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LONG-TERM EFFECTS OF TRAUMATIC BRAIN INJURY IN ATHLETES: THE MOST COMMON CLINICAL MANIFESTATIONS

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Introduction. Traumatic brain injury (TBI) is a pressing issue in high-performance sports. Although most sports-related TBIs are classified as mild, their frequent occurrence and resulting cumulative effect can negatively impact an athlete's health. Furthermore, this impact may not become apparent until several years after the injury, and sometimes only after the athlete has retired from the sport.

Objective. To identify the most frequent clinical manifestations associated with the long-term effects of traumatic brain injury in active and retired athletes from various sports.

Materials and methods. In order to assess the prevalence of symptoms associated with various TBI consequences, a total of 902 active and former athletes from Russian national teams were surveyed anonymously using a secure online platform, LimeSurvey, with a proprietary domain. The participants included 662 (73.4%) adult and 240 (26.6%) minor athletes. The study methodology was based on a questionnaire and did not include objective instrumental examinations. The questionnaire presented to the athletes contained questions clarifying anamnestic data and the presence of symptoms that could serve as clinical manifestations of the long-term effects of intracranial injuries. The entire sample of athletes was divided into groups according to age at the time of the survey (adults and minors). The group of adult athletes was also subdivided based on the number of TBIs in their history, the presence of contact/impacts during training (contact and non-contact sports), and age (18–30 years; 31–40 years; 41–50 years; ≥ 51 years). Statistical data analysis was performed using IBM SPSS Statistics 23.0 software.

Results. The prevalence of concussion among the adult athletes was statistically significantly higher than among the minors (15.3% vs. 2.5%, $p < 0.001$). The most common issues reported by the adult athletes with a history of concussion were sleep (36.6%) and visual disturbances (23.8%), as well as cognitive (25.7%), behavioral (22.8%), and affective (27.7%) disturbances. The aforementioned abnormalities were statistically significantly more frequent in the athletes participating in contact sports ($p < 0.05$). The athletes aged 18–30 years most commonly noted affective disturbances and changes in sleep, while visual disturbances were more prevalent in older age groups.

Conclusions. The most common clinical manifestations of TBI consequences in athletes consist of a complex of affective, cognitive, and behavioral disturbances, as well as impaired sleep and vision. Most consequences of intracranial injuries present with non-specific symptoms. Therefore, a crucial approach to optimizing the biomedical support system for athletes with a history of TBI consists in continuous monitoring of their health status post-injury. This involves developing screening protocols, followed by the formation of risk groups and early identification of impairments, which will help prevent or slow their progression.

Keywords: traumatic brain injury; concussion; consequence of traumatic brain injury; athletes; traumatic encephalopathy syndrome; cognitive impairments; sleep changes

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НАИБОЛЕЕ ЧАСТЫЕ КЛИНИЧЕСКИЕ ПРОЯВЛЕНИЯ ПОСЛЕДСТВИЙ ЧЕРЕПНО-МОЗГОВОЙ ТРАВМЫ У СПОРТСМЕНОВВ.С. Фещенко^{1,2}, Б.А. Поляев^{1,2}, С.О. Ключников¹, В.В. Завьялов¹, А.Н. Федоров¹, М.И. Поляков², А.В. Сливин^{1✉}¹Национальный центр спортивной медицины Федерального медико-биологического агентства, Москва, Россия²Российский национальный исследовательский медицинский университет им. Н.И. Пирогова, Москва, Россия

Введение. Черепно-мозговая травма (ЧМТ) — актуальная проблема в спорте высших достижений. Несмотря на то что большинство ЧМТ в спорте относятся к травмам легкой степени тяжести, частая периодичность их получения и, как следствие, кумулятивный эффект могут привести к негативному влиянию на здоровье спортсмена, которое может проявиться только спустя несколько лет после травмы, а иногда и после завершения спортивной карьеры.

Цель. Выявление наиболее частых клинических проявлений последствий черепно-мозговой травмы у действующих и завершивших спортивную карьеру спортсменов различных видов спорта.

