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Concussion in youth rugby: A systematized state-of-the-art

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Concussion in youth rugby:
A systematized state-of-the-art

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ABSTRACT

This master thesis presents a narrative review encompassing the latest four years of literature to provide a comprehensive understanding of the epidemiology, tackle as a mechanism of injury, and advancements in screening, prevention, and diagnosis of concussions in youth rugby.

This narrative review synthesizes current evidence to provide insights into the multifaceted aspects of concussion in youth rugby and highlights the imperative for ongoing research and collaborative efforts to address this pressing public health issue. Through a systematic examination of the latest literature, this thesis aims to inform stakeholders and guide future directions in the management and prevention of concussions in youth rugby.

The epidemiological landscape of youth rugby-related concussions reveals a concerning trend of increasing incidence rates, underscoring the need for effective preventive strategies. Tackles, particularly in adolescent athletes, emerge as a predominant mechanism of injury in youth rugby, emphasizing the importance of targeted interventions to mitigate the risk and burden associated with this aspect of the game.

Innovations in screening tools and timely identification strategies for higher-risk athletes have facilitated more accurate reporting of concussions, aiding in prompt management and reducing the risk of subsequent injury. Developments in modern diagnostic modalities have enhanced our understanding of the pathophysiology of concussions, enabling tailored management approaches for optimal recovery and minimizing long-term sequelae. Additionally, efforts in prevention strategies, including educational initiatives and neuro-muscular training enhancements, have shown promise in mitigating the occurrence and severity of concussions in youth rugby.

RESUMO

Esta tese de mestrado apresenta uma revisão narrativa abrangendo os últimos quatro anos de literatura para fornecer uma compreensão abrangente da epidemiologia, da placagem como mecanismo de lesão e dos avanços no rastreio, prevenção e diagnóstico de concussões no rugby juvenil.

Esta revisão narrativa sintetiza as principais e mais recentes evidências dentro do campo multifacetado da concussão no rugby juvenil e destaca a necessidade da pesquisa contínua e esforço colaborativo para abordar este urgente problema de saúde pública. Através de um exame sistemático da literatura mais recente, esta tese visa informar os intervenientes e orientar a investigação futura na gestão e prevenção de concussões no rugby juvenil.

O panorama epidemiológico das concussões relacionadas com o rugby juvenil revela uma tendência preocupante de aumento nas taxas de incidência, sublinhando a necessidade de estratégias preventivas eficazes. A placagem, particularmente em atletas adolescentes, emerge como um mecanismo predominante de lesão no rugby juvenil, enfatizando a importância de intervenções direcionadas em mitigar o risco e severidade associados a este aspeto do jogo.

Inovações em ferramentas de rastreio e estratégias de identificação oportuna para atletas de maior risco têm facilitado uma reportagem mais precisa de concussões, permitindo uma rápida gestão e redução do risco de lesões subsequentes. A modernização de métodos de diagnóstico têm aprofundado a compreensão da fisiopatologia das concussões, possibilitando abordagens personalizadas para uma recuperação ótima e minimização de possíveis sequelas a longo prazo. Além disso, esforços dirigidos em estratégias de prevenção, incluindo iniciativas educacionais e aprimoramentos em treinos neuromusculares, têm mostrado promessa na mitigação da incidência e gravidade das concussões no rugby juvenil.

KEYWORDS

Brain Concussion; Rugby; Youth

PALAVRAS-CHAVE

Concussão cerebral; Râguebi; Jovens

1. INTRODUCTION

In recent years, the popularity of rugby among youth has surged, with increasing numbers of children and adolescents participating in the sport. While rugby offers numerous benefits such as physical fitness, teamwork, and discipline, it also carries inherent risks, particularly concerning the potential for traumatic brain injury. Among these injuries, brain concussion stands out as a significant concern due to its prevalence, burden and potential long-term consequences.[1]

As defined by the 6th International Consensus Conference on Concussion in Sport- Amsterdam 2022,[2] sport-related concussion is a traumatic brain injury caused by a direct blow to the head, neck or body, resulting in an impulsive force being transmitted to the brain that occurs in sports and exercise-related activities. This initiates a neuro-transmitter and metabolic cascade, with possible axonal injury, blood flow change, and inflammation affecting the brain. Symptoms and signs may present immediately, or evolve over minutes or hours, and commonly resolve within days, but may be prolonged. No abnormality is seen on standard structural neuro- imaging studies (computed tomography or magnetic resonance imaging T1 and T2-weighted images), but in the research setting, abnormalities may be present on functional, blood flow, or metabolic imaging studies.[2]

Sport- related concussion results in a range of clinical symptoms and signs that may or may not involve loss of consciousness, including but not limited to headache, dizziness, nausea, sensitivity to light or noise, cognitive impairment, and alterations in mood or behavior. Despite being classified as "mild," concussions can have significant short-term and long-term consequences, particularly if not managed appropriately. [2]

This master thesis aims to explore the multifaceted issue of brain concussion in youth rugby, shedding light on its epidemiology, mechanisms of injury, screening and diagnostic challenges, prevention strategies and implications for policy and safety protocols. By delving into this complex topic, we seek to provide a comprehensive understanding of the factors contributing to concussions in youth rugby and offer a state-of-the-art supported by the last 4 year literature review of the best practices in mitigating these risks to safeguard the well-being of young athletes.

2. BODY

2.1. Methods

The review question was the following: What are the most recent effective strategies for preventing and managing concussions in youth rugby players evidenced in the last 4 years of literature? This was our main question which we attempted to answer throughout the review. SANRA[3] served as the starting point for the search strategy (Fig.2).

The search was performed across Pubmed and Embase databases, spanned from the 1st of January of 2020 to the 1st of March of 2024. A comprehensive search strategy was taken utilizing the stated key:

1.PUBMED

((rugby[Title/Abstract]) AND (brain concussion[Title/Abstract])) AND (child[Title/Abstract] OR adolescent[Title/Abstract] OR young[Title/Abstract] OR youth[Title/Abstract]) OR ("Rugby"[Mesh]) AND "Brain Concussion"[Mesh] Filters: Adolescent: 13-18 years, Child: birth-18 years

2. EMBASE

'rugby'/exp AND 'brain concussion/exp AND ([child]/lim OR [school]/lim OR [adolescent]/lim) OR ("brain concussion'/exp OR 'brain concussion') AND ('rugby/exp OR rugby) AND ([child]/lim OR [preschool]/lim OR [school]/lim OR [adolescent]/lim)

A comprehensive search strategy with Medical Subject Headings (MeSH) and free-text terms was taken to ensure study heterogeneity from Pubmed and Medline database to make up the total of 36 articles for assessment. The search was influenced by two main filters, directly selected in the search engines: the studies being published between 2020 and 2024; an age limit of 0-18 years old for the participants/ study focus). The following studies were excluded: duplicated (5), did not focus on youth age group (1), focused primarily on other sports than rugby (2).

Every language, methodologies or designs were included, as well as studies with payment requirement for full-text review. To ensure transparency, the process of selection and eligibility criteria are summarised in **Figure 1.**

By the objective nature of the eligibility criteria, there were no disagreements and no need of consensus nor the necessity of a third author's opinion.

We performed descriptive analyses of the data and summarized the findings from 28 studies. All studies' full texts were obtained through institutional request and exported to SciSummary, where summaries were obtained to help the review.

