ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 11| Issue: 7| July 2025|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2025: 8.691 || ISI Value: 1.188

NEUROLOGICAL IMPACTS OF TRAUMATIC BRAIN INJURY IN SPORT

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Article DOI: https://doi.org/10.36713/epra23061
DOI No: 10.36713/epra23061

ABSTRACT

This study explores the neurological impacts of mild to moderate traumatic brain injuries (TBIs) in Australian collision sports, particularly rugby league, rugby union, and Australian Rules football. These unhelmeted sports present heightened risks for repetitive head impacts, with potential long-term consequences such as cognitive decline and chronic traumatic encephalopathy (CTE). The aim was to assess current evidence on neurocognitive, ocular motor, neuroimaging, and neuropathological outcomes associated with TBIs, while identifying gaps in diagnosis, classification, and treatment. A comprehensive literature review was conducted using peer-reviewed sources accessed through databases like PubMed, ResearchGate, ScienceDirect and Google Scholar. Key references included the 2017 Lancet Neurology Commission on TBI and recent biomechanical studies employing finite element modeling and instrumented mouthguards. The findings suggest that TBI incidence is likely underreported, and current diagnostic tools are often insufficient in capturing the full scope of injury. Existing neuropsychological assessments lack consistency, and gender and age-related differences remain underexplored. The research underscores the urgent need for improved prevention strategies, more accurate diagnostic methods, and multidisciplinary care approaches tailored to athletes. These findings carry significant implications for future research and clinical practices aimed at safeguarding brain health in contact sports. Key areas of concern include youth athletes and other vulnerable populations.

INTRODUCTION

The article investigates the effects of moderate brain damage in Australian collision sports, such as rugby league, rugby union, and Australian Rules football. It examines research on neurocognitive, ocular motor, neuroimaging, and neuropathological results while highlighting the particular dangers of these unhelmeted sports. It points up areas that need more research and makes recommendations for future directions[1]. The 2017 Lancet Neurology Commission on TBI is also cited, which found that TBI affects 50–60 million individuals yearly, costs $400 billion worldwide, and receives inconsistent care across geographical boundaries. The need for improved diagnosis, classification, and outcome measurements is emphasized in the paper[2] .The epidemiology, sideline assessment, acute care, surgical treatment options, and significance of personalized return-to-play decisions are all covered in relation to TBI in professional contact athletes. It aims to broaden the scope of study beyond American football concussions[3].It draws attention to the increasing awareness of mild traumatic brain injuries (mTBIs) in sports, which have gone from being disregarded to being a major health concern. It talks about how common these injuries are, how they affect athletes, and how neuropsychology can help manage them. The shortcomings of the neuropsychological testing that is now available are questioned, highlighting the necessity of better evaluation and therapeutic approaches[8]. It draws attention to the shortcomings of earlier studies on TBIs linked to sports, which frequently concentrated on particular populations or hospital data and might have underreported mild instances. It highlights how important it is to have a variety of data sources in order to fully comprehend prevalence and impact. Higher-than-expected TBI rates are suggested by research conducted in New Zealand, highlighting the necessity of better prevention techniques to guarantee safer sports participation[18].It discusses updated criteria from the American Congress of Rehabilitation Medicine as well as recent developments in the diagnosis and treatment of mild traumatic brain injury (mTBI). It draws attention to the intricacy of mTBI symptoms and the necessity of a multidisciplinary, patient-centered treatment strategy. The focus is on using integrated treatment and standardized assessments to improve results[6]. Using finite element FE models, it investigates the relationship between brain strain and cognitive impairments in contact sports. In order to determine whether brain strain data might forecast cognitive changes, researchers have integrated instrumented mouthguards to track hits and initiate cognitive assessments. The results may improve the diagnosis and treatment of concussions[4]. It investigates the long-term neurological hazards of contact