Материалы и методы. Проведен анонимный опрос с помощью защищенной онлайн-платформы LimeSurvey с использованием собственного домена среди действующих и бывших 902 спортсменов сборных команд Российской Федерации по вопросам распространенности симптомов различных последствий перенесенной ЧМТ. Среди принявших участие 662 (73,4%) совершеннолетних и 240 (26,6%) несовершеннолетних спортсменов. Методология исследования основана на анкетировании и не включала объективные инструментальные обследования. Анкета, предлагаемая спортсменам, содержала вопросы, уточняющие анамнестические данные, а также наличие симптомов, которые могут выступать в качестве клинических проявлений последствий внутричерепных травм. Вся выборка спортсменов разделена по возрасту на момент опроса (совершеннолетние и несовершеннолетние). Дополнительно группа совершеннолетних спортсменов была разделена в зависимости от количества ЧМТ в анамнезе, наличия контактов/ударов во время тренировок (контактные и неконтактные виды спорта), а также возраста (18–30; 31–40; 41–50 лет; старше 51 года). Статистический анализ данных осуществлялся с помощью пакета прикладных программ IBM SPSS Statistics 23.0.

Результаты. Распространенность сотрясения головного мозга среди совершеннолетних спортсменов статистически значимо выше, чем у несовершеннолетних (15,3% против 2,5%, $p < 0,001$). Наиболее частыми у совершеннолетних спортсменов, имевших сотрясение головного мозга в анамнезе, были нарушения сна (36,6%) и зрения (23,8%), а также когнитивные (25,7%), поведенческие (22,8%) и аффективные (27,7%) нарушения. Вышеуказанные отклонения статистически значимо чаще встречались у спортсменов контактных видов спорта ($p < 0,05$). У спортсменов в возрасте 18–30 лет наиболее часто отмечали аффективные нарушения и изменения сна, а в более старшем возрасте — нарушения зрения.

Заключение. Наиболее частые клинические проявления последствий ЧМТ у спортсменов представляют собой комплекс аффективных, когнитивных и поведенческих нарушений, а также ухудшение сна и зрения. Большинство последствий внутричерепных травм имеют неспецифические проявления, в связи с чем важным подходом к оптимизации системы медико-биологического обеспечения спортсменов, получивших ЧМТ, является непрерывный мониторинг состояния их здоровья после травмы с разработкой скрининговых мероприятий с последующим формированием групп риска и ранним выявлением нарушений, что позволит предупредить/замедлить их прогрессирование.

Ключевые слова: черепно-мозговая травма; сотрясение головного мозга; последствия черепно-мозговой травмы; спортсмены; синдром травматической энцефалопатии; когнитивные нарушения; изменения сна

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INTRODUCTION

Traumatic brain injury (TBI) is defined as a disruption in the normal function of the brain resulting from a traumatic impact [1]. In sports, concussions (TBI) occur under conditions of elevated arterial pressure and cardiac output, which contributes to increased intracranial pressure, subsequently expanding secondary neuronal damage

[2]. Such injuries are characterized by a cumulative effect, i.e., the accumulation of consequences from frequent injuries of varying severity (syndrome of repeated impact)

[3]. Sports-related TBI can lead to severe consequences and their rapid development. Moreover, especially in children and adolescents, it is important to consider not only brain damage but also impairments affecting the cervical spine, atlanto-occipital and temporomandibular

joints, as well as cerebral blood flow. The daily life of TBI patients can be significantly affected by the injury: they suffer headaches, vision problems, tinnitus, and difficulties with focus and balance, as well as visuomotor coordination problems, cognitive impairments, and affective disorders [4]. The emerging clinical symptomatology can manifest either acutely or after a long period of time. Of particular concern to specialists is the manifestation of long-term consequences, which present with a varied clinical picture, yet less than 10% of TBI patients undergo regular follow-up monitoring [5].

