The Effectiveness of Interventions to Reduce Neurological Injuries in Rugby Union: A Systematic Review

BACKGROUND: Rugby is characterized by high-speed collisions among the players that predispose them to injuries, particularly to the head, neck, and spine.

OBJECTIVE: To evaluate the effectiveness of current neurological injury prevention strategies in rugby union.

METHODS: Systematic review in May 2010. We assessed the quality and content of studies that evaluated injury prevention strategies for rugby players and reported on neurological outcomes. We searched OVID Medline, OVID HealthStar, CINAHL, Sport Discus, PubMed, Scholar's Portal Physical Education Index, Web of Science, and the Cochrane Controlled Clinical Trials Register (CENTRAL) and conducted a manual search of the cited literature lists of each included study.

RESULTS: Ten articles are included in the review, with 2 of these assessing both headgear and mouthguards. Four studies reported insignificant reductions in neurological injury with the use of headgear. The results of 4 studies on the effectiveness of mouthguards in preventing neurological injury were inconclusive. Four studies reported significant reductions in neurological injury after the implementation of nationwide multifaceted injury prevention strategies with a focus on education.

CONCLUSION: There is limited evidence to support the effectiveness of mouthguards and headgear in reducing neurological injuries; however, system-wide, mandatory interventions are useful in reducing neurological injuries in rugby.

KEY WORDS: Concussion, Head injury, Protective headgear, Protective mouthguard, Rugby, Spinal injury, Sports injury prevention

Rugby is a popular contact sport characterized by high-speed collisions among the players that predispose them to injuries, particularly to the head, neck, and spine.1,2 The use of protective equipment and educational and rule enforcement programs are some strategies for preventing injuries in these areas. However, the effectiveness of these strategies in neurological injury prevention has yet to be systematically reviewed in the sport of rugby.

Professional rugby players sustain injuries at a rate of 91 injuries per 1000 player-hours, with each injury requiring on average 18 days to recover and return to play.3 Concussion is the third most common match injury and accounts for 62% of match head injuries in professional rugby union players.3 In younger players (up to 20 years of age), concussion accounts for up to 11% of all game injuries.4 The incidence of concussion in professional English rugby union players has been reported at 4.1 per 1000 player-hours.5 Two international rugby studies reported relatively lower, yet stable, concussion rates of 2.1 and 2.6 concussions per 1000 match player-hours in elite players in 2003 and 2007, respectively.2,6 It is suggested that the incidence of these injuries may be underreported due in part to the International Rugby Board (IRB) return-to-play law,6,7 which requires either clearance by a neurological specialist for permission to return to play or no participation in rugby for 3 weeks after injury.8
Another form of neurological injury in rugby is spinal injuries, which account for approximately 9% of the total time lost to match injuries by professional English players. Non-catastrophic spinal injuries, which are less severe yet more prevalent than catastrophic spinal injuries, occur at a rate of 10.90 injuries per 1000 player match-hours. Spinal injury cases in elite players needing emergency measures were observed at the 2003 Rugby World Cup. The rates of spinal injury were subsequently quantified at 0.5 injuries per 1000 match-player-hours during the 2007 Rugby World Cup. A prospective cohort study reported that the incidence of spinal injuries was 10.90 per 1000 match player-hours. Although no player sustained a catastrophic spinal injury, three players sustained career-ending injuries. Quarr et al previously outlined player position and phase of play as risk factors for, and hyperflexion of the cervical spine as a mechanism of, spinal injuries. Although most neurological injuries in rugby are mild, there is a small risk of severe neurological trauma that can result in disastrous and permanent neurological disability, paralysis, and, rarely, death.

It is argued that the use of educational injury prevention programs that promote proper playing techniques and enforcement of existing rules can reduce high-risk behaviors and injury in sport. Moreover, rugby players have the option of using headgear (soft-shelled helmet with thin padding), mouthguards, and other limited thin-padded devices for protection against injuries. It is commonly believed that the use of headgear and mouthguards can prevent concussions in the sport of rugby; however, the evidence in support of this theory has not been thoroughly reviewed. Knapik et al reviewed the effectiveness of mouthguards in preventing concussion among several contact sports (including rugby) and found that the use of mouthguards was not correlated with reduced concussion rates. To date, no study has focused on assessing the quality of research and effectiveness of interventions aimed to prevent neurological injuries in rugby only.

