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Quality in Sport. eISSN 2450-3118.

Journal Home Page

<https://apcz.umk.pl/QS/index>

STRZALIŃSKA, Dominika, PISKOR, Michał, PAZIO, Klaudia, CHMIELEWSKI, Michał, BAJKO, Julia, KAPUSTA, Kinga, BŁAŻEWICZ, Juliusz, BULLMANN, Agnieszka, CISZEWSKI, Artur and KOWALCZUK, Maciej. The Impact of Repetitive Head Microtrauma on Cognitive Functions in Amateur Athletes – A Narrative Review. Quality in Sport. 2026;53:70177. eISSN 2450-3118. <https://doi.org/10.12775/QS.2026.53.70177>

The journal has been awarded 20 points in the parametric evaluation by the Ministry of Higher Education and Science of Poland. This is according to the Annex to the announcement of the Minister of Higher Education and Science dated 05.01.2024, No. 32553. The journal has a Unique Identifier: 201398. Scientific disciplines assigned: Economics and Finance (Field of Social Sciences); Management and Quality Sciences (Field of Social Sciences).

Punkty Ministerialne z 2019 - aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398. Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych). © The Authors 2026.

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The authors declare that there is no conflict of interest regarding the publication of this paper.

Received: 23.03.2026. Revised: 30.03.2026. Accepted: 30.03.2026. Published: 04.04.2026.

**The Impact of Repetitive Head Microtrauma on Cognitive Functions in Amateur Athletes
– A Narrative Review**

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Abstract

Introduction

Repetitive head impacts (RHI) represent an important and often underestimated risk factor for impaired brain function in individuals participating in contact sports, including amateur athletes. Although they often do not result in clinically diagnosed concussions, research shows that even sub-concussive impacts can lead to measurable changes in brain structure and function, including alterations in white matter integrity and neural connectivity. Their cumulative nature plays a key role, as repeated low-intensity impacts may trigger processes such as axonal injury and neuroinflammation, which can develop gradually and remain undetected in standard clinical assessments. Neuroimaging studies have demonstrated subtle abnormalities even in asymptomatic individuals. These changes have been associated with declines in cognitive functions such as memory, attention, and processing speed, with their severity depending on exposure and individual susceptibility.

Materials and Methods

This study is a literature review based on publications from PubMed Central, PubMed, ScienceDirect, and related scientific databases. It includes experimental, observational, and systematic review studies examining the effects of repetitive head impacts (RHI) on cognitive functions and mental health, including amateur athletes. The analysis covered results from neuropsychological assessments (e.g., memory, attention, executive functions), neuroimaging techniques such as MRI, DTI, and fMRI, as well as studies on neurological biomarkers related to brain injury and neurodegenerative processes. Particular attention was given to cumulative exposure to head impacts and their frequency and intensity.

Literature Review

The analyzed studies indicate that repetitive head impacts (RHI), including both concussive and sub-concussive events, are associated with impairments in key cognitive functions such as memory, attention, executive functions, and processing speed. Importantly, these deficits may also be observed in individuals without a history of clinically diagnosed concussion, which suggests that even repeated mild impacts can have cumulative effects on brain function. Neuroimaging findings support these observations, showing structural and functional brain

changes in individuals exposed to RHI. In particular, studies using diffusion tensor imaging (DTI) have demonstrated reduced white matter integrity, while functional imaging has revealed alterations in brain network activity related to cognitive processing. These changes are often subtle and may not be detected using standard clinical assessments. The literature emphasizes that the extent of these effects is strongly influenced by exposure factors, including the number, intensity, and cumulative burden of head impacts. Repeated low-intensity impacts, especially over longer periods, may contribute significantly to observed changes. In addition to cognitive deficits, RHI has been associated with neuropsychiatric symptoms such as depression, anxiety, and impulsivity, and is also linked to a potential increased risk of developing chronic traumatic encephalopathy (CTE). However, findings across studies are not entirely consistent and appear to depend on factors such as duration of exposure, intensity of impacts, and individual susceptibility.