The significance of long-term consequences is confirmed by the consensus statement on concussion in sport. Notably, the majority of experts (63.8%) indicate that studying the long-term effects of TBI, including mild sport-related concussions, represents the most promising direction for future research [6]. The work of Cunningham et al. emphasizes the potential negative impact on cognitive health not only from diagnosed intracranial injuries but also from repeated sports-related head impacts [7]. However, to date, it has not been possible to definitively establish a link between multiple intracranial injuries and cognitive, behavioral, emotional, and neurological impairments. This highlights the relevance of further research on the delayed consequences of TBI, as also noted in a recent systematic review by Manley et al. [8].

The study purpose is to identify the most frequent clinical manifestations of TBI consequences in active and retired athletes from various sports.

MATERIALS AND METHODS

In order to assess the prevalence of symptoms associated with various TBI consequences, active and former athletes of Russian national teams were surveyed anonymously using a secure online platform with a proprietary domain (LimeSurvey).

This survey included a total of 902 athletes aged 11–80 years, with a median age of 24 [17; 29] years. The participants included 638 males (70.7%) and 264 females (29.3%).

For comparative analysis, the surveyed athletes were divided into two groups according to their age at the time of the study: adults ($n = 662$ (73.4%), aged 18 years and older; median age: 23 [20; 31] years) and minors ($n = 240$ (26.6%), under 18 years of age; median age: 16 [15; 16] years). Due to likely differences in their health status, the analysis was performed separately for each age group.

The adult athletes were further divided into two subgroups to identify differences in clinical manifestations depending on their history of TBI: athletes who reported having at least one concussion ($n = 101$; median age: 29 [22; 39] years) and athletes who denied having a concussion ($n = 561$; median age: 22 [20; 29] years). Subsequently, in order to identify the cumulative effect of TBIs, the adult athletes who had a history of at least

one concussion were further divided into two subgroups: athletes who experienced one to two concussions ($n = 50$; median age: 27 [23; 39] years) and athletes with three or more concussions in their medical history ($n = 51$; median age: 30 [22; 39] years).

In order to determine the effect of frequent contact/impacts during training and competition on the clinical manifestations of TBI consequences, the adult athletes who had no history of concussion were divided into two subgroups: athletes who reported a high probability of contact/impacts in their sports activity ($n = 298$; median age: 22 [20; 29] years) and athletes who reported a low probability of such occurrences in their sports activity ($n = 263$; median age: 23 [19; 29] years).

For an in-depth analysis of age-related differences in the structure of clinical manifestations associated with the consequences of intracranial injury, the adult athletes were further divided into age subgroups: 18–30 years, 31–40 years, 41–50 years, and ≥ 51 years.

The study included current members of Russian national teams, as well as former members who had already retired from sports. The athletes who refused to participate or whose answers to the questionnaire were incomplete/incorrect were excluded from the study.

The survey was conducted from October 2023 to February 2024 using a questionnaire developed by the present authors. This questionnaire contained 50 questions requiring a yes/no answer, as well as a text response if stated by the question. The participants were asked about the type of sport and continuation of a sports career, anamnestic data (gender, age, marital status, harmful habits, chronic diseases, and medication use), and the presence of symptoms that could be the clinical manifestations of TBI consequences. The questionnaire also contained questions to ascertain the presence of the following groups of impairments: cognitive (decline in memory, attention, and concentration; difficulties performing routine daily tasks), behavioral (excessive impulsivity, cruelty, aggression, anxiety, lethargy, withdrawal, or other behavioral changes), affective (feelings of excessive sadness, depression, or hopelessness; anxiety, irritability, or mood swings), motor (change or unsteadiness of gait, accidental falls, tremors in hands, and muscle weakness), speech impairments (difficulty with pronunciation; distortion of words or individual sounds), sleep disturbances, and deterioration of vision or hearing, as well as significant recent changes in handwriting. The proportion of affirmative responses was then calculated for each group of impairments.

