



Review Article

Headgear in prevention of sports related concussion- A literature review across various sports

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ABSTRACT

Sports related concussion (SRC) remains a challenge for sports physicians to identify because of varied presentation and lack of diagnostic tool. Keeping in mind its long term effect various sports bodies introduced different preventive strategies to reduce incidence of SRC. Commercial headgear is currently being used by players of all ages and skill levels in certain sports to protect themselves from heading and direct impact, even though the protective effect on concussion has not been conclusively demonstrated and limited research has been done. Electronic databases and grey literatures were used to search the evidence using Medical Subject Headings sports headgear, concussion, helmet, cricket, soccer, American Football, boxing for the available research studies from 1990 up to April 2020. The wide variety of prospective surveillance as well as lab studies made the case even more confusing as the simulation model may not actually replicate the on field scenario. Moreover the type and component of the headgear need to be subjected based on sports specific demand. Hence this literature review is aimed at available evidences in different sports to find any consensus between use of headgear and prevention of SRC.

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1. Introduction

Sports - related concussion (SRC) is a traumatic brain injury that is defined as complex pathophysiological process affecting the brain induced by biomechanical forces with several common features that define its nature.¹

Concussion can occur in any sport due to blow to the head, neck or body transmitting a strong force to the head.² It is thought to be due to a combination of linear acceleration, which causestransient increase in intracranial pressure and rotational acceleration, creating a microstructural strain response in brain tissue.³ There has been much focus on the phenomenon of sports-related mild traumatic brain injury (MTBI), with growing fears that prolonged exposure to head impacts in sports may lead to long-term cognitive, behavioural and neuro-pathological

effects. Several studies have also demonstrated increasing incidence of sports related concussion in recent times.^{4,5}

Recent developments signify that the goal of eliminating such injuries is not out of the realm of possibility in the near future. These developments are particularly crucial for high contact sports like American Football, Soccer, Rugby, Boxing and non- contact sport like cricket where head injuries are common. Various on-going efforts are being made to reduce the incidence and severity of head injuries, with examples like regulations on tackling, concussion substitutes and medical timeouts as well as helmet testing. In addition to these, equipment changes have been proposed in an attempt to prevent concussions. Protection of head in sports has seen significant improvement in the last thirty years and has led to the development of innovative protective headgear. Not only being critical for injury prevention, helmets have been shown to protect against skull fractures, severe traumatic brain injury and death.⁶⁻⁸

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Commercial headgear is an equipment designed for head protection in sports which is available in the market of varying quality and cost that may or may not follow international standards or performance specifications for the material used. Although commercial headgear is currently being used by players of all ages and skill level to provide protection from heading and direct impact, the protective effect on concussion has not been conclusively demonstrated and limited research has been done. The purpose of this literature review is to demonstrate the efficacy of current headgear in preventing concussions across various sports.

2. Materials and Methods

A comprehensive literature search was performed electronically in different databases from their inception up to April 2020.

The use of the Medical Subject Headings (MESH) terms like sports headgear, concussion, cricket, soccer, helmet, protection, American football, rugby and boxing produced publications from PubMed/Medline, ISI Web of Knowledge, Scopus and The Cochrane Library. Furthermore, information from the official websites of International Cricket Council (ICC), Federation Internationale de Football Association (FIFA), International Boxing Association (AIBA), International Rugby Board (IRB) and International Federation of American Football (IFAF) was also included. Finally, to complement the present review, selected references cited in the aforementioned literature had been considered on the same topic.

All the laboratory studies, observational studies and randomised trials discussing the effect of headgear in preventing concussion were included in this review.

Studies were excluded based on title and abstract reading. Research studies based on players and coaches opinions regarding headgear use, online poll, effects of headgear on gameplay, studies comparing tests used to assess the headgear efficiency and articles that appeared only as short versions or that did not have full text available were also not included.

3. Results

Our literature search led to 34 publications and was screened for title and abstract. Seven articles were excluded, as they were not full text articles or appeared only as short versions. We excluded 10 more articles: 2 studies about players and coaches opinions regarding headgear use; 4 studies comparing tests used to assess the headgear efficiency; 1 study based on online poll and 3 studies based on effect of headgear on game play. Finally, 17 studies were included in the literature review (Table 1). These 17 articles were published between 2000 and 2020.

