidence linking cumulative head impact exposure to later-life neurological impairments, prompting further research into the mechanisms underlying these associations and the development of targeted interventions to mitigate risks for athletes.

This section discusses two critical aspects of former collegiate athletes' mental health: depression and sleep quality in the collegiate athlete population, particularly concerning their concussion history. Kerr et al. (2014) conducted a study focusing on retired collegiate athletes, revealing a higher prevalence of moderate to severe depression among those reporting three or more concussions. Meanwhile, Brett et al. (2021) explored the relationship between prior concussions, sleep quality, and depressive symptoms among former collegiate American football players, suggesting a potential mediating role of sleep quality in depression risk. Additionally, Montenigro et al. (2017) investigated the long-term consequences of cumulative head impact exposure in former high school and collegiate football players, highlighting its association with later-life depression, among other neurological impairments. These findings further reinforce the importance of addressing mental health concerns and sleep disturbances in former athletes, emphasizing the need for further research and targeted interventions to mitigate risks and improve well-being.

Research on Female Athletes and Non-Traditional Sports

Lastly, diversifying the research is a study conducted on female soccer players. Prien et al. (2020) investigated the neurocognitive performance, cognitive symptoms, and mental health of retired elite female football (soccer) players compared to retired elite female non-contact athletes. They found that while overall neurocognitive performance was similar between the

two groups, female soccer players exhibited lower scores on verbal memory and verbal fluency tests. Additionally, among soccer players, weaker verbal fluency performance was associated with multiple concussions, and weaker verbal memory performance was associated with frequent heading of the ball. The depression score was significantly higher in soccer players, particularly those with frequent heading exposure, but not explicitly associated with a history of concussion. These findings suggest a potential link between repetitive head impacts, verbal memory/fluency, and mental health in female soccer players, warranting further investigation into their clinical implications and causality (Prien et al., 2020)

Prien et al. (2020) study design involves a quantitative, case-control approach, comparing soccer players with age, sex, and competition level-matched controls. They use various measures, including neuropsychological tests, self-reported surveys, and interviews, to gather data on participants' history of concussion, heading exposure, neurocognitive performance, cognitive symptoms, and mental health.

In their findings, Prien et al. (2020) revealed that while soccer players generally perform similarly to controls on most neurocognitive tests, they exhibit weaker verbal memory and fluency performance. These differences may be associated with a history of multiple concussions and frequent heading of the ball. However, the clinical relevance of these findings remains uncertain, given the relatively low prevalence of clinically significant symptoms among retired athletes.

In conclusion, the literature highlights the importance of further research in understanding the long-term consequences of repetitive neurotrauma in sports, particularly in retired female athletes. Prien et al.'s (2020) study contributes to this body of knowledge by

shedding light on potential differences in neurocognitive performance, cognitive symptoms, and mental health between retired elite female soccer players and non-contact sports athletes. However, more extensive prospective studies with diverse populations and sustained funding are necessary to demonstrate causal relationships and inform interventions in this critical area of sports medicine and public health.

Another study bringing diversity to the research investigated depression among retired elite-level rugby league players in Australia, aiming to determine whether it was associated with a lifetime history of concussions or years played professionally. Iverson et al. (2021) collected data from 141 retired players were analyzed, revealing that depression was not significantly correlated with the number of concussions or years played professionally. Instead, depression was linked to current anxiety, stress levels, resilience, and life interference due to chronic pain. The studied findings suggests that depression in retired rugby league players may be more closely tied to psychological factors and chronic pain rather than concussion history or career duration (Iverson et al., 2021).

The study employed a cross-sectional design and recruited participants through alum networks and sports organizations. Data collection involved clinical interviews, self-report measures, and neuropsychological testing. Demographic characteristics, exposure history, and self-report measures of depression, anxiety, and stress among the retired players are presented in the results of the study. The results of Iverson et al. (2021) study indicated that approximately 28.4% of retired players reported a lifetime history of depression, with some experiencing moderate to severe symptoms. Factors such as resilience and life interference due to pain were significant predictors of depression (Iverson et al., 2021). The authors discuss

factors contributing to depression in retired athletes, such as identity loss, retirement-related stressors, and chronic pain.