Given that neurosurgeons are called upon not only to assess and treat injured rugby players, but also to give their opinion about the value of various strategies to prevent neurological injuries, it is important for neurosurgeons to be aware of the value of these interventions. Therefore, the aim of this review is to evaluate the effectiveness of injury prevention strategies such as protective equipment and educational and enforcement programs in reducing brain and spinal injuries sustained by rugby players. We hope the study findings will help facilitate further research and policy in the prevention of neurological injuries involved in rugby.

PATIENTS AND METHODS

Terms used in this review are defined in Table 1. We ran searches on several databases to identify studies that evaluated the effectiveness of injury prevention strategies in rugby. We ran separate searches in OVID MEDLINE (from 1950 to May 2010, including in-process and non-indexed citations), OVID HealthStar (from 1966 to May 2010), CINAHL (from 1981 to May 2010), Sport Discus (from 1800 to May 2010), PubMed (from 1948 to May 2010), Scholars’ Portal Physical Education Index, Web of Science (1976 to May 2010), and Cochrane Controlled Clinical Trials Register (CENTRAL, from 1991 to May 2010).

All articles indexed with the medical subject heading (MeSH) or expert keyword football, or with the keyword rugby were identified. Those also indexed with the following keywords were examined: athletic injuries, brain injury, brain concussion, craniofacial trauma, spinal injuries, spinal cord injuries, head protective devices, helmets, mouth protectors, mouthguards sports equipment, education, intervention studies, and rules. The references cited for all included studies also were searched manually. Journals that commonly publish articles related to rugby—British Medical Journal, British Journal of Sports Medicine, Injury Prevention, and Sports Medicine—also were searched manually from 2000 to 2010. We also searched Google Scholar, DogPile, and other nonspecialist search engines. The search history results obtained from our MEDLINE search are shown in Table 2.

The inclusion criterion in our search was studies that used injury prevention strategies in an attempt to prevent neurological injuries, evaluated their prevention effectiveness, and reported on neurological outcomes. The exclusion criteria were as follows: 1) studies conducted in a laboratory setting; 2) studies that reported on the effects of protective equipment on reducing injuries to the scalp and face or in which we could not isolate the effects of neurological injuries alone; and 3) studies that reported only on the perceived effectiveness of interventions. Studies conducted in the laboratory setting were excluded because our focus is on clinically relevant studies done in the performance environment. Given the limited number of studies reporting on neurological injury prevention in rugby, we included studies without a concurrent control group if the study reported on the effects of neurological injuries.

Rugby football is played according to two codes: rugby union and rugby league. These two codes differ only in the number of players allowed on the field, the size of the field, the scoring of points, and the regulations surrounding restarting of play. Because all of our studies examine interventions in the rugby union style of football, we will be using the terms rugby and rugby union interchangeably.

Description of Search

After completing the keyword searches, the authors independently screened the titles and abstracts of the retrieved articles. Thirteen articles met the inclusion criteria. We excluded 2 articles because they were performed solely in the laboratory setting. One study was excluded because it examined the effectiveness of rugby headgear in preventing facial laceration, abrasion, or fracture in addition to neurological injuries, and it was not possible to distinguish data related solely to neurological injuries. Consequently, 10 articles were selected for the review. Two of the articles were randomized control trial (RCT) studies, and two were prospective cohort studies. One was an ecological study, one was a case-control study, three were case-series studies, and one was a poorly conducted cohort study. Data were extracted by 2 authors independently. There were no disputes needing to be resolved by a third party.

Quality Assessment

The Downs and Black, methodological checklist for quality assessment was used to objectively assess the quality of the included studies. The included studies were reviewed on reporting, external
validity, internal validity (bias and confounding), and power. Due to the heterogeneity of samples, outcomes, and study designs of the included studies, we adopted a narrative approach to synthesize our results.

RESULTS

Included Studies

Ten studies that met the inclusion criteria and passed the exclusion criteria were included in the study (see Table 3). Two studies assessed the effectiveness of headgear,5,23 2 studies assessed the effectiveness of mouthguards,4,26 and 2 studies assessed the effectiveness of both headgear and mouthguards5,24 to prevent concussion during rugby. Four studies reported on system-wide implementation of educational or enforcement of rule strategies aimed at reducing brain or spinal injuries.25,27-29

Of all the included studies, 1 study was conducted in South Africa,26 2 studies were performed in England,5,17 1 study was conducted in Australia,25 and 5 studies were done in New Zealand.24,25,27-29 McIntosh et al14 did not indicate the geographic location of their study. The included studies are described in the following sections and are summarized in Table 3.