4. Discussion

4.1. Rugby

Andrew S McIntosh et al in 2009 was the first to report randomised control trial of headgear as an injury control method in rugby union football and it being one of the few studies of this design of sports injury intervention. The results showed that the padded headgear trialed in this study did not reduce the rate of head injury and concussion, even after adjustment for level of play. There was potential for bias in the analysis presented due to uncontrolled confounding.¹²

Other field studies by Andrew S McIntosh et al in 2001 and Marshall SW et al in 2005 had not observed a reduction in the rate of concussion or head injury as a result of wearing padded headgear; however, these studies were restricted to limited populations.^{13,14}

Earlier laboratory testing by Andrew S McIntosh et al in 2000 showed that the then available standard headgear had limited potential to attenuate impacts to the head and reduce the head's acceleration to tolerable limits. Significant performance differences were observed between brands and models, and even between models manufactured by the same companies.¹⁵

The results from another laboratory study by Andrew S McIntosh et al in 2004 and study by Erin R et al in 2018 were promising and the head guards involved in testing demonstrated a decrease in linear acceleration experienced during impact when compared with the bare head form. However, analysis of the individual drop test results suggested that concussion may not always be prevented by head guard use. Data collection also involved only linear acceleration measurements despite research pointing towards angular acceleration playing an important role in concussive injuries and drop testing was not an accurate way to simulate and assess the angular component of concussive impacts.^{9,10}

The latest laboratory study by Mark Ganly et al in 2018 found out the impact attenuation properties of a new viscoelastic foam rugby head guard (N-Pro) in terms of applied linear and rotational forces. The ability of the N-Pro to attenuate both linear and rotational accelerations marked a new departure for the use of soft-shelled headgear in impact sports such as rugby.¹¹

The laboratory studies however do not always translate into reduction in concussion rates on the rugby field as it is very difficult to measure or simulate the complex dynamics of these real life impact events. Nothing can provide 100% protection against SRC but the development of a head guard with such excellent impact attenuation properties provides great hope, at least, to reduce head-injury risk in such a hugely popular game.

Headgear is not made mandatory till now in rugby and if headgear is to be worn in rugby union, it must carry

Table 1: Summary of concussion risks and studies included in the literature review are shown in the below table:

Game	Concussion as a proportion of all injuries and/ or rate & risk of severe TBI	Total number of studies included (field & laboratory studies)	Studies demonstrating protective effect of head gear against concussion (with findings)	Studies with unfavourable findings on the protective effect of head gear against concussion (with findings)	Inference
Rugby	5-15% 6.9/1000 hr (youth) Minimal risk	7	3 laboratory studies ⁹⁻¹¹ -Reduction in mean peak resultant angular head accelerations with headgear	3 field studies ¹²⁻¹⁴ -No significant differences between control and headgear arms 1 laboratory study ¹⁵ -Significant increase in headform acceleration with headgear	Conflicting evidence. Further studies needed
Boxing		2	1 laboratory study ¹⁶ -Reduction in mean peak resultant angular head accelerations with headgear	1 field study ¹⁷ -Significant reduction in number of stoppages due to head blows without head guards	Conflicting results between field study and laboratory study.
American Football	6.1% 4.1/1000 h Medium risk	3	2 field studies ^{18,19} -Significant difference between concussion rates for players wearing different helmet brands	1 field study ²⁰ -No difference in the incidence of concussion for players wearing different helmet brands	Conclusion difficult to be drawn because of wide difference in methodology
Soccer	3% all levels Union of European Football Association (UEFA): 0.06/1000h Minimal risk	3	1 laboratory study ²¹ -Significant reduction in peak force of impact with head gear	1 laboratory study ²² -No significant difference in head responses with or without headgear 1 field study ²³ -No difference in incidence of concussion between head gear and no head gear groups	Further studies needed
Cricket	1.5/1000 h Minimal risk	2	1 field study ²⁴ -Significant reduction in the frequency of head injuries after the introduction of compulsory helmet use 1 laboratory study ²⁵ -Significant reduction in pressure on the head model and peak acceleration of brain when using a helmet		Scope to enforce by laws of the game

an International Rugby Board (IRB) approved logo and products should confirm to International Organization for Standardisation (ISO) 15487i and BS 3449ii according to regulation no.12 of IRB.²⁶

4.2. Boxing

Head gear controversy in boxing has centred on the perceived risk of head injury. Laboratory study by Andrew S McIntosh et al had shown that the presence of the head guard reduces the force transmitted to the head.¹⁶ However, it is the rotational acceleration of the head that is believed to be the major factor in concussion or mild traumatic brain injury. It was hypothesized that head guards, by increasing the diameter and surface area of the head, will lead to increased rotational force and subsequent stoppage.