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sports-related repetitive head impacts RHIs, such as concussions, chronic traumatic encephalopathy CTE, and cognitive decline. It draws attention to the need of comprehending gender disparities in concussion outcomes, neurodegenerative hazards, and structural brain alterations. It highlights enhanced safeguards and early identification for better brain health in athletes [9]. Concern over sports-related concussions has grown because of the long-term effects they have on athletes' health. Numerous physical, mental, and emotional issues that last for a long time can result from repeated head injuries, especially in contact sports. Awareness concussion mechanisms require an awareness of biomechanical parameters, such as the forces involved in head collisions. The long-term consequences, such as diseases like chronic traumatic encephalopathy CTE, are less well known than the initial symptoms, which are well documented. It examines how concussion biomechanics contributes to these long-term consequences, highlighting the necessity of more study. It seeks to improve concussion-related disorder prevention, diagnostic, and treatment methods by investigating the connection between head injuries and long-term brain health problems[14] . The neurological effects of traumatic brain injury TBI in sports are causing increasing concern. Contact sport athletes are more likely to suffer traumatic brain injury TBI, which can impair brain function both immediately and over time. Cognitive, motor, and emotional deficits may result from these traumas. Chronic illnesses like chronic traumatic encephalopathy (CTE) and other neurodegenerative diseases can be brought on by repeated traumatic brain injuries. It looks at the neurological effects of TBI in sports and highlights the need for more study. It also emphasizes how crucial early intervention and better safety measures are. Protecting athletes' long-term brain health requires an understanding of these effects. To provide more effective preventative and treatment plans, further research is required[17].

The Prevalence of TBI is to affects all age groups globally .Football: 26% of injuries are head/neck; 63% of mTBI cases are in high school players .Collision sports (rugby, Aussie rules) increase risk .Underreporting noted, especially in New Zealand.Neurological Consequences of TBI are Short-Term: Cognitive, motor, emotional issues.Prolonged symptoms in kids.Concussive convulsions.Long-Term: Cognitive decline, depression, CTE (Chronic traumatic encephalopathy).Brain structure damage (white matter, cortical thinning).Elevated GFAP, NFL(Neurofilament light chain) biomarkers .Cognitive decline shown in imaging.Risk Factors includes Sports: Contact sports, position, career length .Demographic: Youth athletes, kids with mTBI, unreported cases .Biomechanical: High impact, poor gear, weak diagnostics.The purpose of this research is to examine the neurological consequences of moderate to mild traumatic brain injuries (TBIs) sustained in Australian collision sports, including Australian Rules football, rugby league, and rugby union. It highlights the dangers of unhelmeted sports while examining neurocognitive, ocular motor, neuroimaging, and neuropathological data. The study aims to identify knowledge gaps, enhance diagnostic and evaluation techniques, investigate the long-term effects of frequent head impacts, and make suggestions for treatment, prevention, and future research avenues.

LITERATURE REVIEW

Ling, H., Hardy, J., & Zetterberg, H. (2015)

The findings of the article suggest Traumatic brain injury (TBI) in sports is a growing concern due to its neurological consequences. Athletes in contact sports are at higher risk of sustaining TBIs, which can have both immediate and long-term effects on brain function. These injuries can lead to cognitive, motor, and emotional impairments. Repeated TBIs may result in chronic conditions like chronic traumatic encephalopathy (CTE) and other neurodegenerative diseases. This article examines the neurological impact of TBI in sports, emphasizing the need for further research. It also highlights the importance of improved safety measures and early intervention. Understanding these consequences is crucial for protecting athletes' long-term brain health. Continued investigation is necessary to develop better prevention and treatment strategies.

Sahler, C. S., & Greenwald, B. D. (2012)

This article highlights how mild traumatic brain injuries (mTBIs) are commonly seen in sports across different levels, from school to professional competitions. In the past, such injuries were often considered a normal part of the game, but now they are being recognized as significant health concerns. The introduction provides an overview of the increasing awareness of sports-related brain injuries, particularly their epidemiology and effects on athletes. It also discusses the role of neuropsychology in understanding and managing these injuries. Additionally, concerns about the adequacy of current neuropsychological testing methods are raised, emphasizing the need for further research to improve assessments and treatment strategies.