Protective Equipment

In total, 4 studies evaluated the effectiveness of headgear in preventing concussion injuries, with none of them finding any benefits from wearing headgear in order to prevent concussions.4,5,23,24 Four studies evaluated the effectiveness of mouthguards in preventing concussions. The results from the 4 studies are inconsistent. Jennings et al17 found that the use of gum shields appeared to be associated with a reduction in the incidence of concussion and loss of consciousness. The remaining studies5,24,26 found no beneficial effects for the use of mouthguards in preventing concussion injuries.

Education and Enforcement Strategies

Four of the studies evaluated the effectiveness of education or enforcement strategies in preventing neurological injuries.25,27-29 In contrast to the equipment studies, all of these studies reported beneficial effects. Concussion management education programs and sideline concussion checklists provided in the RugbySmart program were effective in reducing the incidence of concussion and brain injury claims made to the Accident Compensation Corporation (ACC) compared to the pre-intervention period and compared to forecasted injury trends.27 This resulted in a savings equivalent to US $690 from the decreased claims made to the ACC. Moreover, the mean number of days between concussion/brain injury and the player’s seeking treatment was reduced from 6 to 4.27 The RugbySmart program also was able to reduce the incidence of observed spinal injuries during the study period when compared to forecasted values of spinal injuries.25 Over the 5-year period during which RugbySmart was implemented, injury rates in 2005 were found to be generally less than those in 2001 for injury sites targeted by the program. No similar improvement was observed for injury sites not targeted by the program. Neck and spine injuries had the greatest decrease in rate from 2001 to 2005.25 Lastly, the new scrum engagement law that was implemented by the IRB in the RugbySmart program in 2007 tended to reduce the incidence of contusions and fractures to the neck and back, as well as spinal disc protrusions and prolapsed discs that resulted from the scrum.28

Quality Assessment

See Supplemental Digital Content 1, which summarizes our results as per the Downs and Black30 methodological criteria, http://links.lww.com/NEU/A335.

Reporting

All of the studies described the hypothesis of the study, main outcomes measured, participant characteristics, random variability, intervention, and main findings. No studies reported on adverse events to their intervention; however, 2 studies suggested the possibility of risk compensation31 that may exist in the rugby playing environment.4,24 Only 2 studies reported on the cost-effectiveness of the interventions.26,27 Blignaut et al26 reported that constructing...
mouthguards for players in their study was not cost-effective. Gianotti et al found a total savings equivalent to US $690 690 from the reduced number of claims to the ACC and a return on investment range equivalent to US $12.60 for every US $1 invested.

**External Validity**

Although not explicitly stated, there was no evidence to suggest that participants in any of the studies differed from the entire population from which they were recruited. Also, the staff, places, and facilities where the participants were studied were likely representative of the environment to which most participants would be normally exposed. There is no reason to believe that players, coaches, and officials in New Zealand, South Africa, England, and Australia are different from those in other countries. A limitation of included studies for the review is an uneven distribution of the sex and age of players and the amount of experience players have had. This limitation could lead to considerable differences in the way rugby games are played and types or levels of rugby competition for which the included studies did not account. A review by Brooks et al reported that the incidence of match injuries is much higher in professional players (68–218 injuries per 1000 player hours) compared to senior amateur (15–74 injuries per 1000 player hours), school-boy (7–28 injuries per 1000 player hours), and women (3.6–7.1 injuries per 1000 player hours). The study also found that injury incidence rises with age and competitive level. Although Brooks et al report on all match injuries and do not report specifically on neurological injuries, there is no reason to believe that these same factors are unlikely to affect neurological injuries as well. Kahanov et al reported that different player positions and the level of player experience played a role in the number of concussions sustained by a rugby player. Differences in gameplay style or intensity in an under-overrepresented population may possibly have led to some of the changes observed. Further studies focusing on neurological injuries in rugby accounting for these limitations should be an area of future investigation.