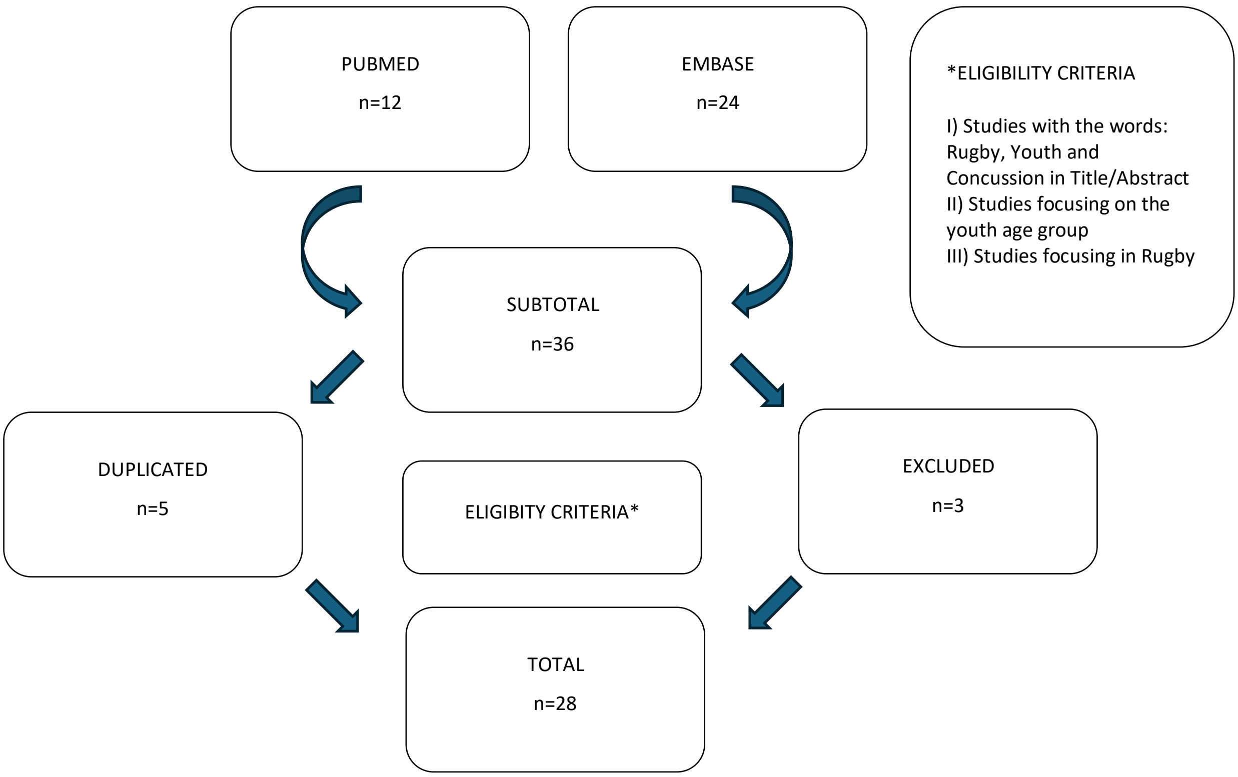
The qualitative analysis carried by the main researcher (FF) involved full-text review screening, identifying descriptions of areas of interest, such as population age range, sex, competition level, years of experience, ethnic background, recommendations, medical interventions, prevention attitudes, symptom reporting, return-to-play guidelines, differences between sex, age, etc. when these results were available, for all studies included in this review.

The information was then narrowed into the categories AGE, DEFINITION, DIAGNOSTIC/SCREENING, GAPS, HEALTH, KNOWLEDGE, INCIDENCE, PREVENTION, RECOMMENDATION, RECOVERY, REPORTNG, RETURN-TO-PLAY, RISK, SEX, STUDY SIZE, TACKLE, TOOLS and TREATMENT.

These categories helped synthetize the information to produce the main 3 titles presented in the results and discussion section of this work.

All study citations were exported to Mendeley Reference Manager.

Figure 1. Study selection and Eligibility criteria



Study sizes in this review:

This review on brain concussion in youth rugby covered a diverse range of study sizes, from smaller cohort studies to larger population-based surveys.

Regarding the information compiled in this review, there was one study involving more than 10.000 participants,[4] four studies with participant numbers exceeding 1000 each,[5–8], four studies with participant ranges between 500 and 1000,[9–12] three studies encompassing participant ranges from 250 to 500[13–15] and twelve studies falling within the sector of fewer than 250 participants.[1,16–26]

Additionally, there were six systematic reviews accompanied by three simultaneous meta-analyses., including 58, 69, 83, 93,192 and 612 studies.[8,22,23,27–29]

The array of study sizes contributed to a contributed to a thorough examination of concussion epidemiology in youth rugby, strengthening the reliability of the findings.

Figure 2. Scale for the assessment of narrative review articles[3]

Scale for the Assessment of Narrative Review Articles – SANRA

Please rate the quality of the narrative review article in question, using categories 0–2 on the following scale. For each aspect of quality, please choose the option which best fits your evaluation, using categories 0 and 2 freely to imply general low and high quality. These are not intended to imply the worst or best imaginable quality.

1) Justification of the article's importance for the readership

The importance is not justified. — 0
The importance is alluded to, but not explicitly justified. — 1
The importance is explicitly justified. — 2

1

2) Statement of concrete aims or formulation of questions

No aims or questions are formulated. — 0
Aims are formulated generally but not concretely or in terms of clear questions. — 1
One or more concrete aims or questions are formulated. — 2

1

3) Description of the literature search

The search strategy is not presented. — 0
The literature search is described briefly. — 1
The literature search is described in detail, including search terms and inclusion criteria. — 2

2

4) Referencing

Key statements are not supported by references. — 0
The referencing of key statements is inconsistent. — 1
Key statements are supported by references. — 2

2

5) Scientific reasoning

(e.g., incorporation of appropriate evidence, such as RCTs in clinical medicine)
The article's point is not based on appropriate arguments. — 0
Appropriate evidence is introduced selectively. — 1
Appropriate evidence is generally present. — 2

2

6) Appropriate presentation of data

(e.g., absolute vs relative risk; effect sizes without confidence intervals)
Data are presented inadequately. — 0
Data are often not presented in the most appropriate way. — 1
Relevant outcome data are generally presented appropriately. — 2

2

Sumscore 10

2.2. Results

The numbers in Youth Rugby Concussion:

The incidence of concussion in youth rugby has been a difficult matter of assessment, with the studies included in this review reporting varying rates across different concussion definitions, age groups, populations and units of exposure.

In this review, there were 3 studies reporting concussion incidences per 1000 player hours,[10,16,22] ranging from 6.1 to 9.03 for overall concussion incidence, while one systematic review analyzed the incidences by sex, reporting 6.2/1000 player-hours (95% CI 5.0–7.4) for males and 33.9/1000 player-hours (95% CI: 24.1–43.7) for females.[22] One of them also reported an approximate training concussion incidence of 0.64 per 1000 player hours.[16]

One study protocol linked the estimated 6.1 concussions per 1000 game hours from the literature to 3 concussions per team per season.[30]

Another two studies described their results per hours, one including concussions per 1000 training/match hours as units of exposure,[14] with incidence rates ranging from 0.6 to 22.0/1000 hours (95% CIs: 15.9-30.4) respectively, as the most common injury type (38).[14] The other study didn't specify on playing hours, revealing a 4.5 concussion incidence per 1000 hours, but also identifying SRC as having the greatest injury burden (102 days/ 1000 hours).[11]

One study reported concussion prevalence rate by percentage of players who recalled sustaining a previous SRC as a schoolboy rugby player, reaching the value of 40%, which the author converted into the proportion 2 in 5.[9]

Another study utilized the term suspected concussion by percentage of total injuries, setting an 8.5% for males and an 3.2% for females.[4] There was also reference to the probability of sustaining a concussion over a season, ranging from 7.7 to 22.7% in junior rugby league and union players.[4]

Finally, one meta-analysis collected the incidence with concussion per 10,000 athlete events, obtaining 25 and 28.12 from two studies.[27]

These findings are combined in **Table 1.**

Table 1. Incidence of concussion through the study sizes in this review

Author (Year of publication)	Study size (n)	Sex	Concussion Incidence	Observations
Cosgrave et al. (2023)	135	NA	0.64 per 1000 player hours	Training incidence
van Tonder et al. (2023)	800-900 per year	NA	6.1-8.9 per 1000 player hours	Match incidence (control-intervention
Cosgrave et al. (2023)	135	NA	9.03 per 1000 player hours	Match incidence
West, Shill, Bailey, et al. (2023)	69 studies	Male	6.2 (5.0–7.4) per 1000 player hours	NA
West, Shill, Bailey, et al. (2023)	69 studies	Female	33.9 (24.1–43.7) per 1000 player hours	NA
McKee et al (2023).	Protocol	NA	3 per team per season	Converted from literature
Murray-Smith et al. (2023)	979 participants	Male	4.5 per 1000 hours	NA
West, Shill, Sick, et al.(2023)	429 participants	NA	22.0 per 1000 match-hours	Match incidence
West, Shill, Sick, et al.(2023)	429 participants	NA	0.6 per 1000 training-hours	Training incidence
Beakey et al. (2020)	866 participants	Male	40% of players who recalled sustaining a previous SRC	Survey
Orr et al. (2021)	13.169 participants	Male	8.5% of total injuries	NA
Orr et al. (2021)	13.169 participants	Female	3.2% of total injuries	NA
Van Pelt et al. (2021)	83 studies	NA	25-28,12 per 10,000 athlete events	junior rugby league and union
Van Pelt et al. (2021)	83 studies	NA	7.7 to 22.7% probability of sustaining a concussion over a season	junior rugby league and union