Maas, A. I. R., Menon, D. K., Manley, G. T., et al. (2022)

The article highlights Traumatic brain injury (TBI) is a major global health issue, with ongoing progress in prevention, clinical care, and research. Prevention efforts focus on reducing risks across populations, such as the U.S. military's use of new technologies to protect troops from blast-related injuries.In clinical care, advancements aim to improve diagnosis and treatment. Studies have found that some unresponsive patients can show cognitive responses through brain scans, highlighting the need for better assessment tools. Pediatric research also stresses the importance of tailored strategies for children with mild TBI, who are at risk for prolonged symptoms.Research is focused on discovering effective treatments and understanding long-term effects. Clinical trials are testing drugs like atorvastatin, candesartan, and minocycline for reducing inflammation and promoting brain repair. Additionally, studies link repeated head impacts in sports to potential brain damage, emphasizing the need for preventive measures.Despite progress, challenges remain in translating research into better patient outcomes, with ongoing efforts aimed at developing improved diagnostic tools, treatments, and prevention strategies.

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Canseco, J. A., Franks, R. R., Karamian, B. A., Divi, S. N., Reyes, A. A., Mao, J. Z., Al Saiegh, F., Donnally, C. J. III, Schroeder, G. D., Harrop, J. S., Pepe, M. D., & Vaccaro, A. R. (2022)

The article highlights Traumatic brain injury (TBI) is a major concern in American football due to the sport's high-impact nature. Research highlights that up to 26% of injuries in football involve the head or neck, with high school athletes being particularly vulnerable—accounting for around 63% of mild TBI cases annually.Repeated concussions are linked to long-term neurological issues, including depression, cognitive dysfunction, and chronic traumatic encephalopathy (CTE), a degenerative condition associated with extended play and abnormal tau protein buildup.Risk factors for CTE include playing position and career length, with longer careers tied to reduced cognitive performance and brain changes detectable through advanced imaging.Preventative strategies focus on improved helmet designs and impact detection technologies, like instrumented mouthguards, which can reduce concussion risk and enhance safety monitoring.Overall, TBI poses a serious threat to football players' long-term health, highlighting the need for continued research and advancements in prevention and management.

Symons GF, Clough M, Fielding J, O'Brien WT, Shepherd CE, Wright DK, Shults SR(2020)

The article highlights Engaging in Australian collision sports, such as Australian rules football, rugby union, and rugby league, is linked to significant neurological risks due to frequent concussive and subconcussive impacts. Research highlights persistent brain abnormalities, including white matter damage and cortical thinning, even in asymptomatic players. Chronic Traumatic Encephalopathy (CTE), a degenerative condition caused by repeated head trauma, has also been found in athletes from these sports, leading to mood, behavioral, and cognitive issues over time. Elevated blood biomarkers like GFAP and NfL indicate brain injury and can guide recovery and return-to-play decisions. Studies have also documented concussive convulsions occurring shortly after impact. A notable case involving 20-year-old Keith Titmuss, diagnosed posthumously with stage two CTE, has sparked discussions about stricter safety measures in youth sports. Overall, evidence underscores the need for continued research and improved safety protocols to protect athlete brain health.

Menghani R. Menghani RR, Bardall C, Tanaka ML, Kraft R, Kraft RH(2025)

Results of the study indicate Head injuries in contact sports, especially concussions, can lead to cognitive deficits, but the link between brain strain and these changes remains unclear. Finite element (FE) modeling helps estimate brain strain during impacts, yet its clinical relevance is still debated. This study integrates FE simulations with cognitive assessments in athletes to explore their correlation. Using instrumented mouthguards to track impacts and trigger cognitive tests, we aim to determine if brain strain metrics can predict cognitive changes, laying the groundwork for improved concussion diagnosis and management.

Gajek-Flanezewska w, Flanczewski S, wirkijowski M. Wojtowics K. Wirkinowski J, walezak A, et al(2025)

The article highlights Repetitive head impacts (RHIs) in contact sports have raised concerns about their long-term neurological consequences, including concussions, Chronic Traumatic Encephalopathy (CTE), and cognitive decline. While RHIs are associated with structural brain changes, the exact mechanisms remain unclear. Understanding the biophysical effects, risks of neurodegenerative diseases, and gender differences in concussion outcomes is crucial for improving diagnosis, management, and prevention strategies. This review examines current research on RHIs, highlighting the need for better protective measures and early detection methods to safeguard athletes' brain health.