**Internal Validity**

It was not possible to use blinding outcome assessors and allocation concealment in any of the study designs. None of the included studies were able to use blinding outcome assessors and allocation concealment as the study designs. Whether all coaches actually implemented RugbySmart principles and the sideline allocation concealment as the study designs. None of the included studies were able to use blinding outcome assessors and allocation concealment in any of the study designs. Whether all coaches actually implemented RugbySmart principles and the sideline intervention groups over the same period of time. Two studies, by Gianotti et al and Quarrie et al had historical control groups because of the design of the time series studies, which involved the implementation of a population-based, ongoing nationwide educational program in New Zealand. The integrity of these controls is unclear, given that the environment of rugby likely changed over the time periods of the New Zealand RugbySmart studies. The involvement of a whole country...
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<td>Blignaut et al, 1987</td>
<td>Investigate whether injuries sustained in rugby differed significantly between wearers and non-wearers of mouthguards</td>
<td>321 first-team players (555 player occasions: 194 wearer occasions, 361 non-wearer occasions) from the residence league of the University of Stellenbosch</td>
<td>NA</td>
<td>Case-control</td>
<td>Protective equipment—mouth guard</td>
<td>Few details provided</td>
<td>Six examiners interviewed the players before and after every match to record the particulars on a computerized form.</td>
<td>Location of injury, type of injury, use of mouthguard</td>
<td>There was no association between the use of mouth guards and a reduction in the incidence of concussion ($\chi^2$-test, $P = .67$)</td>
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<td>Jennings et al, 1990</td>
<td>To study injuries sustained and the incidence of concussion and loss of consciousness by users and non-users of gum shields in rugby players</td>
<td>114 regular English club rugby players (60 gum shield users and 54 non-users)</td>
<td>NA</td>
<td>Retrospective study</td>
<td>Protective equipment—gum shields</td>
<td>Few details provided</td>
<td>Two questionnaires, one for gum shield wearers and the other for non-gum shield wearers, were devised.</td>
<td>Use of gum shields; type of injury</td>
<td>55 (48.2%) had previously suffered from concussion or loss of consciousness. Of these, 39 (71%) were not wearing gum shields while 16 (29.1%) were.</td>
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<td>McIntosh et al, 2001</td>
<td>To determine whether protective headgear reduced the incidence of concussion in an under-15 rugby union league</td>
<td>Rugby players ($n = 294$) from 16 A-grade teams participating in an under-15 rugby league from the Sydney metropolitan area and adjacent Southern Highlands region</td>
<td>6 of 22 schools within the region did not participate.</td>
<td>Cluster (randomized control trial)</td>
<td>Protective equipment—headgear</td>
<td>Single competitive season</td>
<td>Teams were randomly assigned to either the headgear arm or control arm. The required measures were recorded by a team’s nominated “recording officer.”</td>
<td>Player participation; headgear use; head injury incidence per game</td>
<td>There was no significant difference between the concussion injury rates of players with and without headgear ($P = .48$; $z = 0.0648$; 95% CI: 0.0092-0.0086)</td>
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<td>Marshall et al, 2005</td>
<td>To investigate the effectiveness of the protective equipment as an injury prevention strategy used in rugby union</td>
<td>304 competitive rugby union players participating in the 1993 season in Dunedin, New Zealand (Males: 240 and Females: 64)</td>
<td>A total of 52 players were excluded: 10 did not complete preseason assessment, 12 were partially followed during the season, 7 did not have enough exposure in competitive games, 23 school girls also were excluded because the length of their participation was too short and low, respectively, for meaningful analysis.</td>
<td>Prospective cohort design</td>
<td>Protective equipment— including the use of headgear</td>
<td>The study spanned the 1993 competitive rugby union season, which included the preseason and totaled 8149 organized team practices, 4103 scheduled competitive games, and 5378 player-weeks of follow-up.</td>
<td>Preseason assessment, self-administered general health questionnaire, anthropometric measurements, fitness testing. Weekly follow-ups during the 1993 club season. Telephone interviews of cohort members about their participation in rugby and injury experience, with particulars recorded. Generalized Poisson regression was used for result analyses.</td>