Legend: NA- not applicable/available

Irrespective of the definition or the denominator used, West, Shill, Bailey, et al' systematic review and meta-analysis discovered that in male youth rugby, the concussion incidence rates rises with each subsequent age grouping, from U12 to 12–14 years to 15–18 years.[22] Of particular note, the authors identified the change from 12 to 13 years old (7%) and 16 to 17 years old (9%) as the first and second largest single-year rises in injury risk in males (C5) and the change from 12 to 13 years old (8%) and 13 to 14 years old (9%) as the second and third highest single-year rises in injury risk in females.[22]

The most prevalent in elite U16 and U18 players, head injuries deserve an honorable mention, as the most injured body region (35% of total injuries), according to the 13.169 impressive sample study included in this review.[4]

While younger age at first exposure (AFE) to contact or collision sports like rugby has not been associated with worse patient-reported outcomes for either male or female young adult players[5] and the overall injury incidence in junior rugby league, contrary to common community perceptions, has not increased,[4] reported concussion incidence rates, particularly within Rugby, demonstrate a climbing pattern across the literature, scaling as three times greater than American Football.[27] One study particularly connected concussion injuries with the highest average severity of injuries[11] (22.4 days) and recognized concussion age-specific patterns in injury rates and injury burden, with the highest concussion injury rates observed in under-15 (U15) players and the greatest concussion injury burden in under-13 (U13) and under-15 (U15) players.[11]

Interestingly, in this review, the highest incidence of concussion has been observed among female players, included in a systematic review and meta-analysis involving the Youth Rugby Union, exposing a shocking 33.9 concussion IR per 1000 player-hour, obtained through careful examination on 24 female data IR.[22]

Several studies had reported higher rates of concussion in females compared to males and in sex-comparable sports, at both high school and collegiate levels,[27] with the female Canadian sample captured by Shill et al presenting the highest previously reported exposing a shocking 37.5 concussion IR per 1000 match-hours,[14] higher than those reported in the senior professional men's game, often reported as the highest rate.[14]

Once more, these findings underscore the recommendations found throughout the literature regarding the necessity to focus attention on the female game[4,22], particularly addressing the heightened vulnerability within the specific 13-18 gender cohort.[4] The factors contributing to the differing injury rates and their potential causes are further elaborated upon in the Discussion section.

Speaking of risk, Rugby, characterized by the familiar contact sports' ambivalent nature, was classified by a 2021 meta-analysis as the highest concussion risk sport.[27] Compared with other youth sports using similar definitions and denominators, youth male rugby demonstrated concussion rates 4.7 times higher than ice hockey and 2.8 to 37.0 times higher than American football. [27]

It is recognized that numerous variables, such as age, sex, level of participation, training methods and session types can influence the risk of sport-related concussions in contact sports.[27] However, recently, studies revealed that not all players share the same risk, and particularly in rugby, the variability in concussion risk may stretch to player's height,[16] type of pitch,[23] and extraordinarily, carrying the ball.[14] A study highlighted the potential differences between match and training probabilities as to which player is more likely to get injured in the tackle, hovering from the ball carrier to the tackler between training and match contexts.[14] Despite these findings, two studies highlighted in this review emphasized that tacklers experienced a 72% higher incidence of head injuries.[10,16] While the authors did not delve deeply into this aspect, it appeared plausible that the slight 2.8cm variation in height observed among concussed players[16] could potentially be linked to or causative of the observed 4.5-fold increase in head injuries resulting from tackles executed above the armpit.[10,16] Moreover, a systematic review and meta-analysis yielded a statistically significant finding for the Rugby community; the news spread that it had discovered a 40% lower SRC rate when the sport was played on a turf field system compared with natural grass[23], similar to a cited previous meta-analysis.

Another protective effect was described in two 2023 systematic review and meta-analysis, outlining a 59% significant reduction in concussion when accomplishing a tri-weekly neuro-muscular training warm-up program,[22] while the most inclusive of them suggesting values oscillating from 32 to 60% lower concussion rates.[23]

On the other hand, the risks associated with rugby are undeniably shared among all stakeholders representing the sport. At the individual level, many studies focused on the reporting rates and their predictability factors. In one of the few studies in the field boasting a large and representative sample size, Bazo et al. found no current statistical association between concussion knowledge scores and athlete self-reported behavior.[6] However, contrasting expectations emerged from the adult responsible side, as almost one-quarter of surveyed coaches reported seeing their peers exert additional pressure on the already stressed ecosystems involving honest reporting of sports-related concussion.[6] The reasoning behind the found 63% of players who would keep on playing despite experiencing concussion-related symptoms[6] is deeply explored in the discussion section.

What remains clear and consistent across sexes and age groups and independent of the shared risk is the significance of the tackle event as a top priority for managing injury and concussion risk in the game[22], leading this master thesis into the subsequent results section.

Contact Zone Analysis: Dissecting the Anatomy of Concussion in Tackles

As PRISP- the most comprehensive and longest running injury surveillance project in professional rugby union- highlighted concussion as the most commonly reported match injury for the 2019/2020 season,[16] accounting for 22% of all match injuries (Kemp et al., 2021), the scrutiny of the tackle has been subject to comprehensive critique across multiple studies.

Specifically addressing concussion, five studies included in this review have presented data exploring its correlation with the tackle, as outlined in **Table 2.**

In this review, three studies demonstrated a direct correlation with the tackle event, reporting values of 55%,[10] 67%,[16] and one study indicating the tackle blameworthiness for 76% of all match concussions.[14] Similar to the previous section, the study with the largest sample size failed to yield pertinent findings regarding this matter. The 6.62% correlation observed between tackle and concussion, derived solely from its application to match injuries attributed to the tackle mechanism, deviates significantly when juxtaposed with values reported in the other studies. Notably, the mean severity of concussions in this study is also the lowest reported, with other studies estimating time-loss for concussed players ranging from 12.5[14] to 22.4[11] days absent. Keeping in mind the aforementioned study, which reported a 76% correlation[14], it is noteworthy that it also documented one of the highest concussion incidence, rouding 22 concussions per 1000 match-hours. The authors did in fact acknowledged a lack of experience within their analyzed cohort, noting that 41% of players reported no previous rugby experience before baseline. As Burger et al. (2016) demonstrated that poorer tackle proficiency is linked to injury outcomes, this lack of experience may better elucidate why the proportion of concussion injuries associated with tackling is higher than previously reported,[14] particularly during both match and training sessions. Interestingly, when delving into the differences between match and training, the authors found that, during matches, concussion occurred 35% to the tackler and 41% to the ball carrier, but in a similar pattern to all injuries, the player at higher risk (ball carrier vs tackler) of concussion was reversed in training versus matches, with 46% of concussions occurring to the tackler and 23% to the ball carrier.[14]

Once again, a particular study, as observed in the campaign for standardizing the unit of exposure concerning concussion incidence, suggested that future Rugby League injury surveillance should classify tackles as defensive (tackler) and offensive (ball carrier) to achieve optimal tackle injury statistics.[4]

Accordingly, two other studies presented contrasting and higher values. One reported concussion in 50% of the tacklers[16], while an interesting one declared a substantial 72% of concussion stemming from being tackled.[11] When reporting 3.6 fewer concussions in tacklers,[11] the authors of this study suggested that this issue may warrant further investigation into the collision characteristics of the ball carrier. Indeed, while investigating this issue and scrutinizing the precise mechanisms or characteristics of tackles associated with concussion, these authors did highlight recent findings indicating differences in specific mechanisms between male (head-to-head) and female (head-to-ground) players in the adult game.[11,22]

Given the high proportion of injuries associated with the tackle, current studies are underway in both France and the United Kingdom to investigate the effect of tackle-related law changes on injury risk in the youth game.[22]