Summary and Conclusions

The analyzed studies indicate that repetitive head impacts (RHI) may lead to measurable impairments in cognitive functions such as memory, attention, processing speed, and executive functioning, even in the absence of clinically diagnosed concussion. Evidence suggests that these changes are associated with structural and functional alterations in the brain, including reduced white matter integrity and disrupted neural network activity, which may develop gradually as a result of cumulative exposure. Importantly, the effects of RHI appear to be dose-dependent and influenced by factors such as the number, frequency, and intensity of impacts, as well as the duration of exposure. Individual susceptibility, including biological and environmental factors, may further modulate the extent of observed changes, which helps explain variability across studies. In some cases, long-term exposure has been linked to neurodegenerative processes, including those associated with chronic traumatic encephalopathy (CTE). At the same time, the literature highlights limitations in current diagnostic approaches, as many changes remain subclinical and may not be detected using standard methods. This underscores the need for more sensitive diagnostic tools, including advanced neuroimaging techniques and biomarkers. Overall, the findings emphasize the importance of increasing awareness of the potential risks associated with repetitive head impacts, particularly among amateur athletes who are less frequently monitored. Preventive strategies, improved monitoring of exposure, and early detection of cognitive and neurobiological changes are essential. Further research is needed to better understand the underlying mechanisms and long-term consequences of RHI, as well as to identify factors that may protect against or mitigate these effects.

Keywords: repetitive head impacts (RHI), traumatic brain injury (TBI), cognitive functions, amateur athletes, chronic traumatic encephalopathy (CTE), neurodegeneration, neuroimaging, mental health

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1. Introduction

Repetitive head impacts (RHI) are increasingly recognized as an important risk factor affecting brain function in people who participate in contact sports. Unlike classic concussions, these micro-injuries often do not cause immediate or clearly noticeable clinical symptoms, which makes them difficult to identify and monitor. Despite the lack of acute symptoms, their cumulative nature can lead to neurobiological changes and a gradual decline in cognitive abilities. [1,4]

Research suggests that repeated blows to the head may lead to both structural and functional disturbances in the brain. These include damage to white matter, changes in neuronal signaling, and disruptions in the integrity of synaptic connections. Observed alterations also involve changes in the activity of functional brain networks, which may affect cognitive processes such as memory, attention, and executive functioning. [2,12]

A key mechanism underlying these changes involves neuroinflammatory processes and the accumulation of pathological proteins, particularly tau protein. The literature emphasizes that repetitive microtrauma may trigger a cascade of changes leading to neurodegeneration, which is associated, among others, with the development of chronic traumatic encephalopathy (CTE). This phenomenon has been widely described in professional athletes but is increasingly being studied in amateur sports as well. [3]

Studies using advanced neuroimaging techniques such as magnetic resonance imaging (MRI) and diffusion tensor imaging (DTI) have demonstrated subtle structural changes in the brain even in individuals without a history of diagnosed concussion. These findings suggest that microtrauma may lead to cumulative damage that is not detected in standard clinical diagnostics. [4,12]

Additionally, many studies highlight the relationship between the number and intensity of head impacts and the severity of observed cognitive deficits. Long-term exposure to microtrauma may result in reduced cognitive performance, even in younger individuals. At the same time, some studies suggest the possibility of partial reversibility of these changes after cessation of exposure, although the findings in this area remain inconclusive. [5,11]

In the context of amateur athletes, this issue is particularly important because they are often not subject to systematic medical monitoring, and awareness of the risks associated with

microtrauma is limited. As a result, potential neurological consequences may remain unrecognized for a long time. [6,7,17]

In summary, available evidence suggests that repetitive head impacts constitute a significant, though often underestimated, threat to cognitive functioning. Their effects include both structural and functional brain changes, as well as potential neurodegenerative processes, which highlights the need for further research and increased preventive efforts among athletes, including amateurs. [1,6]

2. Materials and Methods

This study is a review of scientific literature. The analysis included articles available in PubMed Central, PubMed, ScienceDirect, and other sources. The inclusion criteria consisted of publications addressing repetitive head impacts and their effects on cognitive functions, with particular emphasis on athlete populations, including amateurs.