Statistical data analysis was performed using IBM SPSS Statistics 23.0 software. The Kolmogorov–Smirnov test was used to assess the distribution of quantitative parameters. Descriptive statistics for quantitative data are presented as median and quartiles; qualitative characteristics are presented as absolute and relative frequencies with their 95% confidence intervals. The non-parametric Mann–Whitney U test was used for

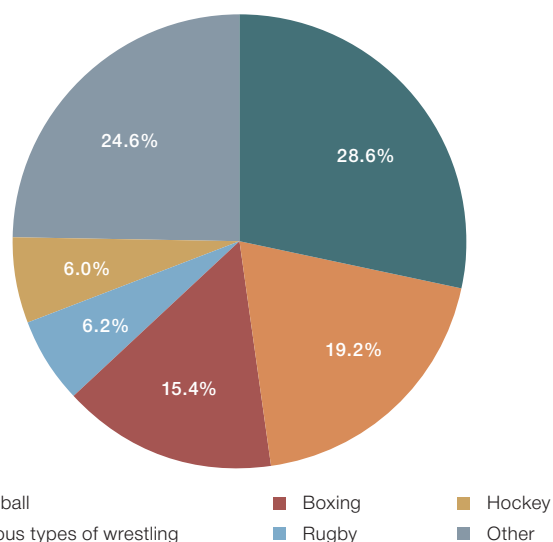


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Fig. 1. Participant distribution by sport

comparative intergroup analysis of quantitative variables. Comparison of discrete variables was performed using Yates’s chi-squared test for cases where the number of observations was less than ten in at least one cell. If the number of observations was less than five in any cell, Fisher’s exact test was used. A significance level of less than 0.05 for all statistical calculations was considered statistically significant.

RESULTS

Initial processing of the questionnaires revealed that representatives of a wide variety of sports participated in the study. Their distribution by sport is presented in Figure 1. The largest number of survey participants represented the following sports: football (28.6%), various types of wrestling (19.2%), boxing (15.4%), rugby (6.2%), and hockey (6%). Other sports included basketball, bobsleigh, athletics, modern pentathlon, fencing, handball, parachuting, luge, skeleton, speed skating, skateboarding, artistic gymnastics, freestyle skiing, and figure skating.

The survey found that 795 (88.1%) athletes continue to engage in professional sports, while 107 (11.9%) athletes are already retired.

Chronic diseases were noted in 52 (5.8%) athletes: allergic manifestations, chronic tonsillitis, diabetes mellitus, psoriasis, and chronic obstructive pulmonary disease.

A total of 145 (16.1%) athletes regularly experience headaches or migraines; however, only 38 (4.2%) of them sought medical help for these conditions. When asked about previously diagnosed anxiety, depression, or other mental disorders, 13 (1.4%) athletes gave an affirmative answer; 2 (0.2%) athletes reported having attention deficit hyperactivity disorder; 3 (0.3%) athletes had writing and reading disorders.

Concussions were reported by 15.3% [95% CI: 12.5; 18] of the adult athletes, with the number of hospitalizations due to TBI being 6.3% [95% CI: 4.5; 8.2]; three or more concussions were reported by 7.7% [95% CI: 5.7%; 9.7%] of the athletes. Noteworthy is that the prevalence of concussions ($p < 0.001$), hospitalizations ($p = 0.002$), and repeated TBIs ($p < 0.001$) is statistically significantly higher in the adult athletes compared to the minors (Table 1).

The recovery period was noted to be statistically significantly shorter in the adult athletes compared to the minors: 8 [4; 21] days vs. 19.5 [7; 45] days ($p < 0.001$).

In the study, unexplained fatigue, headache/dizziness, and exercise-induced nausea during non-excessive individual loads were reported by 382 (57.7%) adult and 14 (5.8%) minor respondents ($p < 0.001$). However, the vast majority emphasized that such situations occurred extremely rarely.

Table 2 compares possible clinical manifestations of TBI consequences in the adult and minor athletes. As compared to the minors, the adult athletes, statistically significantly more frequently reported cognitive impairments (11.6% vs. 6.3%, $p = 0.019$), behavioral disturbances (11.2% vs. 6.7%, $p = 0.046$), sleep disturbances (20.1% vs. 11.3%, $p = 0.003$), vision deterioration (14.1% vs. 3.8%, $p < 0.001$), and hearing loss (4.4% vs. 0.4%, $p = 0.007$).