A significant study delving into the legal aspects of this issue experimented with reducing the legal tackle height from the line of the shoulder to the armpit of the ball carrier in community amateur rugby.[10] This change resulted in a 31% reduction in SRC incidence, similar to the findings of the only previous study investigating the same law variation in a professional rugby setting. Despite proved statistical non-significance of the finding, the reduction in SRC incidence during the lower legal tackle height condition in this amateur male rugby cohort could be deemed clinically relevant. However, the authors caution that without another season of data under the tackle law variation, this conclusion remains speculative.[10] More importantly, this measure provided even stronger evidence regarding the independence of legal tackle height and the occurrence of concussions. With the incidence rate ratio between the control and intervention groups for tackle-related SRC standing at a solid 0.99,[10] it can be postulated that the danger in the tackle-concussion association may be attributed to other components of collision characteristics rather than solely the height of the event. Nevertheless, the effect of reduced maximum legal tackle height law variations on SRC incidence in community and professional rugby requires further ongoing investigation to determine its real-life clinical benefit.[10]

A singular study provided data on the injury burden directly attributable to concussion, indicating 102 days of time loss per 1000 hours.[11] Its findings illuminate the significant impact of concussion injuries in terms of lost playing time, highlighting how player concussion outcomes and inadequate management could impact team performance over the course of a season.[11] In line with proposals by other authors, alongside potential law changes and improved medical management, addressing the issue of concussion in the sport necessitates a substantial societal culture shift involving all relevant stakeholders.[6]

Table 2. Concussion correlation with the tackle							
Author (Year of publication)	Study size (n)	Concussion Incidence	Concussion in overall injuries	Tackle-Concussion correlation (TCC)	TCC Tackler	TCC Ball carrier	Mean Concussion severity
Cosgrave et al. (2023)	135	9.03/1000 player hours	NA	67%	50%	16.7%	20 days
Orr et al. (2021)	13.169 participants	0.46/1000 male player-hours [a]	7.9%	6.62% [a]	NA	NA	10±7 days
West, Shill, Sick, et al.	429 participants	22.0 per 1000 match-hours 0.6 per 1000 training-hours	Match: 38-42% Training: 24-29%	76%	Match: 35% Training: 45%	Match: 41% Training: 23%	12.5 days (6-21)
van Tonder et al. (2023)	800 to 900 participants per year	Control: 8.9/1000 hours Intervention: 6.1/1000 hours	Control: 29%[b] Intervention: 23.45% [b]	55%	Control: 35% Interventio n: 43%	Control: 12% Intervention : 24%	19 ±13 days
Murray-Smith et al. (2023)	979 participants	4.5 per 1000 hours	16.4%	NA	20%	72%	22.4 days Burden: 102days/1000hours

Legend: NA- not applicable/available
(a) 5.9 match injuries per 1000 player hours, tackle accounted for 83.9% of total injuries, concussion 7.9% of total injuries
(b) Reported SRC (control (n=26), intervention (n=21)), reported all injuries (control: (89+90)/2, intervention: ((83+97)/2).

Tackling Concussion: Advances in Screening, Diagnosis, Prevention, and Critical Recommendations

Screening

Given the multifaceted manifestations of concussion, it is paramount for not only affected athletes but also the broader rugby community to remain vigilant regarding potential concussive incidents and their real-world implications.

In this review, some studies presented findings related to the screening of symptoms and metrics clinically associated with concussion.

A study undertook the assessment of a spectrum of symptoms following the sports season, revealing that male high school rugby athletes exhibited a notably heightened and more deleterious symptomatic profile consequent to their engagement in contact sports, in contrast to their non-contact sport counterparts.[25] These effects were exacerbated following a rugby season and may be attributed to both sub-concussive and concussive events. The findings align with studies conducted in South Africa by Shuttleworth-Edwards et al., where schoolboy rugby players exhibited significantly higher post-concussive symptomatology compared to controls (non-contact sport players) following the sports season.[25] This trend persisted even three months post-injury, as evidenced by research conducted by Brooks, Kearney, Marar, and Green.[25]

Other studies have delved into the physical assessment of players, revealing contrasting findings. For instance, one study concluded that adolescent rugby athletes with a history of concussion possess alterations in dynamic balance performance compared with healthy controls, despite normal performance on static balance assessments.[19] Conversely, another study demonstrated strength imbalances in the neck musculature (specifically, a lower flexor/extensor ratio) among male rugby athletes with a previous history of concussion.[15]

A crucial aspect of accurately identifying affected players lies in targeting populations at higher risk. A study that implemented a concussion assessment specifically tailored to the New Zealand rugby community highlighted this point, revealing that age, gender, and ethnicity were correlated with poorer performance on the New Zealand Rugby Concussion Assessment (NZRCA).[7]

Another study identified competitiveness as a significant predictor of both past nondisclosure and future non-disclosure intentions, while concussion knowledge did not emerge as a significant factor.[21] The authors recommended that physicians, coaches, parents, and teammates should be vigilant in identifying and monitoring highly competitive athletes when there is a potential for sports-related concussion (SRC), thereby alleviating some of the responsibility on players to self-report symptoms.[21] Additionally, the study encouraged physicians and trainers to engage in discussions about their athletes' competitiveness and motivations surrounding nondisclosure, rather than solely focusing on educating them about concussion symptoms.[21]

Expanding upon this topic, the role of reporting was extensively discussed throughout this results section. Notably, one study highlighted the concerning reluctance among youth players to self-report potential concussive events in the future.[9] In this context, the pivotal role of coaches in this age group cannot be overstated. However, findings suggest that more experienced coaches may face challenges in staying abreast of evolving concussion-related evidence.[6] Consequently, concussion education initiatives should prioritize addressing the knowledge needs of this group of individuals to enhance their ability to effectively recognize and respond to concussive events among youth players.[6]

Diagnosis

In the medical realm of concussion, various discoveries have been made to improve the accurate diagnosis of this injury.

One study indicated that the Sports Concussion Assessment Tool (SCAT) is particularly effective in distinguishing between concussed and non-concussed athletes within 72 hours of injury and up to 7 days post-injury.[29] However, it was noted that the clinical utility of SCAT tools seems to diminish after the initial 72-hour window.[29]

Another noteworthy discovery from the investigation into the subcomponents of SCAT5 revealed no significant differences when evaluated at a median of 20 minutes after a high-intensity exertion test, such as the 30-15 intermittent fitness test[26]. This suggested that a 20-minute recovery period is adequate for SCAT5 metrics to return to their pre-exertion or resting levels.[26] However, it's worth noting that symptoms tended to be higher among athletes tested within 0-10 minutes following the termination of a volitionally fatiguing protocol.[26]

One study eliminated a ceiling effect for memory scores with the addition of a 10-word list to SCAT5.[6]

Other tests have been scrutinized as well, with one study highlighting that 78% of participants exhibited a notable learning effect in the King-Devick (K-D) test after sustaining a concussion, completing it faster than their baseline performance (C1). However, it is essential to note that agreement with clinical assessment was observed in only 38% of cases.[16]

Regarding additional diagnostic methods, numerous studies evaluating eye metrics have yielded significant findings.

One study concluded some variables demonstrated sufficient reliability to be worthy of further consideration.[20] The proportion of directional errors in the AS task showed good level of reliability in the youth group, strengthening the evidence that this measure can serve as a marker for recognizing cognitive disorders (Kleineidam et al. 2019; Subramaniam et al. 2018) including SRC.[20]

Furthermore, eye blink duration in the MSG and sinusoidal SP tasks of the youth group also demonstrated sufficient reliability.[20] For instance, one study investigating this area confirmed that blink duration during memory-guided saccades and sinusoidal smooth pursuit tasks was increased in a group of concussed youth.[18]

In a healthy population, typical blink duration lies within a range of 100–400 ms (Ousler et al. 2014; Stern et al. 1984), and the SRD values in the current study indicate that a deviation of 60 or more blinks in the MGS task might be indicative of a SRC.[20]

One study dedicated its research to appreciate changes in the blood-brain barrier of contact sport players. Their data suggests that dynamic alterations to the blood-brain barrier (BBB) may occur following a complete season of contact sports, with these alterations observed in up to 52% of adolescents.[1] The study indicates that multiple impacts sustained during a single match result in a broader distribution of brain regions affected, which contrasts with the notion that sub-concussive impacts may accumulate within a single match, exacerbating the severity within specific brain regions.[1] The authors identified discernible patterns in biomarkers detected post-season and post-match (specifically BDNF, MCP-1, and S100B), proposing that these markers could potentially serve as indicators of subconcussive trauma and may also offer insights into return-to-baseline assessments. The imaging of blood-brain barrier (BBB) integrity, coupled with serological analysis of participants engaged in contact sports, could constitute a central framework for diagnosis and might offer enhanced guidance for return-to-play protocols.[1]

A pioneering study delved into the efficacy of blood-based biomarkers in facilitating the diagnosis of sports-related concussion (SRC) on the sidelines of athletic events within a timeframe of 1 hour post-concussion. Unfortunately, it appears that S100B and BLBP do not substantially accumulate in serum within that time frame and, although possibly useful in diagnosing SRC at a later time point, are unlikely to be useful in side- line diagnosis.[24]

Prevention

Regarding prevention atittudes, the findings were notable. While one study suggests that existing concussion management strategies may decrease recurrent concussion rates, it is important to recognize that advancements in concussion innovation have the potential to impact these figures.