<td>Protective equipment (mouthguard and headgear) use; incidence, type, location and setting of injury; phase of the game in which the injury occurred; level of medical attention received</td>
<td>The use of headgear did not appear to be associated with a reduction in the risk of concussion (adjusted rate ratio, RR = 1.13, 95% CI: 0.40-3.16). The use of mouthguards also did not appear to be associated with lessened risk of concussion (RR = 1.62, 95% CI: 0.51-5.11). Overall, use of protective devices and equipment had no detectable effect on risk, and no particular item was associated with an increase or decrease in the risk of injury.</td>
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<td>Quarrie et al, 2007b</td>
<td>To investigate the effect of RugbySmart on the frequency of spinal cord injuries</td>
<td>All New Zealand rugby union players (population at risk of injury)</td>
<td>Compulsory</td>
<td>Ecological study</td>
<td>Educational prevention program RugbySmart, designed to educate rugby participants regarding physical conditioning, injury management, and safe techniques in the contact phases of rugby</td>
<td>Collated and analyzed data from 1976-2005</td>
<td>Numbers of all spinal injuries resulting in permanent disablement due to participation in rugby from 1976-2005 were grouped into 5-year periods and then compared with predicted number of spinal injuries post-RugbySmart implementation (2001-2005). Calculation modeling used</td>
<td>Number of spinal injuries; spinal injury rates</td>
<td>In 2001-2005, 8 spinal injuries were observed; the predicted number based on the rate from the previous periods was 18.9 (RR = 0.46; 95% CI: 0.1901.14). Observed and predicted scrum-related spinal injuries were 1 and 9, respectively. Observed and predicted spinal injuries from phases unrelated to the scrum were 7 and 9, respectively.</td>
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<td>Gianotti et al, 2007</td>
<td>To assess the effectiveness of the concussion management education video and a sideline concussion checklist in rugby in reducing the number and cost of claims for moderate to severe concussion/brain injury.</td>
<td>Annually, approximately 10,000 coaches and 2000 referees participated in RugbySmart in New Zealand.</td>
<td>Compulsory Case series Educational prevention program</td>
<td>July 2003 - June 2005</td>
<td>30,000 sideline concussion check cards were distributed to and used by rugby coaches over the duration of the study. Coaches and referees were required to attend annual compulsory RugbySmart workshops (includes a 45-minute RugbySmart video with 5 minutes dedicated to concussion management and the sideline concussion cards)</td>
<td>The number of registered rugby players; the number of concussive claims made to the ACC each year; the number of days between concussive injury and sought medical attention; the cost of concussive claims for the ACC each year</td>
<td>The incidence of concussion/brain injury reduced by 10.7% between July 2003 and June 2005, although rugby player numbers increased by 13.6% when compared to data from 1999 to July 2003. The median number of days between concussion brain injury and the player seeking medical treatment decreased from 6 to 4 days. Potential of US $690,690 was saved from decreased concussion claims made to the ACC.</td>
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<td>Kemp et al., 2008</td>
<td>To evaluate the effect of headgear and mouthguards on reducing rates of concussion</td>
<td>757 male rugby union players from 13 English Premiership rugby union clubs</td>
<td>Players were included or excluded from the study when they became or ceased to be, respectively, members of a Premiership club’s first team squad</td>
<td>Prospective cohort</td>
<td>Protective equipment—use of headgear and mouthguards</td>
<td>3 years, 2002-2003, 2003-2004, 2005-2006 English Premiership seasons</td>
<td>Medical personnel recorded head injuries on a weekly basis and completed a supplemental standard injury report form for each injury; Z-test used for statistical analyses</td>
<td>Head injury rate per 1000 player-hours; use of headgear and mouthguards</td>
<td>There was no significant difference in the incidence of concussion between wearers and non-wearers of mouthguards ($P = .44$). There was no significant difference in the incidence of concussion between wearers and non-wearers of headgear ($P = .28$). Incidence of concussion (95% CI) for: (i) mouthguard wearers: 4.0 (5.2-5.0); (ii) no mouthguard: 5.8 (3.6-9.3); (iii) headgear wearers: 2.0 (1.0-4.2); (iv) no headgear: 4.6 (3.7-5.7)</td>
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<td>Gianotti et al, 2008</td>
