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Sport-Related Concussion in Youth and Adult Athletes: A Narrative Review of Long-Term Outcomes and Prevention

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Abstract

Sport-related concussion (SRC) is a common form of mild traumatic brain injury and represents a growing public health concern across youth, adolescent, and adult athletic populations. Characterized by transient neurological dysfunction following biomechanical forces to the head or body, SRC presents with a broad range of cognitive, physical, and emotional symptoms and is frequently underrecognized and underreported. This narrative review synthesizes current evidence on the epidemiology, risk factors, long-term neurocognitive outcomes, and prevention strategies associated with sport-related concussion.

Available data indicate that SRC accounts for a substantial proportion of injuries in contact and collision sports, with particularly high incidence among youth and adolescent athletes. Younger individuals appear more vulnerable to prolonged recovery and persistent neurocognitive impairment, likely related to ongoing brain development and biomechanical factors. A history of prior concussion consistently emerges as a major risk factor for subsequent injury and adverse long-term outcomes, with cumulative exposure linked to persistent cognitive deficits and increased risk of later-life mental health disorders. Importantly, growing evidence suggests that neurocognitive impairments may persist beyond clinical symptom resolution, challenging traditional symptom-based return-to-play approaches.

Effective prevention of SRC requires a multifaceted strategy. Protective equipment alone is insufficient, while standardized equipment fitting, rule modifications, consistent enforcement, education, and neuromuscular training programs show promise in reducing concussion risk.

Coordinated efforts across clinical practice, sport policy, and education are essential to improve concussion recognition, management, and long-term neurological health in athletes.

Keywords: sport, concussion, youth athletes, neurocognitive effects, injury prevention

Introduction

Concussion, a form of mild traumatic brain injury, is increasingly recognized as a significant health issue in both youth and adult athletes across a wide range of sports disciplines. Characterized by transient impairment in neurological function following biomechanical impact to the head or body, concussion can result in cognitive, physical, and emotional symptoms that interfere with sport participation and daily activities [1,2].

Sport-related concussion (SRC) is a common injury in adolescent collision sports, with tackle football demonstrating one of the highest concussion rates among youth sports [3]. Epidemiological estimates indicate that SRC represents a substantial public health burden in the United States, with millions of cases occurring annually [4]. SRC are widely believed to be underreported, in part due to reliance on self-reported symptoms and limited injury recognition [5].

The physiological and clinical presentation of concussion is complex and variable. Symptoms may include headache, dizziness, visual disturbance, amnesia, and emotional dysregulation, with onset ranging from immediate to delayed hours after impact [6,7]. Emerging evidence suggests that even a single concussion can have lasting neurocognitive effects, particularly if not managed properly.

Young athletes may be particularly vulnerable to SRC due to ongoing brain development, age-related anatomical differences, and reduced cervical muscle strength, which can increase biomechanical forces transmitted to the brain during impact [8].

Despite increased attention to concussion risk, substantial variability persists in the diagnosis, monitoring, and return-to-play decision-making across sports and institutions. Assessment tools such as the SCAT6, BESS, and computerized neurocognitive testing provide structured

frameworks, but their sensitivity and applicability vary depending on the clinical and sporting context [9,10].

To ensure safer sport participation and long-term neurological health, a comprehensive understanding of concussion epidemiology, risk factors, and prevention strategies is essential. This narrative review synthesizes current scientific evidence to support informed clinical decisions, policy design, and athlete education.

Methods - Literature Search Strategy

A structured literature search was conducted to identify original research articles addressing the epidemiology, risk factors, long-term outcomes, and prevention strategies related to sport-related concussion. The search aimed to capture evidence relevant to athletic populations, with particular emphasis on youth and adolescent sport participation.

Electronic searches were performed in PubMed and Scopus, selected for their broad coverage of biomedical and sports medicine literature. The following search string was applied consistently across both databases: “Concussion” AND “Sport” AND (“Youth” OR “Adolescent” OR “Athlete”).

To ensure relevance to contemporary concussion research and clinical practice, the search was limited to articles published between January 2000 and December 2025. Only studies with full-text availability in English were considered eligible for inclusion.

After removal of duplicate records, titles and abstracts were screened to identify studies relevant to the scope of the review. Eligibility was determined based on general relevance to SRC and alignment with the objectives of the review, including the study population, outcomes of interest, and research design.

Full-text articles were subsequently reviewed to confirm suitability and relevance. Studies were excluded if they did not address concussion in a sporting context, lacked athlete-focused data, or did not report outcomes pertinent to concussion epidemiology, clinical characteristics, long-term effects, or prevention strategies.