One study associated prior concussion history with worse self-reported outcomes on some assessments, specifically poorer psychological well-being and lower quality of life in young adults.[5]

There is sufficient evidence supporting the fact that neither improvement of concussion knowledge nor ad hoc legislative amendments do necessarily translate into actual behavioral changes reducing underreporting and improving secondary prevention.[6] A study protocol which aims to track recovery of sport-related concussion for 12 months in predetermined subgroups may allow for an interesting view of whether adolescent rugby players under-report symptoms when quantitatively measured metrics are still elevated [30]

On the other hand, of the prevention strategies assessed, the most promising for reducing the risk of concussion specifically was a neuro- muscular training (NMT) warm-up programme[22]. Given the significant evidence for efficacy in youth sports broadly, some authors support a critical need in their Canadian context for the implementation of primary injury and concussion-specific prevention strategies, such as this neuromuscular training programs.[22]

Other studies showed clinically important findings for injury prevention programmes as they indicated a need for specific neck training programmes to focus on increasing the neck flexor/extensor strength ratio and subsequent stabilisation of the head on contact, improving a potential protective effect on concussion risk.[15] The authors stated the flexor/extensor ratio was highest in the 11–12-

year-old athletes, therefore injury prevention interventions aimed at maintaining this higher ratio may have their greatest impact if implemented from a young age.[15]

Critical recommendations

In a broader context, this compilation encapsulates the conclusive recommendations derived from numerous studies incorporated within this review.

In the clinical bedside setting, certain authors advocate for the necessity of establishing normative data for SCAT (Sport Concussion Assessment Tool) that incorporate socio-cultural and linguistic variables, as well as cater to para-athlete populations.[29]

Some researchers have even collected data supporting modifications to the SCAT tools. Although effective in their intended application, these tools could benefit from enhancements to accommodate the diverse spectrum of athletes seeking care and guidance before and after sports-related concussions (SRC). For instance, one notable consideration is the significance of sex when interpreting SCAT5 baseline scores.[13]

Other highlighted the need to re-examine our traditional education practices to adopt a more culturally responsive approach that can be tailored to the local context and implement strategies that better target positive reporting behaviours.[12] offering a comprehensive exploration of the psychological and sociocultural factors inherent in sports-related concussion (SRC) prevention strategies.[23] The use of validated injury surveillance methodologies (video-analysis and instrumenting players), consideration of confounding variables like concussion history and consensual concussion definitions are needed.[23]

In the same way, authors suggested future studies should consider using sub-categories for contact sports to more accurately capture concussion risk.[27] For example, comparing the same concussed athletes over time rather than healthy controls and describing player participation to measure IRs (player-hours) to prevent clustering effects.[18,23]

Concerning physical testing, certain findings contribute to an expanding body of evidence indicating that deficits in sensorimotor function endure beyond the typical clinical recovery period following a concussion.[19] For this reason, blink duration in youth athletes may hold promise as a valid metric for concussion diagnostics and monitoring.[18]

The frequency of head and neck injury remains a concern in adolescent rugby union and suggests further measures are required to not only recognise and treat concussion in the community setting, but to prevent it.[11] Several studies have emphasized that an area of interest for mitigating the risk of sports-related concussions (SRC) could be the integration of head-on-neck strength components into a comprehensive whole-body warm-up program.[23] There exists a potential to incorporate a neck assessment protocol into the battery of tests administered during the pre-season period.[15] This protocol, which typically takes 4–5 minutes per athlete to complete and has demonstrated reliability, has been utilized across various earlier studies in both football and rugby contexts.[15]

One study in the area did not discover evidence to advocate for the inclusion of any patient-specific, injury-specific, or other factors (such as imaging findings) as absolute indications for retirement or cessation of participation in contact or collision sports.[28]

The several findings related to the Results section are all gathered in **Table 3.**

Table 3. Main findings presented in the results section of this review.	
Author (Year of publication)	Main findings
West, Shill, Bailey, et al. (2023)	The concussion incidence rates rises with each subsequent age grouping, from U12 to 12–14 years to 15–18 years
West, Shill, Bailey, et al. (2023)	The change from 12 to 13 years old (7%) and 16 to 17 years old (9%) as the first and second largest single-year rises in injury risk in males and the change from 12 to 13 years old (8%) and 13 to 14 years old (9%) as the second and third highest single-year rises in injury risk in females
Orr et al. (2021)	Head was the most prevalent injured body region (35% of total injuries) in U16 and U18
Hunzinger et al. (2021)	Younger age at first exposure (AFE) to contact or collision sports like rugby has not been associated with worse patient-reported outcomes for either male or female young adult players
Orr et al. (2021)	Overall injury incidence in junior rugby league has not increased
Van Pelt et al. (2021)	Rugby appears to have a concussion rate that is three times greater than American Football.
Murray-Smith et al. (2023)	Concussion injuries with the highest average severity of injuries (22.4 days)
Murray-Smith et al. (2023)	Highest concussion injury rates observed in under-15 (U15) players and the greatest concussion injury burden in under-13 (U13) and under-15 (U15) players
West, Shill, Bailey, et al. (2023)	The highest incidence of concussion has been observed among female players (33.9/1000 player-hours)
Pelt et al. (2021)	Higher rates of concussion in females compared to males and in sex-comparable sports, at both high school and collegiate levels
West, Shill, Sick, et al. (2023)	The female Canadian sample captured by Shill et al presented the highest previously reported 37.5 concussion IR per 1000 match-hours, higher than those reported in the senior professional men's game, often reported as the highest rate
Pelt et al. (2021)	The necessity to focus attention on the female game
Orr et al. (2021)	Heightened vulnerability within the specific 13-18 gender cohort
Van Pelt et al (2021)	Rugby as the highest concussion risk sport

Van Pelt et al (2021)	Youth male rugby demonstrated concussion rates 4.7 times higher than ice hockey and 2.8 to 37.0 times higher than American football.
West, Shill, Sick, et al. (2023)	Potential differences between match and training concussion risk for tacklers and ball carriers
Van Tonder et al. (2022), Cosgrave et al. (2023)	An upright tackle was 40% more likely to provoke head injuries and they were 72% more frequently in tacklers comparatively to the tackled player
Cosgrave et al. (2023)	2.8cm variation in height observed among concussed players
Van Tonder et al. (2022), Cosgrave et al. (2023)	4.5-fold increase in head injuries resulting from tackles executed above the armpit
Eliason et al. (2023)	40% lower SRC rate when the sport was played on a turf field system compared with natural grass
West, Shill, Bailey, et al. (2023)	59% significant reduction in concussion when accomplishing a tri-weekly neuro-muscular training warm-up program
Eliason et al. (2023)	32 to 60% lower concussion rates when accomplishing a tri-weekly neuro-muscular training warm-up program
Bazo et al. (2023)	Found no current statistical association between concussion knowledge scores and athlete self-reported behavior
Bazo et al. (2023)	One-quarter of surveyed coaches reported seeing their peers exert additional pressure
Bazo et al. (2023)	63% of players who would keep on playing despite experiencing concussion-related symptoms
West, Shill, Bailey, et al. (2023)	Clear and consistent across sexes is the the tackle remains a top priority in the game
Okusanya & basson (2020)	Male high school rugby athletes experienced adverse and more detrimental symptomatic presentation as a result of contact sport season participation.
Matthews et al. (2021)	Adolescent rugby athletes with a history of concussion possess alterations in dynamic balance performance compared with healthy controls, despite normal performance on static balance assessments

