An ecologic study of protective equipment and injury in two contact sports

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Background Contact sports have high rates of injury. Protective equipment regulations are widely used as an intervention to reduce injury risk. The purpose of this study was to investigate the injury prevention effect of regulations governing protective equipment in two full-body contact sports.

Methods Injury rates in US collegiate football were compared to New Zealand club Rugby Union. Both sports involve significant body contact and have a high incidence of injury. Extensive body padding and hard-shell helmets are mandated in collegiate football but prohibited in Rugby Union.

Results The injury rate in football was approximately one-third the rugby rate (rate ratio [RR] = 0.35; 95% CI: 0.31–0.40). The head was the body site with the greatest differential in injury incidence (RR = 0.11; 95% CI: 0.08–0.16). Rugby players suffered numerous lacerations, abrasions, and contusions to the head region, but the incidence of these injuries in football was almost zero (RR = 0.01; 95% CI: 0.01–0.03). Injury rates were more similar for the knee (RR = 0.61; 95% CI: 0.43–0.87) and ankle (RR = 0.72; 95% CI: 0.46–1.13), two joints largely unprotected in both sports.

Conclusions The observed differences are consistent with the hypothesis that regulations mandating protective equipment reduce the incidence of injury, although important potential biases in exposure assessment cannot be excluded. Further research is needed into head protection for rugby players.

Keywords Sports injuries, protective devices, football, Rugby Union

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Ball-carrying full body contact sports involve extensive personal contact, resulting in a high incidence of injury. 1–4 The most common injury control strategy in these sports has been the introduction of regulations mandating personal protective equipment. North American football has invested heavily in this strategy, requiring participants to wear hard-shell helmets and protective body padding. In the other ball-carrying full body contact sports (Rugby Union, Rugby League, and Australian Rules football) hard-shell helmets are prohibited and body padding is either less extensive or non-existent.

The aim of this study was to investigate whether regulations requiring protective equipment in full contact sports were associated with a reduction in the risk of injury. We used an ecologic design to compare two high profile amateur sports, collegiate football in the US and club Rugby Union in New Zealand. The primary study hypothesis was that football would have a lower injury rate than Rugby Union. The secondary hypothesis was that the best protected body regions in football would have the lowest rates of injury, relative to rugby. Throughout, 'football' refers to North American football at the collegiate level in the US, and 'rugby' refers to competitive amateur Rugby Union at the club level in New Zealand.

Methods

Study design and setting

This study used an ecologic design to compare injury in two full contact sports. Information on football injuries, extracted from the National Collegiate Athletic Association (NCAA) Injury Surveillance System (ISS), was compared to injury data from a...
A cohort study of rugby players in Dunedin, New Zealand (the Rugby Injury and Performance Project, or RIPP). Women's rugby is a popular sport in New Zealand, however, we excluded females from the rugby data because of the absence of a comparable population of female football players in the US. In addition, only those injuries sustained during games were used in the analysis, because the frequency and type of practice drill differ between the two sports.

College football is the highest level of nominally amateur football in the US. Student-athletes are subject to strict controls that limit their direct income and the disbursement of scholarship funding. In addition to participating in football, all athletes must earn academic credit. In an analogous manner, club rugby in New Zealand is a serious competition in which a high level of commitment and training is required of amateur athletes. Virtually all participants are either full-time students or hold full-time jobs.

Regulation of protective equipment

Protective equipment usage differs markedly between football and rugby. Football mandates use of hard-shell helmets, face masks, mouthguards, shoulder pads, hip pads, thigh guards, and kneepads. In addition, some players also wear gloves, elbow pads, and additional body padding. The style of some pads varies by position, e.g. quarterbacks wear a modified shoulder pad to permit a greater range of motion.

The rules of Rugby Union, as promulgated by the International Rugby Board, expressly forbid the use of hard-shell helmets and any type of padding other than light (<1 cm in depth) shoulder pads. Instead, rugby players make extensive use of lightweight devices such as adhesive tape, strips of cloth, and elastic body sleeves. Mouthguard use, although not mandated at the time these data were collected, is common in rugby (53% of RIPP players wore a mouthguard on a regular basis).

Football injuries

Football exposure and injury data were extracted from the NCAA ISS database for fall season football for the academic year 1993–1994. The ISS is the surveillance system for sports injury in NCAA athletes. Participation in the NCAA ISS is voluntary and limited to member institutions of the NCAA. Data are collected from a stratified sample drawn from a listing of NCAA institutions willing to participate in the ISS. The sample is stratified by geographical region and division in order to ensure that the sample is to some extent representative of all NCAA institutions. Injury and exposure data are collected by athletic trainers, on a weekly basis, from the first official day of pre-season practice through to the final post-season contest. In 1993–1994, there were 106 collegiate institutions participating in the football arm of the ISS, representing 12% of all colleges and universities competing in intercollegiate football and approximately 9120 athletes. Details of the methodology are published elsewhere.

Rugby injuries

Data on rugby injury and exposure were extracted from the RIPP study. The source population for the RIPP study was everyone playing competitive club rugby in Dunedin, New Zealand, during the winter 1993 season. Each week, study subjects were telephoned and interviewed about their participation in rugby and any resultant injuries. Follow-up was 90% complete over the course of the season. The design and methodology of RIPP has been described in detail elsewhere, as have the demographics of the study participants and their injury experience. For the purposes of this study, analyses were restricted to males who played at least one rugby game.