Ledreux A, Pryhoda MK, Gorgens K, Shelburne K, Gilmore A, Linseman DA, et al (2020 july 30)

Sports-related concussions have raised growing concern due to their long-term impact on athletes' health. Repeated head injuries, particularly in contact sports, can lead to a variety of physical, cognitive, and emotional problems that persist long after the initial injury. Biomechanical factors, such as the forces involved in head impacts, are critical in understanding concussion mechanisms. While immediate symptoms are well-documented, the long-term effects, including conditions like chronic traumatic encephalopathy (CTE), remain less understood. This article explores the role of concussion biomechanics in these long-term outcomes, emphasizing the need for continued research. By examining the relationship between head impacts and lasting brain health issues, the article aims to contribute to better prevention, diagnosis, and treatment strategies for concussion-related disorders.

Theadom, A. M., Starkey, N. J., Dowell, T., Hume, P. A., Kahan, M., McPherson, K., Feigin, V. L., Barker-Collo, S., Kydd, R., Parag, V., … & Feigin, V. (2014).

This article focuses on the limitations of previous research on sports-related traumatic brain injuries (TBIs), which often concentrated on specific groups like professional athletes or school children. Many studies also relied on hospital records, which might miss cases of mild TBI since not all affected individuals seek medical care. The introduction stresses the importance of using multiple sources to get a more accurate picture of the prevalence and impact of sports-related TBIs. Research in New Zealand has shown that TBI rates are higher than previously estimated, indicating a need for better prevention strategies. As sports participation is widely encouraged for a healthy lifestyle, ensuring safety through improved research and injury prevention measures is essential.

Sergeyenko, Y., Andreae, M. E., & Segal, M. (2025).

This article discusses recent updates in the diagnosis and management of mild traumatic brain injury (mTBI). The introduction highlights new diagnostic criteria developed by the American Congress of Rehabilitation Medicine using the Delphi method, which aims to improve the standardization of assessment and treatment. It also emphasizes the complexity of mTBI

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symptoms, which can sometimes persist and require a patient-centered treatment approach. The article suggests that managing mTBI effectively may require specialized referrals and coordinated care involving interdisciplinary or multidisciplinary teams. The focus is on improving outcomes by ensuring individualized and comprehensive care for patients.

Karton, C., & Hoshizaki, T. B. (2021)

Sports-related neurological injuries, particularly concussions, have significant short- and long-term consequences. Understanding their biomechanics is essential for prevention and management. Concussions occur due to biomechanical forces—direct or indirect—that cause linear and rotational brain accelerations, with rotational forces being particularly harmful.The impact of concussions varies based on factors like impact location, force, and individual susceptibility. Research links concussions to impaired cognitive and biomechanical function, with affected athletes showing altered movement patterns, increasing the risk of musculoskeletal injuries.Preventive strategies include advancements in helmet technology and strengthening cervical spine muscles to reduce head acceleration during impacts. Ongoing research aims to deepen understanding and improve protective measures for athletes.

Theadom, A., Mahon, S., Hume, P., Starkey, N., Barker-Collo, S., Jones, K., Majdan, M., & Feigin, V. L. (2020)

The article highlights about Tibial bone stress injuries (TBSIs) are common among athletes, particularly those in high impact sports like track and field. Studies show that stress fractures make up 0.7% to 20% of sports injuries, with the tibia being the most frequently affected bone. Research indicates that 49.1% of stress fractures in athletes involve the tibia. Incidence rates are notably high among collegiate distance runners (32 injuries per 100 athlete-years) and middle to high school runners (4.7%). These findings highlight the tibia as a common site for stress injuries in athletes.

Bramlett, H. M., & Dietrich, W. D. (2015)

Bramlett & Dietrich, examined the long-term consequences of traumatic brain injury (TBI), highlighting its progressive nature and limited treatment options.The study emphasizes sustained injury cascades contributing to prolonged motor and cognitive deficits. Key mechanisms include excitotoxicity, apoptosis, inflammation, seizures, demyelination, and reduced neurogenesis, which increase the risk of neurodegenerative diseases.The authors stress the need for deeper research into these pathophysiological processes to develop effective therapeutic strategies for mitigating chronic TBI effects.