Both experimental and observational studies, as well as systematic reviews, were included. The analysis focused on findings from neuropsychological assessments, neuroimaging techniques, and neurological biomarkers. Neuropsychological studies evaluated domains such as memory, attention, executive functions, and processing speed. Neuroimaging studies included MRI, functional MRI (fMRI), and diffusion tensor imaging (DTI), while biomarker analyses focused on indicators related to brain injury, neuroinflammation, and tau protein accumulation.

3. Literature Review

a. 3.1. Relationship Between Repetitive Head Impacts and Cognitive Functions

Analysis of available publications indicates that repetitive head impacts (RHI) and multiple concussions are significantly associated with cognitive impairments and neuropsychiatric changes. Studies involving former athletes have shown that a higher number of head injuries is linked to reduced cognitive performance, particularly in memory, attention, and executive functions. Mild cognitive impairment has also been observed, which may represent an early stage of more advanced neurological changes. [4, 8]

Many analyses emphasize that not only the number of diagnosed concussions is important, but also the total exposure to repeated, often subclinical head impacts. Even impacts that do not meet the clinical criteria for concussion may cumulatively contribute to cognitive decline. Some studies have demonstrated a relationship between a history of head injuries and poorer performance in neuropsychological tests, especially in processing speed and working memory. [8]

Research involving younger athletes also indicates a negative impact of repeated head impacts on cognitive functioning. During a single sports season, declines in reaction time, cognitive-motor coordination, and concentration ability have been observed, with the severity of changes depending on the number and nature of impacts. These findings suggest that even short-term exposure can lead to measurable cognitive changes. [4, 9]

Additionally, neuroimaging studies have demonstrated both macro- and microstructural brain changes in individuals exposed to RHI. These include reduced white matter integrity and disrupted functional connectivity between different brain regions, which may impair information processing and cognitive integration. [4, 12]

The literature also highlights that cognitive deficits often co-occur with neuropsychiatric symptoms such as mood disturbances and impulsivity, suggesting a complex and multifaceted impact of microtrauma on brain function. At the same time, some variability in findings has been observed, likely due to differences in exposure levels, duration of sports participation, and individual susceptibility. [10, 11]

3.2. Exposure to Microtrauma (Frequency and Intensity)

The literature emphasizes that not only the number of diagnosed concussions matters, but also the total exposure to repeated, often subclinical head impacts. Many studies indicate that the cumulative number of impacts and their characteristics—even in the absence of clinical symptoms—are crucial factors in brain changes. Repeated low-intensity impacts may lead to effects comparable to or even more significant than single, clearly symptomatic injuries. [1]

Empirical studies have shown that even short-term exposure to microtrauma can result in measurable cognitive changes. In young athletes, declines in reaction time, information processing, and cognitive-motor integration have been observed during a single sports season.

The severity of these changes was directly related to the number and type of head impacts, indicating a dose–response relationship. [4]

Studies using biomechanical sensors and kinematic analyses have demonstrated that parameters such as linear and rotational acceleration of the head are important in assessing potential brain injury. Rotational forces, in particular, are considered especially harmful due to their association with structural brain damage, including white matter injury. [3]

The literature also highlights that the accumulation of mechanical stress over time may lead to gradual neurobiological changes. A greater number of impacts has been associated with more pronounced changes in neuroimaging studies and poorer neuropsychological test results. This relationship has been observed in both professional and amateur athletes. [11]