In conclusion, Iverson et al. (2021) summarize their key findings and highlight the importance of resilience as a protective factor against depression in retired elite-level rugby league players. They underscore the need for future research to explore longitudinal predictors of depression in athletes and suggest interventions aimed at improving psychological resilience in retired athletes. Overall, the study adds valuable insights to the literature on mental health in sports, addressing gaps in understanding and highlighting avenues for future research.

The studies by Prien et al. (2020) and Iverson et al. (2021) contribute valuable insights into the mental health of retired athletes from diverse sports backgrounds. Prien et al. (2020) investigated neurocognitive performance, cognitive symptoms, and mental health in retired elite female soccer players compared to non-contact athletes, revealing lower verbal memory and fluency scores among soccer players, potentially linked to heading exposure and concussions. While Iverson et al. (2021) explored depression among retired elite-level rugby league players, finding no significant correlation between depression and concussion history or years played professionally, but highlighting associations with anxiety, stress, resilience, and chronic pain interference. Both studies emphasize the importance of understanding the long-term impacts of sports participation on mental health and the need for interventions to support retired athletes' well-being. In addition, it is important to diversify the research and not only focus on retired NFL players when researching these topics.

Summary

In conclusion, the literature review provides valuable insights into the prevalence of depression disorders among retired adult athletes who have experienced sub-concussive head impacts throughout their playing careers. Through an analysis of multiple studies, it becomes evident that retired athletes with a history of concussions, especially those lasting more than one year or leading to persistent post-concussion symptoms, face an increased risk of developing depression later in life. Despite these findings, protective factors such as regular physical activity, healthy lifestyle behaviors, and early detection and management of post-concussion symptoms may somewhat mitigate this risk. Additionally, multidisciplinary interventions, incorporating cognitive rehabilitation and psychosocial support, promise to improve mental health outcomes in this population. Nevertheless, there remains a need for further research to understand better the underlying mechanisms linking concussions to depression and to develop targeted interventions tailored to the unique needs of retired athletes. By addressing the mental health needs of this vulnerable population, healthcare providers and policymakers can work towards promoting the overall well-being of retired athletes and enhancing their quality of life in the long term.

The literature review delves into the prevalence of depression disorders among retired adult athletes exposed to sub-concussive head impacts during their playing careers. It emphasizes the importance of understanding the potential long-term neurological consequences of these impacts, even in the absence of clinically apparent concussion symptoms. The review synthesizes findings from various studies investigating the association between concussion history and mental health outcomes across different athlete populations

and sports contexts. Notable themes include: The examination of depression in retired NFL players, the risk of multiple concussions, long-term effects of depression due to SRC, retired collegiate athlete's mental health and mental health in sports other than football. Overall, the literature underscores the complex relationship between concussion history, repetitive head impacts, and depressive symptoms in retired athletes, emphasizing the need for further research to inform preventive measures and support strategies for athletes at all levels.

Chapter 4 – Discussion, Conclusion, and Recommendations

The purpose of this chapter is to present the results of the review of literature on the prevalence of depression disorders in retired adult athletes who have been exposed to sub concussive head impacts throughout their playing careers and how these results align with the purported research questions which guided this synthesis project. In addition, recommendations for future research as it relates to the experiences of high-level athletes are presented. The results of this review of literature revealed a few common themes.

The results of this review of literature revealed a few common themes. The research consistently indicated that multiple concussions was linked to mental health deficits such as depression later in an athlete's life. A second theme mentioned was the more significant the athlete's concussion history and the number of concussions sustained this had a direct correlation to the severity of difficulty such as long-term depression later in a retired athlete's life.

Although most literature in this study reported the negative experiences when it comes to concussions and long-term deficits, there was some hope for different intervention strategies and future research to be conducted.