Nutt et al. (2022)	Strength imbalances in the neck musculature (specifically, a lower flexor/extensor ratio) among male rugby athletes with a previous history of concussion
Salmon et al. (2022)	Age, gender, and ethnicity were correlated with poorer performance on the New Zealand Rugby Concussion Assessment (NZRCA)
Doucette et al. (2021)	Competitiveness as a significant predictor of both past nondisclosure and future non-disclosure intentions, while concussion knowledge did not emerge as a significant factor
Doucette et al. (2021)	Physicians, coaches, parents, and teammates should be vigilant in identifying and monitoring highly competitive athletes when there is a potential for sports-related concussion
Doucette et al. (2021)	Encouraged physicians and trainers to engage in discussions about their athletes' competitiveness and motivations surrounding nondisclosure, rather than solely focusing on educating them about concussion symptoms
Beakey et al. (2020)	Worrying lack of desire to self-report future potential concussive events
Bazo et al. (2023)	More experienced coaches may experience more difficulties in keeping up to date with concussion-related evidence
Bazo et al. (2023)	Concussion education should pay particular attention to the knowledge needs of this group of individuals
Echemendia et al. (2023)	SCAT) is particularly effective in distinguishing between concussed and non-concussed athletes within 72 hours of injury and up to 7 days post-injury.
Burma et al. (2022)	A 20-minute recovery period is adequate for SCAT5 metrics to return to their pre-exertion or resting levels
Black et al. (2020)	Eliminated a ceiling effect for memory scores with the addition of a 10-word list to SCAT5.
Snegireva et al. (2021)	The proportion of directional errors in the AS task showed good level of reliability in the youth group
Snegireva et al. (2021	Eye blink duration in the MSG and sinusoidal SP tasks of the youth group also demonstrated sufficient reliability
Snegireva et al. (2022)	Blink duration during memory-guided saccades and sinusoidal smooth pursuit tasks was increased in a group of concussed youth
Snegireva et al. (2021)	A deviation of 60 or more blinks in the MGS task might be indicative of a SRC

O'Keeffe et al (2020)	Dynamic alterations to the blood-brain barrier (BBB) may occur following a complete season of contact sports, with these alterations observed in up to 52% of adolescents
O'Keeffe et al (2020).	Multiple impacts sustained during a single match result in a broader distribution of brain regions affected, which contrasts with the notion that sub-concussive impacts may accumulate within a single match, exacerbating the severity within specific brain regions
O'Keeffe et al (2020).	Discernible patterns in biomarkers detected post-season and post-match (specifically BDNF, MCP-1, and S100B)
O'Keeffe et al (2020).	S100B and BLBP do not substantially accumulate in serum within the 1-hour time frame post-concussion
Eliason et al. (2023)	Current concussion management strategies may reduce recurrent concussion rates
Hunzinger et al. (2021)	Prior concussion history with worse self-reported outcomes on some assessments, specifically poorer psychological well-being and lower quality of life in young adults
Bazo et al. (2023)	Neither improvement of concussion knowledge nor ad hoc legislative amendments do necessarily translate into actual behavioral changes reducing underreporting and improving secondary prevention
West, Shill, Bailey, et al. (2023	The most promising for reducing the risk of concussion specifically was a neuro-muscular training (NMT) warm-up programme.
Nutt et al. (2022)	Need for specific neck training programmes to focus on increasing the neck flexor/extensor strength ratio and subsequent stabilization of the head on contact, improving a potential protective effect on concussion risk
Nutt et al. (2022)	Stated the flexor/extensor ratio was highest in the 11–12-year-old athletes
Echemendia et al. (2023)	Incorporate socio-cultural and linguistic variables, as well as cater to para-athlete populations in SCAT
Black et al. (2020)	The significance of sex when interpreting SCAT5 baseline scores.
Salmon et al. (2020)	Re-examine our traditional education practices to adopt a more culturally responsive approach that can be tailored to the local context
Eliason et al. (2023)	Use of validated injury surveillance methodologies (video-analysis and instrumenting players), consideration of confounding variables like concussion history and consensual concussion definitions are needed

Pelt et al. (2021)	Future studies should consider using sub-categories for contact sports to more accurately capture concussion risk
Matthews et al. 2021)	Sensorimotor function endure beyond the typical clinical recovery period following a concussion
Makdissi et al. (2023)	Did not discover evidence to advocate for the inclusion of any patient-specific, injury-specific, or other factors (such as imaging findings) as absolute indications for retirement or cessation of participation in contact or collision sports

2.3. Discussion

The numbers in Youth Rugby:

Firstly, even with the considerable influence of consensus worldwide on the topic, the determination of the most suitable unit of exposure for actively quantifying this form of injury within the realm of contact sports remains subject to questioning. The extraordinary heterogeneity observed within the dataset being reported is unquestionably impeding the advancement of data quality and accessibility, both of which are fundamental principles that modern scientific methodologies strive to uphold in the 21st century.

In a 2021 meta-analysis, Van Pelt et al. noted the underestimation of rates could be due to most concussion epidemiology studies using AE as the unit of exposure,[27] even though AEs cannot serve as exact measures of athlete exposure as they do not capture the true amount of time an athlete was active in practice or game.[27] A year prior, Beakey et al. had already taken strides in the right direction by pioneering the first study to standardize the self-reporting rate per 1000 concussive events.[9] Eliason et al. also noted the importance in considering individual player exposure data (i.e., player participation) to accurately measure IRs and clustering effects for team-based sports.[23]

The increasing awareness, deepening knowledge, enhanced diagnostic capabilities, and greater reporting of sports-related concussions (SRC) stemming from scientific advancements over the past decade[10] have collectively fueled the observed rise in SRC incidence rates.

This trend is apparent in this review, where the inclusion of Cosgrave et al.'s 9.03 concussion incidence rate adds to the growing body of literature suggesting that the incidence of match-related concussions is higher than previously believed.[16] Indeed, given that participants were required to contact the clinic for follow-up, the actual incidence of concussion may indeed be higher than what was reported.[16] One study addressing this issue reported a concussion incidence of 6.1-8.9 per 1000 player hours.[10] This was compared to the 11.7 per 1000 player hours found in a study conducted over eight seasons among a Japanese collegiate cohort, to Silver et. Al’s 2018 (C1) 12.7 concussions / 1000 player hours reported in youth community study over 4 seasons, as well as to the aforementioned PRISP project.[10] While lower than the rate of 20.9 per 1000 player hours documented for professional rugby, the findings by Van Tonder et al. were 2-3 times higher than those observed in comparable study cohorts in the RFU community study.[10]

The study that should hold the utmost academic significance fundamentally is the one with the larger sample size of participants, particularly in the youth setting. With a substantial participant pool of 13,169 athletes spanning from the U6 to U18 age groups, concussions, while ranking as the third most frequent injury, comprised 8.5% and 3.2% of overall injuries in male and female players, respectively.[4] These percentages, applied to the study's reported injury incidence of 5.9 match injuries per 1000 player hours[4], result in the unexpectedly low match concussion incidence rate of 0.46 concussions per 1000 male player-hours. However, when narrowing down these values to high school-aged children, the incidence rate of concussions may increase by at least 1.45 times. This may be due to older cohorts experience distinct playing conditions, as factors such as the transition from a modified to a full International-size field, increased participation in representative competitions, enhanced playing standards, elevated training loads and greater variation in body composition and size during this peri-pubertal life stage[4] collectively contribute to the reproduction of concussions.[4]

One study commented on this age-risk finding stating it likely reflects the changes in the size of players over this period, growing in both height, weight and speed, increasing the physicality of the game, although each country adopted a unique approach to the age of contact introduction, as discussed further in the concussion-related law topics.[22]

Additional noteworthy commentary pertains to the incidence of concussions among females, extensively investigated by authors West, Shill, Bailey, et al. Although the authors noted a growing interest in the availability of female data since 2020,[22] the discovered concussion incidence rate of 33.9 per 1000 player-hours is the holy grail the research has been pursuing, its significance resonating profoundly amid the global surge in female participation in the sport.[22] As a lack of epidemiological data related to the female game[22] may be causing this overestimated values, a study's protocol included in this review seeks to address the jeopardized female rugby players concussion research with a large sample of both male and female adolescent rugby players.[30] The cause for these high rates of injury in females may be found in differences in reporting between males and females or varying levels of concussion awareness within these populations.[22] However, the potential existence of genuine disparities in injury risk between male and female populations should not be dismissed.[22] While physiological and physical characteristics have been suggested as potential explanations,[27] a study has indicated that this differentiation may be due to variances in neck muscle strength, as males typically demonstrate greater neck muscle strength compared to females in the same age group.[15] Consequently, this directs our attention towards the neck as a critical area for implementing preventive measures, as will be briefly explored in the following section.