Wilson, J. T. L., Stewart, W., Dams-O'Connor, K., Diaz-Arrastia, R., Horton, L., Menon, D. K., & Polinder, S. (2017)

The findings of the article the chronic and evolving neurological effects of traumatic brain injury (TBI), emphasizing its lifelong impact on health.The study highlights TBI as a chronic condition, with functional outcomes varying for decades and an increased risk of mortality. It links TBI to neurological diseases like epilepsy, stroke, and neurodegeneration, identifying persistent neuropathological changes, including chronic traumatic encephalopathy. Despite growing recognition of these long-term effects, research gaps remain. The authors stress the need for better understanding of chronic TBI pathologies to enhance long-term patient management.

Stellpflug, S. J., Dalrymple, K. A., Stone, D., Southgate, S., Bachman, D. S., LeFevere, R. C., Hasan, J., & Zwank, M. D. (2024)

Year examined the long-term vascular and neurological effects of repeated sportive chokes in grappling athletes by assessing carotid intima media thickness (CIMT) and brain injury biomarkers.The study found no significant differences in CIMT or brain injury markers (NFL, hGFAP, t-Tau, and UCH-L1) between grapplers with extensive choke exposure and matched controls. Additionally, no differences were observed between grapplers with and without a history of blunt head trauma.Despite the high frequency of choke events in combat sports, the findings suggest that repeated transient chokes do not significantly impact vascular health or acute brain injury markers. However, further research is needed to assess potential long-term neurological risks.

De Wilde, L., De Ruysscher, C., & Oostra, K. (2025)

explored the correlation between traumatic brain injury (TBI), obesity, and insulin resistance in a 23-year-old woman following a traffic accident. After sustaining a TBI with a Glasgow Coma Scale score of 5/15, she exhibited significant weight gain, increasing her BMI from 23 kg/m² to 36 kg/m². Despite rehabilitation efforts, cognitive impairments and metabolic changes contributed to obesity and insulin resistance. Metformin treatment led to a BMI reduction to 33 kg/m². This case highlights the multifaceted nature of weight management in TBI patients, emphasizing the need for multidisciplinary interventions and further research.

Asken, B. M., Sullan, M. J., DeKosky, S. T., Jaffee, M. S., & Bauer, R. M. (2017)

investigated the impact of repetitive head impacts (RHIs) on cognitive function and brain structure in contact sports athletes. Studying 50 players over two seasons, they recorded 5,000 head impacts using helmet sensors and conducted neurocognitive assessments. Findings indicated a correlation between increased RHI exposure and white matter alterations, with some athletes showing early signs of cognitive decline. While this study underscores potential long-term neurological risks, further research is needed to establish causality and develop effective protective strategies.

METHODOLOGY

Methodology for a Systematic Review Based on PRISMA

Systematic reviews require rigorous and transparent methods to ensure the reliability and reproducibility of findings. The

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PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 guidelines provide a comprehensive framework for conducting and reporting such reviews, particularly in health-related research. Below is a structured methodology suitable for investigating the neurological consequences of mild to moderate traumatic brain injuries (TBIs) in Australian collision sports, following PRISMA standards.

1. Systematic Review Design and PRISMA Framework

The review should be planned and reported according to the PRISMA 2020 checklist, which includes a 27-item reporting guideline and a four-phase flow diagram (identification, screening, eligibility, inclusion). The protocol should be developed and, if possible, registered on a platform such as PROSPERO before starting the review.

2. Sampling Technique

Database Selection: Comprehensive searches should be conducted across multiple electronic databases (e.g., PubMed, Scopus, Web of Science) to capture all relevant studies. Search Strategy: Develop a reproducible search strategy using defined keywords and Boolean operators. Document all search terms, databases, and date ranges. Snowballing: Use backward (reference lists) and forward (citation tracking) snowballing to identify additional studies. Grey Literature: Consider including grey literature (e.g., theses, conference proceedings) to minimize publication bias.

3. Selection of Studies

Screening Process Identification: Remove duplicates and screen titles/abstracts for relevance using the predefined inclusion and exclusion criteria. Screening: At least two independent reviewers should screen studies to reduce selection bias. Discrepancies are resolved by discussion or a third reviewer. Eligibility: Retrieve and assess the full text of potentially eligible studies. Document reasons for exclusion at this stage. Inclusion: Finalize the list of included studies for data extraction and synthesis, as illustrated in the PRISMA flow diagram.