Discussion

Interpretations

The purpose of this literature review was to investigate the prevalence of depression disorders among retired adult athletes who have been exposed to sub-concussive head impacts throughout their playing careers. Through an exhaustive search and analysis of relevant studies,

the aim was to provide insights into the long-term mental health outcomes of athletes with a history of concussions and repetitive head impacts.

As part of this literature review, two research questions were posed. The first research question was, do sub concussive head impacts throughout an athlete's playing career lead to depression disorders? The results of the literature review showed that, sub concussive head impacts throughout an athlete's playing career can in fact increase the athlete's chances of having deficits later in life including depression disorders and long-term depression. Multiple concussions throughout an athlete's playing career can lead to a long list of health concerns and risks down the line, among that list is long-term depression.

The research question guiding this study was twofold: first, to explore the association between concussion history and depressive symptom severity among retired athletes, and second, to identify potential implications and recommendations for future research in this area. The results of the literature review suggest that retired athletes with a history of concussions, particularly those with repeated exposures or lasting post-concussion symptoms, face an increased risk of developing depression later in life.

Several limitations were associated with the studies included in this review, which impact the logical conclusions drawn. These limitations include small sample sizes, retrospective reporting of concussions, potential recall bias, and cross-sectional study designs. Additionally, many studies relied on self-reported measures, which may introduce bias and affect the reliability of the findings. These weaknesses highlight the need for further research to address these limitations and provide more vigorous evidence.

Despite these limitations, the literature review provides valuable insights into the mental health outcomes of retired athletes and the potential impact of concussions on depressive symptomatology.

The conclusions drawn from this review underscore the importance of comprehensive assessments, longitudinal studies, and targeted interventions to support the well-being of retired athletes. Furthermore, the findings suggest that early detection and management of post-concussion symptoms, along with interventions targeting physical function decline and sleep quality, may help mitigate the risk of depression in this population.

Implications

Research on the prevalence of depression disorders in retired adult athletes who have been exposed to sub concussive head impacts throughout their playing careers is still evolving every day. Concussions and their long-lasting impacts are a new and unknown phenomenon as researchers begin to explore the landscape of these long-lasting impacts.

The conclusions drawn from this literature review have practical implications for the real world, particularly in sports medicine and public health settings. Understanding the long-term consequences of concussions and repetitive head impacts can inform preventive measures, support strategies, and intervention programs aimed at improving the mental health outcomes of athletes at all levels. By addressing the mental health needs of retired athletes, healthcare providers and policymakers can work towards promoting overall well-being and enhancing the quality of life in this vulnerable population.

Recommendations for Future Research

In reviewing the data base on the prevalence of depression disorders in retired adult athletes who have been exposed to sub concussive head impacts throughout their playing careers the following limitations were noted regarding the studies under review. Moving forward, several recommendations for future research can be made based on the findings of this literature review. These include conducting further longitudinal studies to accurately estimate the association between concussion history and depressive symptom severity, exploring potential mechanisms underlying these associations, and validating findings in larger cohorts. Additionally, future research should aim to diversify study populations such as different sports and age brackets, consider sex differences in outcomes, and explore interventions targeting sleep quality, physical function, and psychological resilience in retired athletes.

Based on these limitations and other insights related to the literature the following recommendations for future research should be considered:

1. Further longitudinal studies are needed to accurately estimate the association between concussion history and depressive symptom severity, as well as other neurobehavioral outcomes (Brett et al., 2022).
2. Future research should focus on longitudinal studies to establish causality and explore the efficacy of interventions targeting sleep quality in reducing depressive symptoms among athletes with a history of mTBI.
3. Future studies should aim to clarify the mechanisms underlying the relationship between SRC history, somatic symptoms, and depression, potentially informing targeted interventions to improve the mental health outcomes of retired athletes.