Table 1. Number of concussions, hospitalizations, and repeated concussions in the adult and minor athletes

Parameter	Adult athletes (n = 662)	Minor athletes (n = 240)	Statistical significance level, p
Number of concussions, %	15.3 [12.5; 18]	2.5 [0.5; 4.5]	< 0.001
Number of hospitalizations due to concussion, %	6.3 [4.5; 8.2]	0.8 [0.3; 1.9]	0.002
Number of participants with a history of three or more concussions, %	7.7 [5.7; 9.7]	1.3 [0.4; 3.3]	< 0.001

Table compiled by the authors based on their own data

Note: n — number of athletes; data are presented as relative frequencies and their 95% confidence intervals.

Table 2. The most common clinical manifestations associated with the consequences of intracranial injury in the adult and minor athletes

Clinical manifestations	Adult athletes (<i>n</i> = 662)	Minor athletes (<i>n</i> = 240)	Statistical significance level, <i>p</i>
Decline in memory, attention, concentration; difficulties performing routine daily tasks, %	11.6 [9.2; 14.1]	6.3 [3.2; 9.3]	0.019
Excessive impulsivity, cruelty, aggression, anxiety, lethargy, withdrawal, or other changes in behavior, %	11.2 [8.8; 13.6]	6.7 [3.5; 9.8]	0.046
Feelings of excessive sadness, depression or hopelessness, anxiety, irritability, or mood swings, %	16.3 [13.5; 19.1]	11.7 [7.6; 15.7]	0.085
Change or unsteadiness of gait; accidental falls; tremors in hands; muscle weakness, %	4.2 [2.7; 5.8]	1.7 [0.1; 3.3]	0.103
Speech impairments; difficulty with pronunciation; distortion of words or individual sounds, %	2.3 [1.1; 3.4]	4.2 [1.6; 6.7]	0.192
Sleep disturbances, %	20.1 [17; 23.1]	11.3 [7.3; 15.3]	0.003
Significant recent changes in handwriting, %	4.7 [3.1; 6.3]	5 [2.2; 7.8]	0.844
Deterioration of vision, %	14.1 [11.4; 16.7]	3.8 [1.4; 6.2]	< 0.001
Hearing loss, %	4.4 [2.8; 5.9]	0.4 [0.03; 1.2]	0.007

Table compiled by the authors based on their own data

Note: *n* — number of athletes; data are presented as relative frequencies and their 95% confidence intervals.

A comparative analysis of the clinical manifestations of TBI consequences in the adult athletes revealed that these changes were statistically significantly more frequent in the athletes with a history of concussion (Fig. 2).

Among the athletes with a history of concussion, the most common manifestations were sleep disturbances (36.6%), affective disturbances (27.7%), cognitive impairments (25.7%), behavioral disturbances (22.8%), and visual disturbances (23.8%). The athletes without a history of concussion most frequently reported sleep disturbances (17.1%), visual disturbances (12.3%), and affective disturbances (14.3%).

In the adult athletes who had a history of one or two concussions (*n* = 50), the conducted analysis revealed no statistically significant differences in any of the studied impairments as compared to those who had three or more TBIs (*n* = 51).

However, despite the lack of statistically significant differences, the difference in some manifestations reaches two-fold or more. Thus, the adult athletes with repeated concussions exhibit a trend towards a greater prevalence of behavioral disturbances (29.4% vs. 16%, *p* = 0.171), affective disturbances (35.5% vs. 20%, *p* = 0.136), as well as changes in handwriting (17.7% vs. 6%, *p* = 0.134), compared to the athletes with a single concussion.

The adult athletes specializing in contact sports more frequently reported affective (*p* = 0.012), behavioral (*p* < 0.001), and cognitive impairments (*p* = 0.009), as well as visual disturbances (*p* = 0.032), as compared to athletes not engaged in contact sports (Fig. 3).