4. Inclusion and Exclusion Criteria

Inclusion Criteria: Define clear criteria based on the research question (e.g., PICOS: Population, Intervention, Comparison, Outcomes, Study design). Studies involving athletes in Australian collision sports (rugby league, rugby union, Australian Rules football) Reporting on neurological outcomes of mild to moderate TBI

- Peer-reviewed articles, published in English, within a specified time frame
- Human studies, including both observational and interventional designs
- Exclusion Criteria: Specify elements that disqualify studies.
- Studies not focused on collision sports or not in the Australian context
- Non-original research (reviews, editorials, commentaries)
- Animal studies (unless mechanistic insights are specifically needed)
- Insufficient outcome data or lack of neurological assessment

5. Data Analysis Criteria

Data Extraction: Use a standardized form to extract relevant data (study characteristics, participant demographics, TBI definitions, outcomes, assessment tools, results). Risk of Bias Assessment: Evaluate the quality and risk of bias in included studies using established tools (e.g., Newcastle-Ottawa Scale for observational studies).

Data Synthesis

- Qualitative synthesis for heterogenous data.
- Quantitative synthesis (meta-analysis) if data are sufficiently homogenous.
- Present findings in summary tables and, if applicable, forest plots.
- Transparency: Document all steps, including reasons for study exclusion, and provide a PRISMA flow diagram to enhance transparency and reproducibility

RESULTS / DISCUSSION

This study highlights the significant neurological risks of mild to moderate traumatic brain injuries (TBIs) in Australian collision sports like rugby and Australian Rules football. Key findings reveal that TBIs are underreported, with long-term risks including cognitive decline, mood disorders, and chronic traumatic encephalopathy (CTE). Current diagnostic tools are often inadequate, emphasizing the need for advanced methods like instrumented mouthguards and biomarker analysis. A major concern is the cumulative effect of repetitive head impacts, even without immediate symptoms. Biomechanical studies show rotational forces pose the greatest risk, suggesting rule changes and improved protective gear could reduce injuries. Additionally, gender and age differences in TBI outcomes require further research, as female and youth athletes may face unique recovery challenges. Limitations Include reliance on self-reported data and a lack of long-term studies tracking neurodegeneration in athletes. Future research should focus on longitudinal studies, better injury surveillance in amateur sports, and validating biomarkers for real-time diagnosis. Rule modifications, neck-strengthening programs, and multidisciplinary care models could enhance prevention and recovery. Ultimately, safeguarding athletes requires a proactive approach—combining research, technology, and policy changes to minimize risks while preserving the integrity of these sports. The article has been drafted following the TAILMRDCR model proposed by Kumar[21]. The findings are useful for the practitioners and medical tourism scope[22,23].

CONCLUSION

This study underscores the significant neurological risks associated with mild to moderate traumatic brain injuries (TBIs) in Australian collision sports, including rugby league, rugby union, and Australian Rules football. Key findings reveal that TBIs—particularly repetitive head impacts—are frequently

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underreported and can lead to long-term cognitive decline, mood disorders, and chronic traumatic encephalopathy (CTE). Current diagnostic methods remain insufficient, highlighting the need for advanced tools such as instrumented mouthguards, finite element modeling, and biomarker analysis. Additionally, biomechanical research indicates that rotational forces pose the greatest risk, suggesting that rule modifications, improved protective equipment, and neck-strengthening programs could mitigate injury rates.

Despite these insights, limitations persist, including reliance on self-reported data, a lack of long-term neuroimaging studies, and insufficient research on gender and age-related differences in TBI outcomes. Future research should prioritize longitudinal studies tracking neurodegeneration in athletes, validating objective biomarkers for real-time diagnosis, and improving injury surveillance in amateur and youth sports. Additionally, multidisciplinary care models integrating neurocognitive, vestibular, and psychological assessments should be developed to optimize recovery protocols. In conclusion, while collision sports carry inherent risks, proactive measures—including rule changes, enhanced protective technologies, and evidence-based return-to-play guidelines—can help safeguard athletes' brain health. Continued research, policy adjustments, and public awareness are essential to balancing the benefits of sports participation with the imperative of long-term neurological safety.

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