Importantly, the nature of exposure—such as frequent low-intensity impacts versus less frequent but stronger impacts—may influence brain function differently. Some studies suggest that long-term exposure to repetitive low-intensity impacts may lead to subtle but progressively worsening cognitive changes. [1]

3.3. Structural and Functional Brain Changes

Numerous studies have demonstrated structural and functional brain changes in individuals exposed to repetitive head impacts. These include disruptions in white matter integrity, particularly visible in diffusion tensor imaging (DTI). Changes in parameters such as fractional anisotropy indicate microstructural damage to nerve fibers and impaired neuronal signaling. [12]

Neuroimaging studies have also revealed changes in gray matter, including alterations in the volume and activity of specific brain regions. Changes have been observed in areas responsible for cognitive functions, such as the frontal and temporal lobes, which play key roles in memory, attention, and executive control. [13]

The literature emphasizes that these changes may be diffuse, affecting multiple brain regions, and may increase with the duration and level of exposure to microtrauma. Repeated mechanical stress is believed to lead to gradual damage to neuronal structures, resulting in reduced efficiency of brain network functioning. [11]

An important aspect is that these changes are often subclinical, meaning they may occur without clear clinical symptoms or abnormal results in standard neurological examinations. As a result, traditional diagnostic methods may not be sensitive enough to detect early stages of damage. [12]

Functional MRI (fMRI) studies have also shown changes in brain activity during cognitive tasks. Both reduced activity in certain areas and compensatory increases in other regions have been observed, suggesting that the brain may attempt to adapt to injury. [7]

3.4. Neuropsychiatric Disorders and Mental Health

An important area of research concerns the impact of repetitive head impacts on mental health. Studies have shown that individuals exposed to long-term RHI have an increased risk of conditions such as depression, anxiety, post-traumatic stress disorder (PTSD), and impulse control disorders. These symptoms may occur even without a diagnosed concussion, highlighting the significance of subclinical microtrauma. [11, 14]

Research involving former athletes has demonstrated that a greater number of head injuries is associated with increased severity of depressive symptoms and mood disorders. These symptoms may be chronic and may worsen over time after the end of a sports career. [15]

Some studies have also found a relationship between RHI exposure and behavioral disturbances, including impulsivity, aggression, and difficulties in emotional regulation. These neuropsychiatric symptoms often coexist with cognitive deficits, creating a complex clinical picture. [15]

The literature suggests that structural and functional brain changes observed in individuals exposed to microtrauma may underlie these mental health disturbances. Some symptoms also overlap with those associated with chronic traumatic encephalopathy. [16]

Factors such as the duration of sports participation, intensity of exposure, and individual susceptibility may influence the risk of developing mental health problems. There is also a need for more sensitive diagnostic tools to detect early changes in mental health. [17]

3.5. Chronic Traumatic Encephalopathy (CTE)

The literature extensively describes the relationship between repetitive head trauma and the development of chronic traumatic encephalopathy (CTE), a progressive neurodegenerative disease associated with long-term exposure to microtrauma. CTE is characterized by the accumulation of abnormal tau protein in the brain, particularly around blood vessels and in deeper layers of the cerebral cortex. [3]

Neuropathological studies have shown that tau accumulation leads to neuronal dysfunction and gradual degeneration. This process is also associated with neuroinflammation and brain atrophy. It is believed that repeated mechanical stress leads to axonal damage and disruptions in intracellular transport, initiating these pathological processes. [3]

Clinical symptoms of CTE include a wide range of cognitive, emotional, and behavioral disturbances. Early stages often involve mood changes such as depression, irritability, and impulsivity. As the disease progresses, more severe impairments in memory, attention, and executive functions appear, along with difficulties in decision-making and behavioral control. Advanced stages may involve dementia. [18]

The literature emphasizes that CTE is primarily linked to cumulative exposure to repetitive head impacts rather than single concussive events. Duration and intensity of exposure also influence the risk and course of the disease. [18]