For instance, a glaring concern, considering the traits of the youth demographic, undoubtedly concerns the under-reporting linked to this specific age cohort. Numerous studies have embraced this inquiry. Some tried to understand the correlation between concussion knowledge and reporting,[12] as Salmon et al. did in the New Zealand context, showing improved concussion guidelines knowledge across 416 players from 21 schools, except founding it had little influence on positive reporting behaviours.[12] In fact, there was still one-third of the population unaware of these guidelines, predominantly among players from low-decile schools and those of Maori and Pasifika descent, highlighting the need to re-examine a more culturally responsive approach in these communities.[12] These findings are mirrored in one particular study, with a nearly 2000 survey sample size based in the Italian setting, investigating both athletes and coaches, which concluded there was no statistical association between knowledge scores and athlete self- reported behavior.[6]

Furthermore, in addition to the robust response rates that bolstered its credibility, this study comprehensively investigated the role of coaches simultaneously in the under-reporting phenomenon. Nearly all coaches deny allowing or pressuring a player with suspected concussion to keep playing, however almost one-quarter reports seeing their peers doing so.[6] Coincidentally, the found 51.6% of players who reported finishing a game during which they were concussed corroborates the idea of prioritizing the importance of a game over the identification of a concussion.[6] Motivated to play by values resembling machismo and stoicism, 63% of athletes would keep on playing despite experiencing concussion- related symptoms, mainly for fear of not playing the following games or weakening the team.[6] These factors may enhance performance and outcomes; nevertheless, they may also pose a risk to the health of young athletes.. Despite being associated with the most significant injury burden overall[11], these concussion findings unfortunately mirror the published values by McIntosh et al. in 2010, where less than 10% of concussed athletes were reported to miss more than two matches.[11]

There were in fact outcomes related to this match-training phenomenon in one study included in this review, which introduced a 1.96-times greater reporting rate per 1000 suspected SRCs in training when compared with match play.[9] This assumption was contradicted by the reported training concussion rates of 0.60 and 0.64 per 1000 player hours as described in the review by West, Shill, Sick, et al. (2023) and Cosgrave et al. (2023), respectively.[14,16]

Regardless of reporting, a study indicated that younger athletes exhibited greater concussion knowledge, contrasting with prior research.[21] Doucette et al. welcomed it as a positive finding, given that adolescents have been identified to be at a higher risk for the detrimental effects of concussions,[21] postulating that the fairly recent push for more concussion education initiatives in youth sport may have graced younger athletes with more opportunities for concussion education and awareness in their sport experience.[21] Nonetheless, the lack of awareness regarding the potential duration of symptoms exceeding one month (42.6% of athletes and 35.3% of coaches),[6] as well as the heightened risk of experiencing a second concussion following an initial one (with only 33.3% of athletes and 40% of coaches acknowledging this risk),[6] underscores the ongoing need for further efforts and education in this domain.

As concussion requires a clinical diagnosis by a doctor, surveillance in community sport carries the idea of under-reported concussion prevalence,[4] as doctors' presence is not always required and rarely present at matches. Nevertheless, the consistency and standardization of medical care rendered in the gathering of injury data during some studies[10] shows we are headed in the correct direction in the medical field.

One of the fundamental challenges at hand is the absence of a diagnostic test or biomarker for concussion in adolescents, being the current cornerstone of concussion diagnosis confirming the presence of a constellation of signs and symptoms with multiple tests after an individual has experienced a hit to the head or body.[30]

While current evidence is inadequate to determine the optimal combination of measures,[30] the subsequent section of this master's thesis endeavors to outline the key recommendations derived from the findings of this review.

Contact Zone Analysis: Dissecting the Anatomy of Concussion in Tackles

In the dynamic and physical sport of rugby, the tackle stands out as the primary mechanism leading to concussions among players.

The described attributed tackle's fault in the climbing SRC values is not surprising news to anyone. Not only existing research affirms the prevalence of tackle-related incidents as the primary cause of injuries in both male and female matches,[22] with a notable propensity for inducing head injuries,[4,11,16] a direct association with concussion has been established.[10,14,16] This association encompasses a substantial proportion, with 3 studies in this review pointing to values ranging from 55%[10] to 76%[14] of diagnosed concussions attributable to the tackle event.

Furthermore, specific characteristics of tackles have been associated with the likelihood of head injury assessment (HIA) in rugby.[23]

Firstly, Tucker et al. identified tacklers adopting a "head up and forward/face up" position and "head placement on correct side of ball carrier" as less likely to trigger HIA. [23] Lower risk of SRC for the tackler was also described when the ball carrier took a side step prior to contact.[23]

Unsurprisingly, head contact between the tackler and ball carrier's head or shoulder significantly elevated the risk of HIA.[23] Moreover, Gardner et al. identified a heightened risk, particularly when head contact occurred at very low angles (such as knee or boot impacts) or high angles (such as with the head or elbow).[23] Additionally, factors such as tackle height, tackler's upright position and its acceleration into the tackle contribute significantly to the increased risk of sports-related concussion (SRC) for both the tackler and the ball carrier.[23] More importantly, Suzuki et al demonstrated that the tackler's head or neck not remaining bound to the ball carrier after initial contact was the game changer in technical avoidable-risk.[23]

The sex-differences in the specific mechanism of concussions also came as huge surprise and deserves further exploration.[11,22]

Moreover, in addition to the observed differing risk profiles between tacklers and ball carriers regarding SRC,[14] and considering the reported potential disparities associated with match-training data, Davidow et al. proposed that both players bear responsibility for each other's safety during tackles.[23] Collins et al. demonstrated a significantly higher incidence of concussions during instances of illegal play compared to those not involving illegal activity (25.4% vs. 10.9%) across youth sports.[23]

In addition to this metrics, Hendricks et al 2016 framework outlined a 5-week program which aimed to adequately prepare players for the tackle contact demands of the season.[14] Some authors theorized, given the usual shorter than optimal preseason period in place for youth players, mainly atrributable to the non-professional nature of their game, being able to achieve the conditioning level required to play, particularly on aspects related to contact, may be limited, with previous research demonstrating a lower in-season risk with a higher number of preseason sessions performed.[14] The potential for missed or indoor training sessions due to weather cancellations was as well postulated to contribute to higher match injury risk in the tackle.[14]

Whilst tackling is a recognised element of Rugby that may lead to injuries, it is nonetheless imperative to investigate strategies to effectively reduce the number of tackle-related injuries.[4] Particularly in juniors., there is a growing concern within the rugby community regarding the need for tackle-related law changes to mitigate concussion incidence.[10]

Nevertheless, despite the current findings indicating a reduced legal tackle height, which, without another season of data under the tackle law variation, did not yield statistically significant evidence,[10] further investigation into tackle-related interventions aimed at reducing the incidence of concussion in amateur rugby is warranted. This necessitates conducting better-controlled longitudinal studies to better understand the effectiveness of such interventions.

Initiatives like the Tackle Ready program, developed by The National Rugby League in Australia, are teaching correct and safe tackle techniques to junior players.[4] Further research in teaching safe tackle techniques in junior grades is warranted, approaches that emphasize the analysis of excellent tackling technique, height and player body position and that identify the primary mechanisms of injury while providing evidence-based game education remains paramount in the context of rugby.[4]

Another qualitative measure to gauge the true impact of concussion in youth lies in assessing its real-life burden. Here, the figures speak volumes, even though they are reported in only one study specifically addressing concussion.[11] The burden of 102 days lost represents a critical aspect of this research: even if future brain damage is not certain, the tangible deterioration in real-life functioning and its impact on quality of life, particularly during such crucial developmental stages, cannot be overlooked. A third of a year undoubtedly has the potential to profoundly affect the mental, physical, and social well-being of any professional player, with its impact likely even more pronounced among youth players.

This input sets the stage for the final segment of the work, where numerical data intersects with the clinical aspects of concussion.

Tackling Concussion: Advances in Screening, Diagnosis, Prevention, and Critical Recommendations

Screening

In this results section, various findings were delineated pertaining to the accurate identification of concussed or at-higher-risk players.