The final set of included studies was synthesized narratively and organized into three thematic areas:

1. epidemiology and risk factors of sport-related concussion,
2. long-term neurocognitive and psychosocial outcomes,
3. prevention strategies, including equipment, rule modifications, education, and training-based interventions.

Epidemiology and Risk Factors of Sport-Related Concussion

SRC is a common injury in contact and collision sports, particularly among youth and collegiate athletes. Previous estimates suggest that concussions account for approximately 1-9% of all reported athletic injuries, with higher proportions observed in sports such as American football, rugby, and ice hockey [1]. Previous estimates have suggested that between 1.6 and 3.8 million SRC may occur annually in the United States, although the true incidence is likely higher due to persistent underreporting [4].

Previous research indicates that adolescent athletes often experience a longer duration of post-concussion symptoms and less favorable recovery trajectories compared with adults, highlighting age as an important modifier of concussion risk and recovery [11]. The same study highlighted differences in processing speed and attention, suggesting incomplete neurodevelopment may render youth more vulnerable to prolonged effects.

In a recent study of volleyball players, no meaningful sex differences were observed in the odds of reporting sport-related concussion, although reporting behaviours and access to medical care varied across participants [12]. These findings align with broader meta-analyses indicating that female athletes may experience greater symptom burden and slower recovery across a variety of sports.

Experience and technique may act as important modifiers of concussion risk. In a study by Kolstad et al. (2025), Canadian youth football coaches reported inconsistent helmet-fitting practices and highlighted variability in player technique, factors they perceived as potentially contributing to an increased risk of head injury among youth players [3]. Furthermore, the study highlighted that formal and regular athlete education on head safety was inconsistent among coaches, underscoring the importance of coach awareness and training in concussion risk mitigation.

A history of prior concussion is one of the most consistent and well-established risk factors for subsequent injury. Prospective data from collegiate athletes indicate that individuals with a

previous concussion have a substantially increased risk of sustaining another concussion, with evidence of a dose-response relationship as the number of prior concussions increases [13]. This is further supported by evidence indicating that athletes may return to play before full neurological recovery has occurred, thereby increasing cumulative vulnerability to subsequent injury over time [9].

Sociocultural factors also contribute to underreporting and delayed diagnosis. Kroshus et al. (2022) emphasized that athletes often downplay symptoms to avoid losing their place on a team, particularly in high-competition environments where toughness is valued over safety [5]. This underreporting is more prevalent among male athletes and in sports like American football and wrestling.

Environmental and organizational factors also influence concussion incidence and recognition. Schools and teams with limited access to trained medical personnel and standardized concussion protocols have been shown to identify fewer sport-related concussions, suggesting that resource availability directly affects detection and management [14].

Long-Term Effects and Neurocognitive Outcomes of Sport-Related Concussion

Numerous studies have found that athletes with a history of multiple concussions perform worse on tests of memory, attention, and executive functioning. In pediatric populations, longitudinal evidence shows that a significant proportion of children and adolescents experience persistent cognitive symptoms, including slowed processing and attention difficulties, for weeks to months after concussion [14]. These results suggest that standard return-to-play criteria may overlook subtle but clinically significant deficits in brain function.

A study of Hou X. et. al found that adolescents can exhibit measurable cognitive impairment for **1-6 months** after sport-related concussion, including deficits in attention and executive function [15]. These findings challenge the widely held belief that SRC recovery is always complete within two weeks. Similarly, longitudinal research in adolescent athletes has demonstrated that cognitive functions involved in working memory and attention may remain disrupted beyond clinical symptom resolution, even several weeks post-concussion [16].

Ransom et al. (2015) investigated the academic impact of concussion in children and adolescents and found that many students experienced difficulties with concentration, memory, and cognitive stamina after injury. These impairments often interfered with school performance

and could persist beyond the acute symptomatic phase, even after return to the classroom. The authors highlighted the importance of individualized academic accommodations and collaboration between healthcare providers, families, and schools to support recovery [17].

Another study analyzed data from retired professional American football players and demonstrated a clear association between cumulative concussion exposure and later-life depression. Players who reported a history of **three or more concussions had approximately a threefold higher likelihood of being diagnosed with clinical depression** compared with those who reported no prior concussions, while those with one or two concussions showed an intermediate increase in risk, indicating a **dose-response relationship**. Importantly, this association remained significant after adjustment for potential confounders such as age, years of professional play, and medical comorbidities, suggesting that recurrent concussion exposure independently contributes to long-term depressive outcomes [18].