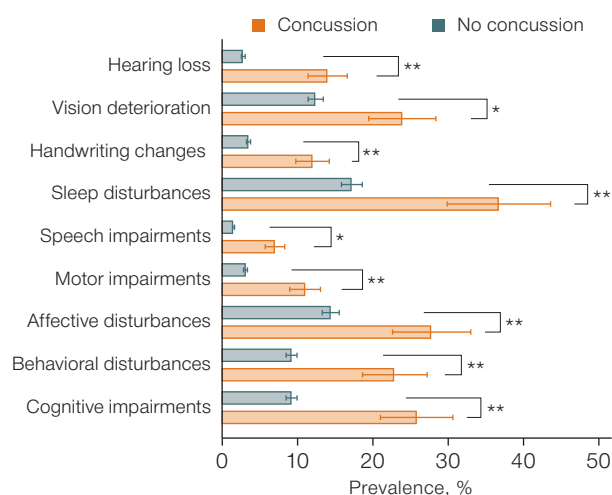


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Fig. 2. Prevalence of clinical manifestations associated with the consequences of intracranial injury in the adult athletes: * — statistical significance level of *p* = 0.003; ** — statistical significance level of *p* < 0.001

Among the adult athletes representing contact sports, the most prevalent issues were sleep disturbances (19.5%), affective disturbances (17.8%), visual disturbances (15.1%), behavioral disturbances (13.1%), and cognitive impairments (12.1%).

A prevalence analysis of TBI-related impairments in the adult athletes found that in the adults aged 18–30 years, the most common disturbances (relative to all identified pathologies) were as follows: sleep disturbances in 26.4% [95% CI: 21.6; 31.1] of the respondents, affective disturbances in 23.4% [95% CI: 18.8; 27.9], and behavioral disturbances in 13.2% [95% CI: 9.6; 16.8].

In the 31–40 years age group, sleep disturbances were identified in 18.8% [95% CI: 11.5; 26.0]; cognitive impairments, in 7.9% [95% CI: 10.8; 25.0]*; vision deterioration, in 17.9% [95% CI: 10.8; 25.0].

In the age group 41–50 years, vision deterioration was noted by 29.2% [95% CI: 18.7; 39.7] of the respondents; sleep disturbances and

cognitive impairments, by 16.7% [95% CI: 8.1; 25.3] and 16.7% [95% CI: 8.1; 25.3] of the respondents, respectively. In the age group 51 years and older, vision deterioration was reported by 24.4% [95% CI: 14.2; 34.3] of the athletes; sleep disturbances, by 17.1% [95% CI: 8.3; 26.0]; cognitive and behavioral impairments, by 11.4% [95% CI: 4.0; 18.9]. In all age groups, sleep disturbances were among the most prevalent issues, while visual disturbances also ranked highly in the group over 40 years of age (Fig. 4).

The detailed prevalence analysis of clinical manifestations associated with the consequences of intracranial injury revealed that among the athletes over 40 years of age with a history of concussion, behavioral disturbances were statistically significantly more frequent compared to athletes without such injuries ($p < 0.05$). Conversely, among athletes under 30 years of age with a history of TBI, cognitive ($p = 0.003$) and affective disturbances ($p = 0.003$) were statistically significantly more frequent.

DISCUSSION

Both active and former athletes participated in this survey. The study sample was predominantly composed of athletes engaged in contact sports, where the probability of sustaining a head injury is higher. This indicates the representativeness of the sample and is consistent with data from other studies [9–11].

The low prevalence of diagnosed affective, cognitive, and behavioral disorders (0.3%, 0.2%, and 1.4%, respectively) among all athletes may indicate both their reluctance to seek medical help and the social stigmatization of the aforementioned disorders, as reported by some authors [12–15]. In high-performance sports, it is not uncommon for athletes to dissimulate their health problems in order to be cleared for participation. Published research indicates that up to half of respondents may deliberately hide symptoms from coaching staff and medical personnel, while some athletes may not pay attention to concussion