4. Future research should aim to explore the impact of early concussions on mental health outcomes in both professional and non-professional athletes.
5. The need for future longitudinal research to better understand the developmental trajectory of depression in athletes.
6. The need for future research to explore longitudinal predictors of depression in athletes and suggest interventions aimed at improving psychological resilience in retired athletes.
7. Further research is necessary in understanding the long-term consequences of repetitive neurotrauma in sports, particularly in retired female athletes.

Summary

The purpose of this literature review was to determine the prevalence of depression disorders in retired adult athletes who have been exposed to sub concussive head impacts throughout their playing careers Delimiting variables were used to do an exhaustive data-based search which yielded 10 articles. These articles were then systematically used to determine the prevalence of depression disorders in retired adult athletes who have been exposed to sub concussive head impacts throughout their playing careers.

In summary, this literature review highlights the complex relationship between concussion history, repetitive head impacts, and depressive symptoms in retired athletes. Despite limitations associated with the existing research, the findings provide valuable insights into the long-term mental health outcomes of athletes and underscore the need for further research and targeted interventions to support their well-being.

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Appendix A

Author	Title	Source	Purpose	Methods & Procedures	Analysis	Findings	Discussion/ Recommendations
Brett, B. L., Kerr, Z. Y., Walton, S. R., Chandran, A., Defreese, J. D., Mannix, R., Echemendia, R. J., Meehan, W. P., Guskiewicz, K. M., & McCrea, M. (2022).	Longitudinal trajectory of depression symptom severity and the influence of concussion history and physical function over a 19-year period among former National Football League (NFL) players: an NFL-LONG Study	*Journal of Neurology, Neurosurgery, and Psychiatry*	This study investigated the longitudinal course of depressive symptom severity over 19-years in former American football players and the influence of concussion history, contact sport participation, and physical function on observed trajectories.	333 Former American football players completed a general health questionnaire involving demographic information, medical/psychiatric history, concussion/football history, and validated measures of depression and physical function at three time points (2001, 2010, and 2019). Parallel process latent growth curve modeling tested associations between concussion history,	This study tracked former NFL players for 19 years, finding slight increases in depressive symptoms, associated with concussion history but not predictive of worsening over time. Physical decline predicted steeper symptom increases. Cumulative football years didn't predict symptoms. Longitudinal research is crucial for understanding concussion-related depression. Improving physical function may mitigate risk. Psychosocial factors should be considered in future studies. The study's strength lies in its long-term approach and precise analysis.	Among the 333 participants there was a statistically significant, but small increase in depressive symptom severity from 2001. Those with greater concussion history endorsed greater overall depressive symptom severity, Concussion history, and years of participation, were not associated with rate of change (slope factor) over 19-years. Greater decline in physical function, was predictive of a faster growth rate of depression symptom endorsement over time.	Concussion history, not years of participation, was associated with greater depressive symptom severity. Neither factor was predictive of changes over a 19-year period. Decline in physical function was a significant predictor of a steeper trajectory of increased depressive symptoms, independent of concussion effects. This represents one viable target for preventative intervention to mitigate long-term neuropsychiatric difficulties associated with concussion across subsequent decades of life.