<td>To determine the effect of the new law on scrum-related moderate to serious neck and back (including spine) injury claims in 2007</td>
<td>All coaches, referees, and rugby players over the age of 12 y registered to the New Zealand Rugby Union</td>
<td>Compulsory Case series</td>
<td>Educational prevention program—law change</td>
<td>The 2007 competitive rugby season in New Zealand</td>
<td>Coaches and referees completed a compulsory 1-hr RugbySmart workshop, which contained video footage of the new scrum law. Coaches and referees were encouraged to educate their players accordingly. Poisson linear regression was used to compare the observed claims per 100 000 forwards with the rate predicted from the 2002-2006 data</td>
<td>Number of registered players and their positions; number of serious neck and back (including spine) injury claims made to the ACC; the phase of play during which injuries occurred</td>
<td>The observed number of registered players and their positions was 100 000 forwards, respectively (rate ratio of 0.69; 90% CI: 0.42-1.12). The mean rate of claims for 2002-2006 was 66 per 100 000 forwards, and the observed rate relative to this mean rate was a ratio of 0.79 (90% CI: 0.53-1.18).</td>
<td>Number of claims made to the ACC: 52 and 76 per 100 000 forwards, respectively (rate ratio of 0.69; 90% CI: 0.42-1.12). The mean rate of claims for 2002-2006 was 66 per 100 000 forwards, and the observed rate relative to this mean rate was a ratio of 0.79 (90% CI: 0.53-1.18).</td>
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<td>Gianotti et al, 2009</td>
<td>To evaluate the effect of RugbySmart on reducing injury rates per 100 000 players and on increasing safe sporting behaviors and techniques.</td>
<td>Annually, approximately 10 000 coaches and 2 000 referees participated in RugbySmart in New Zealand. Male rugby players over the age of 19 y</td>
<td>Compulsory Case series Educational prevention program included RugbySmart workshops (includes a 45-minute RugbySmart video). Coaches and referees were then encouraged to educate their players accordingly.</td>
<td>The annual program was launched in 2001.</td>
<td>Prior to the intervention, players were to complete an annual survey for 3 consecutive years (1996-1998) which measured demographics, activities undertaken at practice, activities undertaken at game, questions on their preseason training, their injury management and reporting, and knowledge of ACC advertising material. The RugbySmart program was then launched in 2001. In 2005, players were asked to complete the same survey and the effects of the RugbySmart program were determined by comparing responses from 2005 with the 1996-1998 data; Poisson regression model used</td>
<td>Rate of injury claims per 100 000 players per year</td>
<td>Player's behavior during match circumstances</td>
<td>A decrease in neck/spine (a targeted injury site) injury claims per 100 000 players from 2001 to 2005 (RR = 0.77; 90% CI: 0.62-0.97). The program had a negligible impact on other non-targeted injury sites; an increase in safe behavior in the contact situations of tackle, scrum, and ruck technique.</td>
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<td>McIntosh et al, 2009</td>
<td>To investigate the efficacy of padded headgear in preventing head injuries in rugby union football</td>
<td>Players in male rugby teams in 1 club and 3 school-based competitions at the levels of: schoolboy under-13, schoolboy under-15, schoolboy under-18, and club Colts rugby under 20. Male youth rugby players were aged 12-21 y.</td>
<td>NA</td>
<td>Clustered randomized control trial</td>
<td>Protective equipment—headgear</td>
<td>Two competitive seasons</td>
<td>Teams from 1 club and school-based levels that agreed to participate were randomized into 3 study arms: control, standard headgear, and modified headgear. 82 teams participated in year 1 and 87 teams participated in year 2 of the study. Primary data collectors were trained and paid to record injury, compliance, and exposure in each game. Incidence rates and incidence rate ratios from Poisson regression models</td>
<td>Rate of head injury and concussion; injury rates for all body regions combined</td>
<td>A total of 1841 injuries were experienced by 1159 players. Concussion accounted for 11% of all game injuries (199). Both standard and modified headgear provided no preventative benefit to concussion rates in game injuries ($P = .65$ and $P = .87$, respectively) and missed game injuries ($P = .50$, $P = .95$ respectively). Similar results were observed when analyses were adjusted for the level of play.</td>
</tr>
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$^a$ACC, Accident Compensation Corporation; NA, not applicable.