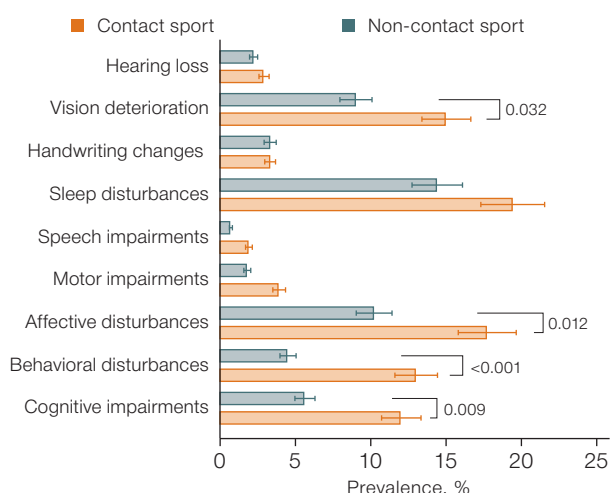


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Fig. 3. Prevalence of clinical manifestations associated with the consequences of intracranial injury in the adult athletes from contact and non-contact sports

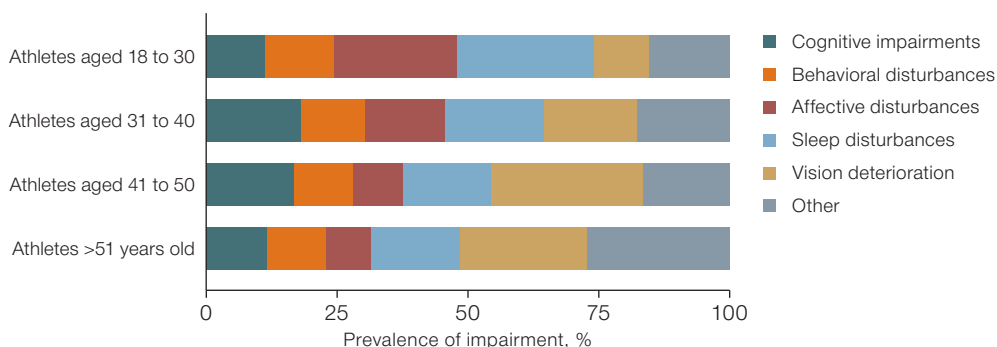


Figure prepared by the authors based on their own data

Fig. 4. Age-structured prevalence of clinical manifestations associated with the consequences of intracranial injury in the adult athletes

symptoms due to limited awareness of the issue [15, 16]. This is confirmed by the present study: 16.1% of the athletes reported regularly experiencing headaches/migraines; however, only 4.2% sought official medical help for these conditions.

A history of TBI was reported by 15.3% of the adult athletes and 2.5% of the minor athletes, confirming the validity of age-based grouping for further analysis of clinical manifestations associated with the consequences of intracranial injury. According to foreign authors, the frequency of concussions in football ranges from 0.1 to 5% [17–20]. Such differences may be explained by the broader age range in the present study, which included retired athletes, the predominant inclusion of athletes from contact sports, and the fact that statistics in foreign studies are often reported only for concussion cases documented by medical personnel. In this study, the rate of repeated concussions was 7.7% among surveyed adult athletes, with every second athlete reporting ≥ 3 concussions. The number of hospitalizations due to head injury was 6.3% among the adult athletes, which aligns with data from other authors [20, 21].

The present study indicates a statistically significantly higher frequency of cognitive and behavioral impairments, sleep disturbances, and deterioration of vision and hearing among the adult athletes compared to the minors. Given the significantly higher prevalence of concussions in adult athletes, as well as the greater neuroplasticity in young athletes, this observation seems logical [22–25]. Moreover, head injury in minor athletes is often accompanied by trauma to the cervical spine (particularly the atlanto-occipital joint), which can lead to reduced cerebral blood flow and development of clinical symptoms. As noted by Pfister et al., the prevalence of concussions in minor athletes may be underestimated due to low awareness regarding the possible clinical manifestations of this condition among athletes, as well as parents and coaching staff [26].

Of particular interest is the statistically significantly higher prevalence of all possible clinical manifestations associated with the consequences of intracranial injury in the adult athletes with a history of at least one concussion. Their most frequent complaints were sleep disturbances, as well as affective, cognitive, and behavioral disturbances, as also noted by several authors [27–34]. Noteworthy is that the identified disturbances cannot be unequivocally interpreted as a direct consequence of organic brain damage, as this study did not include objective instrumental examinations. Furthermore, no statistically significant difference was observed in the amount of subjective symptomatology between the athletes based on the number of concussions. This may indicate the high potential danger of intracranial injuries in athletes, where even a single case can trigger a cascade of pathological, irreversible reactions.