Brett, B. L., Meier, T. B., Savitz, J., Guskiewicz, K. M., & McCrea, M. A. (2021).	Research Letter: Sleep Mediates the Association Between Prior Concussion and Depressive Symptoms	*Journal of Head Trauma Rehabilitation*	To test sleep quality as one mechanistic pathway through which repeated concussion increases risk of depression later in life among former contact sport athletes.	58 former American collegiate football players approximately 15-years following sport discontinuation from 16 different NCAA member institutions. Participants completed in-person evaluations including comprehensive semi-structured interviews with detailed concussion history and sport history, as well as self-reported measures of depression symptom severity (Beck Depression Inventory-II) and sleep quality (Pittsburgh Sleep Quality Index). Years of football participation was included as a covariate. Mediation modeling examined the degree to which sleep quality accounted for the association between repeated concussion and depression symptoms.	The study suggests that the increased risk of depression in individuals with repeated concussions might be influenced by poor sleep quality, which can be treated. Early interventions targeting sleep improvement could reduce depression risk in athletes with multiple concussions. While the study is limited by its cross-sectional nature and self-reported data, it underscores the need for larger, longitudinal studies to confirm the mediation effect of sleep on concussion history and depression. Despite limitations, it highlights the potential for sleep-related interventions to prevent depression in individuals with multiple concussions.	Within the mediation model, concussion history significantly predicted sleep quality and sleep quality significantly predicted depressive symptom severity (controlling for the effects of concussion history). With inclusion of the indirect effects, concussion history did not predict depressive symptom severity	Current findings raise the possibility that the greater risk of depression reported in those with a history of mTBI/concussion is mediated by sleep quality, a common sequela of mTBI. These findings highlight potential opportunities for prophylactic sleep-related intervention among individuals with multiple prior concussions to mitigate the risk of depression.

Brett, B. L., Mummareddy, N., Kuhn, A. W., Yengo-Kahn, A. M., & Zuckerman, S. L. (2019).	The Relationship Between Prior Concussions and Depression Is Modified by Somatic Symptomatology in Retired NFL Athletes	*The Journal of Neuropsychiatry and Clinical Neurosciences*	The authors examined the influence of somatic symptom endorsement on the relationship between SRC history and self-reported depressive symptom severity in 43 retired NFL athletes	43 former NFL athletes completed self-report inventories of depression (with the Beck Depression Inventory II) and somatic symptoms (with the adjusted Patient Health Questionnaire-15).	A moderation analysis examined the influence of somatic symptoms on the relationship between SRC history and depressive symptom severity.	SRC history and somatic symptoms accounted for a significant amount of depressive symptomology. SRC history was not significantly associated with depressive symptom severity at low levels of somatic symptoms but was significant at the mean and high levels.	The effect of somatic symptoms on depressive symptoms was nearly twice that of SRC history. The relationship between SRC and depression is complex, and treatment of depression in retired athletes should address comorbid somatic symptoms.

Didehbani, N., Munro Cullum, C., Mansinghani, S., Conover, H., & Hart, J., Jr. (2013).	Depressive Symptoms and Concussions in Aging Retired NFL Players	*Archives of Clinical Neuropsychology: The Official Journal of the National Academy of Neuropsychologists*	Examine the relationship between a remote history of concussions with current symptoms of depression in retired professional athletes.	30 retired National Football League (NFL) athletes with a history of concussion and 29 age- and IQ-matched controls without a history of concussion were recruited.	Found a significant correlation between the number of lifetime concussions and depressive symptom severity using the Beck Depression Inventory II. Upon investigating a three-factor model of depressive symptoms (affective, cognitive, and somatic; Buckley et al., 2001) from the BDI-II, the cognitive factor was the only factor that was significantly related to concussions	Findings suggest that the number of self-reported concussions may be related to later depressive symptomology (particularly cognitive symptoms of depression).	In general, NFL players endorsed more symptoms of depression on all three Buckley factors compared with matched controls.