Furthermore, head guards are considered to increase the risk of blows to the head because the padding around the eyes limits the boxer's peripheral vision. The most convincing hypothesis is that head guards give a false sense of safety and so boxers partake in more high-risk behaviours than they would have done without wearing a head guard.

When a sport adopts head guards, technique often changes to use the head to gain advantage. In support of this hypothesis, the data presented by Michael P Loosemore et al showed approximately twice as many stoppages due to blows to the head when wearing a head guard.¹⁷ Limitations of this study were the small sample size and use of stoppages due to blows to the head as a surrogate for concussion.

Many different forms of head guards have been tried over the years as AIBA (The International Boxing Association) strived to find the most protective form of head guard. However, acceleration and deceleration forces that contribute to concussion will still remain irrespective of head guard design. In addition, emerging medical science indicates that sub-concussion, cranial impacts which do not lead to recognized or diagnosed concussion, may be important in a cumulative way.

To reduce the number of head impacts, surely the solution is to suppress or mitigate the number and strength of head contacts or head blows by changing boxing behaviour through education and proper technique instruction. Head guards could play a protective role in groups of boxers where concussions are extremely rare such as women boxers and young male boxers. However, there are no comparative studies in these populations.

In 2013 AIBA introduced a rule banning headgear for male senior open class boxers during the competition motivated by safety and internally unpublished studies.²⁷

4.3. Soccer

The use of headgear for soccer athletes is a controversial topic. Timothy McGuine et al were the first to report that there was no difference in the severity of concussion for

players wearing or not wearing headgear. The data did not support the risk compensation theory which suggests that players wearing headgear may play more aggressively due to the feeling that the added head protection limits risk of injury.²³

It is important to note that SRCs occurred at twice the rate among females than males. Only 35% of the SRCs were sustained by head contact with a soccer ball, while head-to-player contact resulted in most SRCs. This study had several potential limitations such as risk for selection bias, participants were not instrumented with accelerometers and had no video of the concussive injuries and the usage of different headgear models by the head gear group.

Most recent studies on soccer headgear efficacy were carried out in laboratory settings. While Steven P Brogolio et al reported that various protective headbands attenuated the peak force, to a limited degree, of a soccer ball,²¹ another study by Withall et al found out that the impact of a soccer ball will not be decreased to a sufficient degree to prevent a SRC.²² These studies used the impact of a soccer ball to the head as the possible injury-causing mechanism, which may not reflect what actually occurs on the soccer field.

Although the findings of Steven P Brogolio indicated that headgear designed for the soccer athlete may be effective at reducing the peak force and impulse from an impact, further testing is warranted before soccer officials require them for regular play.²¹ The flat surface of the force platform in his study was not representative of the human head, and the distance between the Soccer Machine and the force platform was closer than what normally occurs in practice and game situations. Also, the study lacked collection of both linear and rotational acceleration variables that may provide beneficial information on the headbands ability to protect the brain from trauma.

Headgear is not included as compulsory equipment by FIFA (Federation Internationale de Football Association) but is officially allowed as per FIFA Rule 4 on Equipment that meets the ASTM standard.²⁸

4.4. American Football

The retrospective analysis by Rowson et al was the first study to show a significant difference in concussion risk between helmet models (Revolution helmet and VSR4 helmet) while utilizing a large cohort and controlling for the number of head impacts each player experienced. From a biomechanical standpoint, the difference in concussion risk between helmets was logical. Not all helmets were designed equally in their ability to reduce the head accelerations resulting from impact. For matched impacts, the Revolution helmet resulted in lower head accelerations than the VSR4 helmet. This reduction of head acceleration in the Revolution helmet reduced the risk of concussion compared with the VSR4 helmet.¹⁸

But results of the largest prospective study by Timothy et al showed that no particular helmet brand, age and recondition status of helmets provided superior protection against sustaining an SRC compared with other helmet brand or models and were in contrast with the findings of Rowson et al.²⁰

The difference in findings from the previous researches may be due to several factors. First, Timothy et al conducted a prospective epidemiologic study in a large sample of high school players rather than a laboratory study and secondly, data were recorded from a much larger variety of new and older helmets being used in high school settings. Moreover, they controlled for multiple variables in their analyses, including history of concussion, which had been widely reported as a significant risk factor for concussion in athletic populations. But this study also had limitations as this was not a randomized controlled study but rather a cohort study with data obtained from a convenience sample of schools that agreed to take part in the study. As such, it was susceptible to the effect of the unknown or unmeasured confounders.