$^b$These studies applied their interventions over a similar time period (2003-2005).
by a uniform reporting system is, however, a strong point of the New Zealand RugbySmart studies.25,27-29

Only 2 of the studies explicitly reported on characteristics of study participants lost to follow-up.1,24 Marshall et al24 reported that 18 individuals of 52 excluded participants from a total of 356 participants were lost during the study, and McIntosh et al4 reported that there were no participants lost to follow-up. The participants lost to follow-up in the study by Marshall et al24 were excluded from the analyses. The New Zealand RugbySmart studies25,27-29 did not report on loss of study participants, likely due to the compulsory nature of the program. However, the nature of the players, coaches, or officials participating in rugby in New Zealand may be changing, and those prone to injury may be excluded. It is not clear how many coaches and teams were withdrawn from competition because of the mandatory participation in the education programs.

Only the studies by Marshall et al24 and McIntosh et al4 adjusted for confounding in the analyses from which the main findings were drawn. Inadequate adjustment for confounding may threaten the internal validity, because confounding factors as well as the intervention strategies might have contributed to observed results.

The 2007 and 2009 studies by Gianotti et al29 and the study by Quarrie et al25 were all based on the same New Zealand ACC database of injuries over a short time frame. Because the authors used similar data to assess the impact of “sideline management,” RugbySmart, and new scrum laws on neurological injuries, it becomes somewhat difficult to determine which of the interventions is responsible for the reported effects. It could be that one of the interventions has a more powerful effect than the others or that one effect can occur only in the setting already “primed” by a priori state that makes participants ready to accept the next effective intervention.

Statistical Power

Only McIntosh et al4 reported on statistical power a priori. Given the rates of 2.1 and 2.6 concussion cases per 1000 professional match player-hours in 2003 and 2007, respectively,7,6 it is unlikely that any but the New Zealand RugbySmart studies25,27-29 and the McIntosh et al4 study had sufficient power to detect significant changes. The lack of effect seen may be due to type II errors or because of a lack of effectiveness of the interventions.

DISCUSSION

Our paper reviewed the results of 10 studies that reported on the effectiveness of injury prevention strategies used in rugby union. Six studies evaluated the effectiveness of headgear and/or mouthguards, and 4 studies evaluated the effectiveness of education and rule enforcement strategies. From our systematic review, it can be concluded that headgear and mouthguards have limited or no benefit in reducing concussion in rugby, whereas nationwide multifaceted injury prevention strategies with a focus on education led to a significantly reduced incidence of concussion and head/neck and spinal injury.

A statistically nonsignificant decline of concussion injuries associated with the use of headgear alone was ascertained.4,5,23,24 Laboratory studies of the impact attenuation properties of headgear in rugby show that they have a very limited capacity to lessen the likelihood of concussion.23 These reasons, combined with the relatively small sample sizes of the studies by McIntosh et al23 and Marshall et al24, show no statistically significant effects for headgear. Marshall et al’s study24 reported on the effectiveness of headgear in 1993; there is no reason given for the delay from data collection to publication of results. However, we have not been able to identify any publications on changes in the standards of or the design of headgear for rugby since 1993.

Reports on the benefits of mouthguards were conflicting. Several researchers4,24,26 reported limited benefits for the use of mouthguards in reducing concussion, whereas Jennings and colleagues17 reported statistically significant valuable effects for the use of mouthguards in reducing concussion. However, the study by Jennings et al had many methodological limitations, such as its retrospective nature, its use of different questionnaires in the 2 groups, its failure to report on important methodological aspects, and its provision of few details on the statistical analyses. Given the limitations of Jennings et al’s study17 and the consistent results from others,5,24,26 we conclude that there is no evidence for the benefits of mouthguards as concussion-preventing equipment. It is possible that some mouthguard designs are more effective than others, but a recent RCT suggests otherwise.46

Mouthguards are the most commonly used protective item in rugby.37 Contrastingly, less than 10% of players used headgear with high frequency.49 There are strong indications for the use of headgear and mouthguards to prevent orofacial injuries. Numerous studies have shown that mouthguards are beneficial in reducing and preventing the number of orofacial injuries in contact sports, including rugby.17,24,48,49 Similarly, headgear can reduce the risk of developing scalp lacerations and abrasions in rugby.24 Despite their limited ability to prevent concussion injuries, we suggest that headgear and mouthguards continue to be used to prevent orofacial injuries.