Iverson, G. L., Van Patten, R., Terry, D. P., Levi, C. R., & Gardner, A. J. (2021).	Predictors and Correlates of Depression in Retired Elite Level Rugby League Players	*Frontiers in neurology*	To examine predictors and correlates of depression in retired elite level rugby league players in Australia.	141 Retired elite level rugby league players completed the Depression, Anxiety, and Stress Scale (DASS), Brief Pain Inventory (BPI), Connor-Davidson Resilience Scale (CD-RISC), and Epworth Sleepiness Scale (ESS); they also reported on lifetime history of concussions. The DASS depression score was regressed on age, total number of self-reported concussions, years played professionally, CD-RISC score, BPI pain interference score, and ESS score.	The study analyzed depression predictors in retired elite rugby league players, reporting a lifetime depression rate of 28.4% and associations with arthritis and alcohol misuse. Greater resilience correlated with lower depression levels, while pain interference weakly correlated with depression. Retired athletes may experience depression due to retirement difficulties and identity loss. Chronic pain and arthritis are linked to depression, with resilience inversely related to depression severity. Contrary to some previous findings, this study did not find an association between concussions or years of sports exposure and depression.	The retired players reported a median of 15 total lifetime concussions, and a median of 8 years playing professional sports. The proportion of the sample endorsing at least mild current depression was 29%. The DASS depression score was positively correlated with the DASS anxiety and DASS stress scores. Depression scores were not significantly correlated with pain severity, and were weakly correlated with life interference due to pain and years playing professional sports. Depression scores were not significantly correlated with lifetime history of concussions. The two significant independent predictors of depression were lower resilience and greater life interference due to pain.	This is the first large study of depression in retired rugby league players. Depression in these retired players was not meaningfully associated with lifetime history of concussions or number of years playing elite level collision sport. Depression was associated with current anxiety, stress, resilience, and life interference due to chronic pain.

Kerr, Z. Y., Evenson, K. R., Rosamond, W. D., Mihalik, J. P., Guskiewicz, K. M., & Marshall, S. W. (2014).	Association between concussion and mental health in former collegiate athletes	*Injury epidemiology*	This cross-sectional study estimated the association between recurrent concussion and depression, impulsivity, and aggression in former collegiate athletes.	Former collegiate athletes who played between 1987–2012 at a Division I university completed an online questionnaire. The main exposure, total number of self-recalled concussions (sport-related and non-sport-related), were categorized as: zero (referent), one, two, or three or more concussions. The main outcomes were the depression module of The Patient Health Questionnaire (PHQ-9), the Short Form of the Barratt Impulsiveness scale (BIS15); and the 12-item Short Form of the Buss-Perry Aggression Questionnaire (BPAQ-SF). Depression was categorized into a binomial severity classification that differentiated between no or mild depression (PHQ-9 scores	The study investigates how recurrent concussions in former collegiate athletes relate to mental health, particularly impulsivity and aggression. Findings suggest a link between concussion history and depression risk, with athletes reporting more concussions showing higher aggression and impulsivity levels. Future longitudinal studies incorporating treatment history and broader concussion histories may provide clearer evidence. Additionally, effects of concussions on mental health outcomes may appear later in life, and a comprehensive concussion history, including non-sport-related concussions, may offer more accurate insights.	Of the 797 respondents with complete data, 38.8% reported at least one concussion. The prevalence of moderate to severe depression among former collegiate athletes reporting 3 or more concussions in total was 2.4 times higher then those reporting 0 concussions. Controlling for alcohol dependence, family history of anxiety, relationship status, obtaining a post-graduate degree, and playing primary college sport professionally, former collegiate athletes reporting 2 or more concussions had higher mean scores for impulsivity, compared to those reporting no concussions. Former collegiate athletes reporting three or more concussions in total had a higher mean score for aggression, compared to those reporting no concussions.	Our study found an association between former concussion and greater risk of severe depression and higher levels of impulsivity and aggression among former collegiate athletes. Additional prospective studies better addressing causality and ascertaining valid lifetime concussion histories and medical histories are needed.