A comparative analysis of the studied clinical manifestations associated with the consequences of intracranial injury found that the athletes in contact sports reported cognitive, affective, behavioral, and visual disturbances statistically significantly more often compared to athletes in non-contact sports. This creates the need for screening studies specifically for the aforementioned disturbances and particularly among athletes at high risk of sustaining concussions.

In athletes over 30 years of age, the most common manifestations were sleep disturbances, visual disturbances, and cognitive impairments, while in the age group 18–30 years, affective disturbances and sleep disorders were predominant. Therefore, the athlete's age is an important factor in the selection of screening measures. Of note is that cognitive changes and visual disturbances in athletes over 40 years of age may be associated not only with a history of TBI but also with age-related changes. Conversely, the identification of cognitive impairments in athletes under 30 years of age may indicate the need for additional examination to interpret the disturbances in the context of consequences following intracranial injuries.

One of the most severe long-term consequences of TBI is traumatic encephalopathy syndrome, for which diagnostic and therapeutic strategies are yet to be established. Despite certain limitations of this survey, it revealed that nine (1%) athletes meet the criteria for diagnosis of traumatic encephalopathy syndrome (history of TBI; participation in a contact sport with five or more years of athletic experience; no TBI in the 6 months prior to the study; cognitive impairments and mood and/or behavioral disturbances; onset of symptom progression less than 12 months prior) [35]. This confirms the need to pay close attention to the health status of athletes and highlights the important role of questionnaires in athlete assessment.

The study of consequences following intracranial injuries is significantly complicated by the current lack of consensus within the global community regarding the classification of these conditions. Noteworthy is that most consequences of intracranial injuries are characterized by non-specific manifestations, which are difficult to interpret without considering the subject's medical history [6]. Many authors unequivocally state that professional sports activity is an undeniable risk factor for TBI, especially in contact sports [5, 36].

According to Ledreux et al., long-term monitoring of athletes with a history of multiple TBIs has important practical significance for the early detection of possible abnormalities in organs and systems [37]. Therefore, it seems promising to introduce methods for psychometric assessment of baseline cognitive function in athletes into the practice of sports medicine physicians; however, this requires the preliminary development of the most valid tests [38].

The limitations of this study include its conduct at a single center and the insufficient number of surveyed retired athletes in the older age group, as well as the subjectivity of the survey due to the lack of objective medical examination data to confirm the athletes' complaints.

Future research directions should include conducting long-term observational prospective studies aimed at developing sensitive methods for the early diagnosis of clinical manifestations associated with the consequences of intracranial injury, identifying specific biomarkers for the premorbid diagnosis of neurodegeneration, and searching for predictors of adverse outcomes after concussions in athletes. The methodology of subsequent studies should incorporate objective instrumental methods for examining both the brain and adjacent structures (cervical spine; atlanto-occipital and temporomandibular joints), particularly in adolescents.

CONCLUSION

In the adult athletes with at least one prior concussion, the most common clinical manifestations associated with the consequences of intracranial injury are as

follows: sleep disturbances (36.6%); affective (27.7%), cognitive (25.7%), and behavioral (22.8%) disturbances; visual disturbances (23.8%). These are statistically significantly more frequent in athletes participating in contact sports. Particular attention should be paid to athletes with a history of TBI who exhibit cognitive impairments identified before the age of 30 and those exhibiting behavioral disturbances after the age of 40.

Most of the post-traumatic syndromes associated with TBI consequences have a wide range of non-specific clinical manifestations. Due to the similarity between the clinical picture of post-traumatic syndromes and that of general somatic syndromes, the interpretation of observed disturbances in athletes is significantly complicated, with already existing pathological conditions treated only symptomatically.

A promising area of research is the development of highly sensitive and specific screening measures, including the early detection of the most common clinical manifestations associated with the consequences of intracranial injury. These measures could be easily integrated into the biomedical support for high-performance sports and contribute to the preservation of athletes' health.

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