Some authors have argued that the use of protective equipment may result in increased aggressive behaviors and attitudes in rugby players that may lead to an increase in rugby injuries. In sports, this effect is known as risk compensation.51 Finch et al50 reported that rugby players under 15 years old were more confident and able to tackle harder when wearing headgear. Two of the included studies suggested the possibility of risk compensation by illustrating the association between the use of standard headgear and a higher incidence of developing a game injury.4,24 Risk compensation was not directly examined in either study, but it may have been present.

The studies by Gianotti et al29 drew their data from the New Zealand ACC database of injuries; however, each study evaluated the effectiveness of their interventions over a short time frame.
Combined, the studies provided evidence that mandatory, system-wide interventions had statistically significant effects on neurological injuries such as concussion and neck and spinal injuries, at least in the short-term. Although the studies reported by Gianotti et al.\textsuperscript{27-29} primarily implemented educational reforms to educate players, they were able to demonstrate statistically significant effects of this strategy. This is consistent with findings reported by Cook et al.,\textsuperscript{15} who showed that an educational intervention could improve knowledge and reduce high-risk behaviors in another contact sport, ice hockey. Whether confounders exist in the studies\textsuperscript{27-29} by Gianotti et al. is unclear. It is possible that highly publicized cases of catastrophic injuries or rising insurance rates for teams and leagues were responsible for the effect or prepared the setting for the effect to be possible. It will be of great interest to see follow-up studies of these cohorts or other cohorts in other countries to determine whether the findings are robust and whether plateau are quickly realized with these sorts of interventions.

Gianotti et al.\textsuperscript{27} did not indicate whether the reduced number of concussions was due to fewer concussion injuries or lessened reporting. However, the authors do mention that there was almost a 14% increase in the number of rugby players post-intervention; therefore, it is unlikely that the observed effects are due to reduced reporting. Given that the 2007 and 2009 studies by Gianotti et al.\textsuperscript{27,29} and Quarrie et al.,\textsuperscript{22,29} 2007 study involved interventions applied over a similar timeframe (2003–2005), it may be that only one of the interventions is more effective than the others or that one is required for the others to be effective. It is difficult to disentangle these effects given the way the studies were done. Future work could try to address which specific aspects of a multifaceted intervention are contributing most to an observed effect and what other aspects are contributing. It will also be important to determine whether the findings are specific to New Zealand or whether the approach can be successful on an international scale. Additionally, some of the included studies reported data from the perspective of statistical significance. It will be of great interest to see if statistical significances of interventional effectiveness can be translated into clinical or practical significances, producing the desired outcomes.

One of the strengths of this review is the incorporation of various types of high-quality papers that address our research question. Although we endeavored to keep the hierarchy of evidence in mind when identifying articles, there were only two RCTs that met our inclusion criteria. Since several of the studies likely were insufficiently powered, further evaluations are required to assess the effects of headgear and newer designs of headgear in well-powered and well-designed studies.

Except for the 2007 study by Gianotti et al.,\textsuperscript{27} none of the studies carried out multifaceted approaches to injury prevention. Future studies should assess multifaceted strategies that combine protective gear interventions with education, rule enforcement changes, and other incentives to better understand the relative benefits of each. Such a study would require the cooperation of multiple sites with ample sample sizes. Randomized controlled designs with blinded assessors would be best to address the issue of confounding factors and bias introduced by unblended outcome assessors.

CONCLUSIONS

The best available evidence suggests that multifaceted intervention programs combining education and rule enforcement implemented in a mandatory fashion across a whole country are likely to be effective in reducing the incidence of neurological injuries among rugby players. We did not find evidence that headgear and mouthguards prevent neurological injuries in rugby. However, there may be a place for better equipment design.

Given the increasing popularity of rugby and the high rates of neurological injuries, better designed randomized controlled studies with sufficient power and across different settings should be performed to understand the role of protective equipment and educational, legal, and economic interventions.

Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENT

The authors have completed a much needed systematic review of the rugby literature surrounding the prevention of neurologic injuries (e.g., concussion). The authors narrowed their review to examine the effects of headgear, mouthguards, and education and rules enforcement protocols. While a minimum number of well-designed investigations were available for review, the use of rugby headgear and mouthguards to prevent concussions is supported. Similar results relative to mouthguard use have been reported in American football and other sports. Conversely, educational and rule enforcement plans showed significant benefits through a reduction of injuries and overall medical costs. Clearly additional work investigating the best means to develop more sophisticated helmets that can reduce injury risk.

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