While certain strategies suggest that reporting effectiveness may not solely rely on the athlete's discretion[21], the significance of genuine reporting remains noteworthy. Some authors believe modifying athlete reporting behaviors is as a necessary step in allowing effective interventions in the adolescent rugby union players population.[9] Altering these negative beliefs about concussion reporting should be a major focus of future interventions, especially in athletes with an SRC history.[9]

Other important aspect lies with the best practice when assessing players to baseline values. The study establishing normative reference values for high-school rugby players in New Zealand could assist healthcare providers in identifying suspected concussions when individualized baseline test data is unavailable.[7] It should be recognized as a best practice within the global rugby community.

The screening methodology outlined endeavors to incorporate individualized prognostic factors such as age[22], sex[13], ethnic background[7], competitiveness[21] and concussion knowledge[6] into the assessment of each concussed player. Given the frequent interchangeability of playing positions observed in schoolboy rugby, particularly among junior athletes, focusing on the prevalence of concussions per position or designing educational interventions exclusively based on an athlete's current playing position should be avoided.[9]

Worthy of special mention, the findings concerning the physical assessment of players provide insight into future youth research endeavors. They prompt investigation into the potential role that imbalances in neck strength[15] and dynamic balance[19] may play in the genesis of concussions.

Diagnosis

Conducting effective diagnostic assessments for concussion is crucial for timely intervention and management. Therefore, the reported findings carry vital importance.

Enhanced timing for the clinical application of SCAT tools could facilitate clinicians in their decision-making processes. The 72-hour[29] and the 20-minute[26] windows were determinant. Clinicians should be cognizant symptom reporting may be elevated during the resting state and may benefit from holding a playing out of a sporting game/practice and retesting them ~10-min to understand if the symptoms are due to exertion or a potential concussion.[26]

The changes introduced by the 10-word list to SCAT5 may also play a protective role, as for the reference values on SCAT5 introduced for high school rugby.[13]

Rejecting the use of computerized neurocognitive tests (CNTs) in isolation for monitoring sports-related concussions (SRC) in the adolescent population was deemed crucial, as false negatives could lead to athletes returning to play while still experiencing symptoms.[16]

In addition to being groundbreaking, it seems that these blood biomarkers may have limited effectiveness as standalone indicators, as evidenced by the observation of decreased levels of S100B in the blood of players after a full season of rugby.[1] Furthermore, the elusive temporal pattern of these biomarkers post-trauma poses challenges in their sole use as indicators of brain injury.[1] The same was observed by the authors of the eye tracking studies. While reliability of a measure can influence type II error, effect sizes, and confidence intervals, it is strongly advocated to conduct dedicated reliability evaluations prior to any validity studies.[20] It was demonstrated that the reliability of eye tracking measures proposed for assessing SRC in current literature might be low for some of them in athletes without concussion, suggesting that they may not be useful diagnostic markers.[20]

Prevention

Interventions to ensure appropriate concussion reporting behaviors are required and enhanced concussion education should be undertaken.

Most studies thus far have in fact been undertaken in different cultural and political contexts, with specific policies integrated within their healthcare systems, which one could argue are lacking in Italy and in other countries where Rugby is not native although highly popular among youth.[6]

With legal requirements and concussion-related policies certaintly representing the main driver to change practice, it is pivotal to ensure wide implementations of standards of care in these countries through laws dealing with concussion education, management and return-to-play clearance.[6] Concussion education should become logistically and financially sustainable, salient for its different population targets and framed within a sport culture where communication to and from athletes is encouraged and valued, as well as supported by appropriate laws.[6]

Returning to play while still symptomatic has many problematic consequences, such as Second-impact syndrome (SIS) which is a fatal rare condition occuring in adolescents of 14 - 16 years of age where a seemingly mild blow to the previously concussed head may result in massive brain swelling, increased intracranial pressure and brain herniation.[25]

The introduction of the ‘blue card’ was a step forward in player welfare and ensures players with concussion followed a graded return to play.[11]

Given the reported impact that the Activate injury prevention program (Hislop et al. 2017) has on reducing concussion and non-contact injury in adolescents, greater efforts are required to increase awareness and compliance within the community setting.[11]

Critical recommendations

Recommendations derived from literature findings are instrumental in shaping policies, guidelines, and interventions aimed at improving concussion management and prevention strategies.

From modifications to the current screening tools to the incorporation of different approaches to target a broader picture of concussed players, the recommendations were various. Many of them attributed space for improvement in the systematic way of assessing concussion.

Utilizing current diagnostic tools in conjunction with clinical assessment is recommended for better accuracy in concussion diagnosis.[16] However, further research is needed to explore the utility of these tools in different contexts and populations to optimize concussion management strategies.

Despite advancements in concussion screening and diagnostic methods, significant research gaps persist. For instance, there is a need for context-specific normative reference data to aid healthcare providers in identifying suspected concussion, especially in the absence of individualized baselines.[7]

Standard procedural protocols and pathways in injury management are essential for ensuring consistent and effective care particularly in club and community-based settings[4] and should be developed to prioritize player safety, enjoyment, and participation in sports activities.[4]

Addressing competitiveness as a significant predictor of nondisclosure is paramount in promoting a culture of concussion reporting and player safety.[21] Enhanced concussion education and reporting behavior strategies are crucial for fostering awareness and promoting timely reporting of injuries.[12] Moreover, culturally responsive education strategies tailored to local contexts are needed to ensure effective dissemination of concussion information.[12] Understanding the impact of sociodemographic factors on baseline performance in concussion assessment is vital for interpreting assessment results accurately.[7]

Academically, the focus stood on the use of validated methodologies and the incessant search for innovative ones. Understanding the molecular etiology of concussive and sub-concussive brain injuries is crucial for informing return-to-play guidelines in contact sports.[1] Additionally, further research is warranted to investigate the reliability of biomarkers like S100B in diagnosing SRC, particularly in the absence of baseline data.[24]

Furthermore, studies combining advanced brain imaging with biomechanical modeling and kinematic sensors are recommended to enhance understanding of underlying injury mechanisms.[8]

This discussion section is finally resumed in the final part of this work.

Limitations:

This study conducted a systematic search across selected literature. Despite thorough review, there remains potential for misunderstanding or ambiguous interpretation of certain studies, as this review did not adhere to a structured protocol typical of systematic reviews nor did it attain the statistical rigor associated with meta-analyses. Instead, emphasis is placed on the author's narrative perspective and concentration on specific issues that were more meticulously scrutinized. The SANRA scale applied to this narrative review by the main researcher (FF) performed a sumscore of 10/12.

3. CONCLUSION

This review encompasses 28 distinct studies characterized by diverse research areas.

Concerning the numbers in concussion, the primary conclusions emphasize the importance of conducting high-quality research that utilizes consistent units of exposure and enables the replication of true player participation,[23] accurately assesses concussion risk within sub-categorized samples[27] and accounts for consensus on confounding variables and concussion definitions.[23]

Examining the anatomy of concussions in tackles delved into the fundamental factors underlying this issue- its burden.[11] The enduring necessity of instructing superior tackle techniques at junior levels is evident,[4] necessitating emphasis on proper height and player body positioning and dynamics.[4] Additionally, there is a call for additional research into tackle-related interventions aimed at mitigating the incidence of concussions in amateur rugby, especially targeting the physical conditioning level required to play.[14]

In the tackling concussion clinical discussion, one study presented a broad perspective on the issue. Recently, there has been an increasing recognition of the implications of concussive brain injuries in sports. There is a clear imperative for comprehending the molecular origins of concussive and subconcussive brain injuries, as well as for developing methodologies to aid in their diagnosis and management.[1]

The existing clinical assessment of concussion lacks objective criteria that can furnish patients with meaningful and clinically reliable diagnostic and prognostic insights. This inadequacy is compounded by the absence of a suitable imaging framework and the dearth of systemic biomarkers capable of forecasting injury severity.[1]

With clinical recovery after sports-related concussions typically spanning between 10 days and 4 weeks in adolescents, the accurate identification of factors linked to heightened risk of recurrent or prolonged recovery holds paramount importance for implementing targeted interventions and support measures.[28] Monitoring post-concussion assessments, which should include evaluations of sensorimotor and oculomotor function, is recommended for tracking recovery progress over time.[30]

Awareness of return-to-play protocols and minimum stand-down periods among athletes is typically lacking, underscoring the necessity for enhanced education and adherence to guidelines.[12] Decisions regarding return-to-play should be made by clinicians with specialized expertise in traumatic brain injury, considering psychosocial, injury-specific, and sport-specific factors to safeguard the safety and well-being of youth athletes.[28]

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