Prevention Strategies

The increasing awareness of the long-term consequences of SRC has accelerated the development and evaluation of preventive strategies in both youth and adult sports. Prevention can be approached from multiple angles: equipment design, behavioral interventions, rule changes, and technological innovations. This section synthesizes recent findings on what works, and what still needs improvement, in concussion prevention.

Although helmets and mouthguards are standard in contact sports such as American football and ice hockey, their effectiveness in preventing concussion remains limited. In a study of Canadian youth football, Kolstad et al. (2025) reported substantial variability and gaps in helmet-fitting practices among coaches, with many perceiving improper fit as a potential contributor to head injury risk. The authors emphasized the need for standardized helmet-fitting protocols across all levels of competition [3].

Despite the widespread belief that mouthguards prevent concussion, a meta-analysis found no conclusive evidence that mouthguard use significantly reduces the incidence of sport-related concussion, although their effectiveness in preventing dental and orofacial injuries is well established [19]. Thus, equipment alone is insufficient and must be supported by other measures.

One of the most effective macro-level strategies for reducing concussion risk involves rule modifications that facilitate proper head injury assessment. In elite football, allowing temporary substitutions to enable off-field concussion evaluations without placing teams at a numerical disadvantage has been shown to improve the quality and timeliness of medical assessment [9].

Similarly, rule changes in American football aimed at discouraging head-first contact, including the introduction of targeting penalties, have been associated with changes in concussion mechanisms and trends in reported SRC in NCAA football [20]. However, the effectiveness of concussion-related policies depends heavily on consistent implementation and compliance at the coaching and officiating levels, which remains variable, particularly in youth and amateur sport. Evidence suggests that rule enforcement must be accompanied by education, as limited understanding or intentional noncompliance by coaching staff can undermine the intended protective effects of such regulations [5].

A growing body of evidence suggests that neuromuscular training may contribute to concussion risk reduction. In an interventional study of youth soccer players, neck and trunk strength training was associated with reduced peak head acceleration during sport-specific tasks, indicating a potential biomechanical mechanism for mitigating concussion risk [21]. Neuromuscular training programs incorporating plyometric and proprioceptive exercises have been shown to improve postural control and may reduce the risk of SRC by enhancing athletes' ability to respond to and absorb collision forces [22].

Recent advances in wearable head-impact sensors may support real-time monitoring of impact exposure; however, current consensus statements emphasize that such technologies should not be used as standalone diagnostic tools and must be integrated with clinical sideline assessment [9].

Conclusions

SRC represents a substantial and persistent public health concern, particularly in youth and adolescent athletes participating in contact and collision sports. The evidence synthesized in this narrative review highlights that concussions are common, frequently underreported, and characterized by heterogeneous clinical presentations and recovery trajectories. Younger athletes appear especially vulnerable to prolonged neurocognitive effects, likely due to ongoing brain development and biomechanical factors, underscoring the need for age-specific management strategies.

The history of prior concussion consistently emerges as one of the strongest predictors of subsequent injury and adverse long-term outcomes, with cumulative exposure associated with persistent cognitive deficits and increased risk of later-life mental health disorders. Importantly, growing evidence demonstrates that neurocognitive impairments may persist beyond clinical symptom resolution, challenging traditional return-to-play paradigms and emphasizing the limitations of symptom-based clearance alone.

Prevention of SRC requires a multifaceted approach. Protective equipment, while essential, is insufficient as a standalone strategy. Effective risk reduction depends on standardized equipment fitting, evidence-based rule modifications, consistent enforcement, and comprehensive education of athletes, coaches, and officials. Emerging data also supports the potential role of neuromuscular and strength-based training programs in mitigating biomechanical risk factors for concussion.

Overall, improving concussion outcomes will require coordinated efforts across clinical practice, sport governance, and education systems. Standardized assessment protocols, equitable access to trained medical personnel, and a cultural shift toward prioritizing neurological health over competitive advantage are essential to enhance concussion recognition, management, and long-term athlete well-being.

Disclosure

Author's contribution:

Conceptualisation and Methodology: MS

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Check: AH, MS, WK, KW

Formal analysis: MS, MJ, KK, AM

Investigation: AH, MP, MS, MJ

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The authors deny any conflict of interest.

Declaration of generative AI and AI-assisted technologies in the writing process

In preparing this work, the author(s) utilized AI for the purpose of enhancing the clarity and readability of the text. After using this tool, the author(s) have reviewed and edited the content as needed and accept full responsibility for the substantive content of the publication.

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