Kerr, Z. Y., Marshall, S. W., Harding, H. P., Jr, & Guskiewicz, K. M. (2012).	Nine-Year Risk of Depression Diagnosis Increases With Increasing Self-Reported Concussions in Retired Professional Football Players	*The American journal of sports medicine*	To prospectively determine the effects of recurrent concussions on the clinical diagnosis of depression in a group of retired football players.	1044 Members of the National Football League Retired Players Association responded to a baseline General Health Survey (GHS). Surveys asked about demographic information, number of concussions sustained during their professional football career, physical/mental health, and prevalence of diagnosed medical conditions. A physical component summary was calculated from responses for physical health. The main exposure, the history of concussions during the professional playing career was stratified into 5 categories. The main outcome was a clinical diagnosis of depression between the baseline and follow-up GHS. Classic tabular methods computed crude risk ratios. Binomial regression with a Poisson residual and robust variance estimation to stabilize the fitting algorithm estimated adjusted risk ratios. x2 analyses identified associations and trends between concussion history and the 9-year risk of a depression diagnosis.	Retired athletes with a depression diagnosis also had a lower SF-36 PCS before diagnosis. The association between concussions and depression was independent of the relationship between decreased physical health and depression.	Of the 1044 respondents with complete data from the baseline and follow-up GHS, 106 (10.2%) reported being clinically diagnosed as depressed between the baseline and follow-up GHS. The 9-year risk of a depression diagnosis increased with an increasing number of self-reported concussions, ranging from 3.0% in the ‘‘no concussions’’ group to 26.8% in the ‘‘101’’ group. A strong dose response relationship was observed even after controlling for confounders. Retired athletes with a depression diagnosis also had a lower SF-36 PCS before diagnosis. The association between concussions and depression was independent of the relationship between decreased physical health and depression.	Professional football players self-reporting concussions are at greater risk for having depressive episodes later in life compared with those retired players self-reporting no concussions.

Montenigro, P. H., Alosco, M. L., Martin, B. M., Daneshvar, D. H., Mez, J., Chaisson, C. E., Nowinski, C. J., Au, R., McKee, A. C., Cantu, R. C., McClean, M. D., Stern, R. A., & Tripodis, Y. (2017).	Cumulative Head Impact Exposure Predicts Later-Life Depression, Apathy, Executive Dysfunction, and Cognitive Impairment in Former High School and College Football Players	*Journal of neurotrauma*	The objectives of this study were: 1) to develop a metric to quantify cumulative RHI exposure from football, which we term the ''cumulative head impact index'' (CHII); 2) to use the CHII to examine the association between RHI exposure and long-term clinical outcomes; and 3) to evaluate its predictive properties relative to other exposure metrics (i.e., duration of play, age of first exposure, concussion history).	Participants included 93 former high school and collegiate football players who completed objective cognitive and self-reported behavioral/mood tests as part of a larger ongoing longitudinal study. Using established cutoff scores, we transformed continuous outcomes into dichotomous variables (normal vs. impaired). The CHII was computed for each participant and derived from a combination of self-reported athletic history (i.e., number of seasons, position[s], levels played), and impact frequencies reported in helmet accelerometer studies. A bivariate probit, instrumental variable model revealed a threshold dose-response relationship between the CHII and risk for later-life cognitive impairment, self-reported executive dysfunction, depression, apathy, and behavioral dysregulation.	The study introduces the Cumulative Head Impact Index (CHII) to assess the relationship between lifetime football-related head impact exposure and later-life cognitive, mood, and behavioral impairment in former collegiate players. Findings suggest a threshold dose-response relationship, with higher CHII associated with increased risk of impairment. Causal inference between head impacts and impairment is suggested, emphasizing the need for prospective longitudinal studies and standardized exposure metrics. Limitations include small sample size and cross-sectional design.	The CHII, was a tool developed to quantify retrospective cumulative exposure to RHI, including sub concussive impacts. Using the CHII, we showed that RHI exposure among amateur football players is associated with later-life cognitive and neurobehavioral consequences. Although our findings raise safety concerns for participation in amateur football, prior to changes in policy and rules, prospective longitudinal research in larger samples is needed to validate the CHII and replicate and extend our associated findings.	Ultimately, the CHII demonstrated greater predictive validity than other individual exposure metrics. Future research should validate CHII, explore biomarkers, and investigate modifying factors