Dustin A Greenhill et al suggested that there was an increased risk of concussion severity and duration if the high school football player's helmet is fitted improperly.¹⁹ One possible explanation for the more severe concussions in the group with a poorly fitted helmet is that the cervical muscles play an important role in absorbing impact forces as the helmet and head function as a single unit. A loose helmet also may delay the cervical muscle contraction response to an impact since the direction of the force to resist may not be detected until it reaches the head. But this study lacked a uniform method to measure helmet fit, and a comparison group. Despite these limitations, this study identified an important new potential intervention that may reduce concussion severity and possibly concussion incidence.

Helmets were made compulsory in National Football League from 1943 onwards. Article 2 of International Federation of American Football (IFAF) rule book refers about the helmet and mandatory padding that are intended to provide reasonable protection to a player while avoiding risk of injury to other players.²⁹

4.5. Cricket

Many recent incidents were reported in relation to head injuries caused by the impact of cricket balls. A key finding of the study by L Shaw et al was the reduced rate of head/neck/facial injuries overall in batters, in the 2004-05 season compared with the two earlier seasons. The most likely explanation for this was the introduction of compulsory helmet before the 2004–05 seasons.²⁴

The overall rate of head/neck/facial injuries in the 2003–04 season was not significantly different to that after the introduction of compulsory helmet, and is likely to

reflect the fact that some players did wear headgear during that season, before it was made compulsory. Unfortunately, evaluation of reduced injury frequency was not controlled in the study and this may be due to bias or confounding. However, the magnitude of the reduction in batters, the players specifically targeted by compulsory headgear, was so large that it is unlikely to be due to chance alone, suggesting that the protective effect was real.

The major drawback of the study was that the injury data could not be compared directly with that across different levels of cricket because of the limitations in the data collection. The data collection did not include collection of exposure time at risk and the severity of the injuries.

Furthermore, the study lacked a formal injury surveillance process and the involvement of untrained game scorers led to relatively large proportions of cases assigned to non-specific categories such as “Unspecified acute overexertion”. There is no doubt that more rigorous and continuous injury surveillance is warranted for community level cricket to identify risk factors, and to implement and evaluate head injury prevention strategies.

A recent laboratory study in 2018 by Damith Mohotti et al, showed approximately a 60% reduction in the pressure on the head model when the helmet was used. However, the numerical simulations showed that significantly high pressures could be exerted on the brain, even with the helmet on, which could lead to concussion. This highlighted the necessity of improvements to the existing standard cricket helmet. Furthermore, numerical simulations showed a 67% reduction in the force on the skull and a 95% reduction in the skull internal energy when introducing the helmet and this significantly reduces the probability of skull fracture due to impact.²⁵

The new regulations, which have been incorporated in the International Cricket Council (ICC) Clothing and Equipment Regulations effective from 1st of January 2017, do not make it compulsory to wear a helmet when batting, but when a batsman elects to wear a helmet it must be compliant with the new British Standard BS7928:2013.³⁰

5. Conclusion

The current evidence regarding role of headgear to prevent SRC is quite diverse though it is evidenced to prevent fatal head injury and fracture. The available literature in the form of prospective observational studies or laboratory studies across various sports is still inconclusive. But it is true that when used it has to be a standard headgear. The efficacy of headgear in gender and age perspective is yet to be evaluated. The mandatory rule changes in relation to headgear also need to be based on science rather than assumptions. Even a paradoxical effect on protection from concussion has also been hypothesised in some combat sports. These knowledge deficits can be addressed through further research focussing on biomechanical understanding

of the impacts, and helmet efficacy and effectiveness across many sports.

6. Conflict of Interest

The authors declare that there are no conflicts of interest in this paper.

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None.

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