Diagnosis of CTE remains challenging, as definitive confirmation is currently only possible through postmortem examination. Therefore, ongoing research focuses on identifying biomarkers and neuroimaging techniques that could allow diagnosis in living individuals. [18]

Not all individuals exposed to repetitive head impacts develop CTE, suggesting the influence of additional factors such as genetics and environmental conditions. [9]

3.6. Inconsistencies in Research Findings

The literature also highlights inconsistencies regarding the long-term effects of repetitive head impacts, particularly in amateur athletes. Some studies have not demonstrated a clear

relationship between RHI exposure and persistent cognitive decline, suggesting that outcomes may vary and depend on multiple interacting factors. [19]

Epidemiological studies indicate that individuals participating in contact sports at lower levels of intensity do not always show an increased risk of neurodegenerative diseases later in life. This may be due to lower exposure intensity and shorter duration compared to professional athletes. [19]

Methodological differences between studies also contribute to inconsistent findings. These include variations in defining and measuring microtrauma, differences in diagnostic tools, sample sizes, and follow-up duration. Difficulties in accurately assessing the number and nature of past head impacts may lead to underestimation of true exposure. [6]

Individual susceptibility also plays an important role. Factors such as genetics, age at the start of sports participation, overall health, and lifestyle may influence how the brain responds to repetitive impacts. [17]

Some studies suggest that certain cognitive changes may be partially reversible after stopping exposure, particularly in cases of lower intensity or shorter duration. This further complicates the interpretation of results. [8]

Overall, the lack of consistent findings does not indicate the absence of an effect, but rather highlights the complexity of the issue and the need for further research using more precise methods and longer follow-up periods. [6]

4. Summary and Conclusions

Based on the analyzed literature, repetitive head impacts can be considered an important factor affecting cognitive functioning in athletes, including amateurs. Evidence suggests that even without clinically diagnosed concussion, the accumulation of repeated head impacts may lead to measurable impairments in memory, attention, processing speed, and executive functions.

These changes are associated with structural and functional brain alterations, including reduced white matter integrity and changes in neural network activity. Neuroimaging studies indicate that these changes may be diffuse and progressive, increasing with prolonged exposure.

A key finding is the relationship between exposure level (number, frequency, and intensity of impacts) and the severity of cognitive deficits. Long-term participation in contact sports increases the risk of chronic changes and, in some cases, neurodegenerative processes such as CTE.

Biological mechanisms underlying these changes include neuroinflammation, oxidative stress, and the accumulation of pathological tau protein, all of which contribute to gradual brain degeneration and impaired cognitive and emotional functioning.

At the same time, variability in findings highlights the need for further well-designed studies that consider individual differences, exposure levels, and environmental factors.

From a practical perspective, the findings emphasize the importance of increasing awareness of risks associated with repetitive head impacts, implementing preventive measures, and developing more sensitive diagnostic tools. Special attention should be given to amateur athletes, who often lack regular medical monitoring.

In conclusion, repetitive head impacts may lead to significant cognitive changes and represent a potential risk factor for neurodegenerative processes. The extent and reversibility of these changes depend on multiple factors, underscoring the need for further research and preventive strategies.

Disclosure

Author's contribution

Conceptualization: [DS], [KP]

Methodology: [MP], [MC], [KK]

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Data curation: [AC], [MP], [MK], [MC]

Writing - rough preparation: [KK], [JBa], [KP]

Writing - review and editing: [AB], [MK]

Visualization: [DS], [JB], [AC]

Project administration: [DS], [MP], [MC]

Funding Statement

The article did not receive any funding.

Institutional Review Board Statement

Not Applicable.

Informed Consent Statement

Not Applicable.

Data Availability

Statement Not Applicable.

Acknowledgements

This research has not received any administrative or technical support.

Conflict Of Interest

The authors declare no conflict of interest.

All authors have read and agreed with the published version of the manuscript.

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