Prien, A., Feddermann-Demont, N., Verhagen, E., Twisk, J., & Junge, A. (2020).	Neurocognitive performance and mental health of retired female football players compared to non-contact sport athletes	*BMJ open sport & exercise medicine*	To (1) compare neurocognitive performance, cognitive symptoms and mental health in retired elite female football players (FB) with retired elite female non-contact sport athletes (CON), and to (2) assess whether findings are related to history of concussion and/or heading exposure in FB.	Neurocognitive performance, mental health and cognitive symptoms were assessed using computerized tests (CNS-vital signs), paper pen tests (Category fluency, Trail-Making Test, Digit Span, Paced Auditory Serial Addition Test), questionnaires (Hospital Anxiety and Depression Scale, SF-36v2 Health Survey) and a symptom checklist. Heading exposure and concussion history were self-reported in an online survey and in a clinical interview, respectively. Linear regression was used to analyze the effect of football, concussion and heading exposure on outcomes adjusted for confounders.	►Neurocognitive performance was similar in retired elite female football players and athletes from non-contact sports, except for significantly lower verbal memory and fluency scores. ► Reported mental health scores and cognitive symptom prevalences were similar except for a significantly worse depression score and a higher prevalence of subjective memory problems. ► A history of ≥2 concussions was associated with significantly lower verbal fluency scores among football players. ► Higher heading exposure was associated with significantly Higher psychomotor speed, but significantly lower verbal memory and worse mental health scores.	FB (n=66) performed similar to CON (n=45) on neurocognitive tests, except for significantly lower scores on verbal memory (mean difference (MD)=−7.038, 95% CI −12.98 to –0.08, p=0.038) and verbal fluency tests (MD=−7.534, 95% CI –13.75 to –0.46, p=0.016). Among FB weaker verbal fluency performance was significantly associated with ≥2 concussions, and weaker verbal memory performance with frequent heading. The depression score differed significantly between study populations, and was significantly associated with frequent heading but not with history of concussion in FB.	Further studies should investigate the clinical relevance of our findings and whether the observed associations point to a causal link between repetitive head impacts and verbal memory/fluency or mental health.

Strain, J., Didehbani, N., Cullum, C. M., Mansinghani, S., Conover, H., Kraut, M. A., Hart, J., Jr, & Womack, K. B. (2013).	Depressive symptoms and white matter dysfunction in retired NFL players with concussion history	American Academy of Neurology	To determine whether correlates of white matter integrity can provide general as well as specific insight into the chronic effects of head injury coupled with depression symptom expression in professional football players.	We studied 26 retired National Football League (NFL) athletes who underwent diffusion tensor imaging scanning. Depressive symptom severity was measured using the Beck Depression Inventory II (BDI-II) including affective, cognitive, and somatic subfactor scores. Fractional anisotropy (FA) maps were processed using tract-based spatial statistics from FSL. Correlations between FA and BDI-II scores were assessed using both voxel-wise and region of interest (ROI) techniques, with ROIs that corresponded to white matter tracts. Tracts demonstrating significant correlations were further evaluated using a receiver operating characteristic curve that utilized the mean FA to distinguish depressed from nondepressed subjects.	The study reveals a significant link between white matter integrity, measured by DTI FA, and depressive symptoms in retired NFL athletes with a history of concussions or sub concussive impacts. The findings indicate that various depressive symptoms correlate with both general and localized white matter disruption. The results suggest that compromised white matter integrity in frontal regions is closely tied to depressive symptom severity. The study highlights the potential of DTI as a tool for detecting depression severity in individuals with a history of concussion, although further longitudinal research is needed to confirm causation.	Voxel-wise analysis identified widely distributed voxels that negatively correlated with total BDI-II and cognitive and somatic subfactors, with voxels correlating with the affective component localized to frontal regions. Four tract ROIs negatively correlated with total BDI-II: forceps minor, right frontal aslant tract, right uncinate fasciculus, and left superior longitudinal fasciculus. FA of the forceps minor differentiated depressed from nondepressed athletes with 100% sensitivity and 95% specificity.	Depressive symptoms in retired NFL athletes correlate negatively with FA using either an unbiased voxel-wise or an ROI-based, tract-wise approach. DTI is a promising biomarker for depression in this population.