Analysis

We developed a common classification scheme for body site and type of injury and used it to re-code both the rugby and the football data. Based on the level of protection afforded under NCAA protective equipment regulations, body sites were classified into three groups:

1. Protected: head, including scalp, eyes, ears, teeth, and jaw.
2. Partly protected: shoulder, groin, hips, upper leg, neck, and foot.
3. Unprotected: arm, wrist, hand, knee, lower leg, and ankle.

We classified the arm as partly protected because of the frequent use of elbow pads in football. Neck injuries are influenced by the helmet and therefore were also classified as partly protected. The knee was classified as unprotected because football knee pads are designed to protect only the patella and offer no protection to the joint itself.

The prime outcome of interest was the rate of injury per 1000 player-games, defined as the number of injuries divided by the total number of player-games at risk in each sport. The 95% CI for the rates were calculated under Poisson assumptions. Incidence density ratios were computed by dividing the incidence rate for football by the rugby rate. The resulting rate ratio (RR) estimates the increase or decrease in the risk of injury associated with participation in a football game relative to participation in a rugby game.

On both the football and rugby databases, multiple injuries (either from a single injury event, or from multiple injury events) were represented by multiple injury records, one per injury. When multiple injuries occur to the same player, the injuries are not statistically independent and standard formulae may incorrectly estimate the rate variance. To account for this, variance estimates for the injury rates were inflated by a standard factor. Exploratory analysis of the rugby data indicated that an increase of 50% was appropriate and the rugby and football rate variances, and rate ratio variances, were adjusted by this amount.

Results

The overall rate of injury in football games was approximately one-third of the rate in rugby (RR = 0.35; 95% CI: 0.31–0.40). In NCAA football, there were 2113 injuries in 52 965 player-games, giving an overall rate of 39.89 per 1000 player-games (95% CI: 37.81–41.98). The rugby players, on the other hand, accumulated 398 injuries from 3489 player-games for a rate of 114.07 per 1000 (95% CI: 100.35–127.80).

Injury rates were lower in football for all body regions (Table 1). The most common site of injury in football was the knee (24% of all injury), followed by the trunk/pelvis/hips region (14%), and ankle (14%). By contrast, the most common site injured in rugby was the knee (53% of RIPP players wore a mouthguard on a regular basis).
rugby was the head (19%), followed by the knee (13%), and trunk/pelvis/hips region (12%).

Group 1: Protected

The sole body site classified as protected, the head region, had a markedly lower incidence of injury in football, with a rate nearly one-tenth the rugby rate. Whereas football players suffered almost no damage to the scalp, face, eyes, and ears, the rugby players had a high incidence of injury at these body sites (Table 2). The injury rate for scalp, face, eyes, and ears combined was 14.33 per 1000 player-games (95% CI: 9.47–19.20) in rugby, accounting for 14% of total injuries. For football, the rate was only 0.19 per 1000 player-games (95% CI: 0.05–0.33), accounting for less than 1% of total injuries, yielding a rate ratio, for the scalp, face, eyes, and ears combined, of 0.01 (95% CI: 0.01–0.03). Compared to other head injuries, concussion rates were only modestly lower in football (RR = 0.41; 95% CI: 0.22–0.75).

Group 2: Partly protected

With the exception of the foot, which is partly protected in both sports, the RR for the Group 2 sites ranged from 0.19 to 0.52. Large risk differentials were observed at the upper leg and the hand/wrist. For both sports, injuries to the upper leg were evenly divided between contusions/haematomas (50% of football and 47% of rugby injuries to the upper leg) and sprains/strains (43% of football and 42% of rugby injuries to the upper leg). The majority of injuries to the hand/wrist were sprains/strains in rugby (40%) and fractures in football (49%).

Table 1: Frequency and rate of game injury in two full contact sports

<table>
<thead>
<tr>
<th>Body site of injury</th>
<th>North American Football</th>
<th>Rugby Union</th>
<th>Rate Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of injuries</td>
<td>Rate of injury per 1000 player-games (95% CI)</td>
<td>Rate of injury per 1000 player-games (95% CI)</td>
</tr>
<tr>
<td>Group 1 (Protected)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head</td>
<td>129</td>
<td>2.44 (1.92–2.95)</td>
<td>74</td>
</tr>
<tr>
<td>Group 2 (Partly protected)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neck</td>
<td>110</td>
<td>2.08 (1.60–2.55)</td>
<td>28</td>
</tr>
<tr>
<td>Shoulder</td>
<td>285</td>
<td>5.38 (4.62–6.15)</td>
<td>36</td>
</tr>
<tr>
<td>Arm</td>
<td>62</td>
<td>1.17 (0.81–1.53)</td>
<td>11</td>
</tr>
<tr>
<td>Hand/wrist</td>
<td>144</td>
<td>2.72 (2.17–3.26)</td>
<td>42</td>
</tr>
<tr>
<td>Trunk/pelvis/hips</td>
<td>259</td>
<td>4.89 (4.16–5.62)</td>
<td>47</td>
</tr>
<tr>
<td>Upper leg</td>
<td>130</td>
<td>2.45 (1.94–2.97)</td>
<td>45</td>
</tr>
<tr>
<td>Foot</td>
<td>76</td>
<td>1.43 (1.04–1.83)</td>
<td>6</td>
</tr>
<tr>
<td>Group 3 (Unprotected)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee</td>
<td>474</td>
<td>8.95 (7.96–9.94)</td>
<td>51</td>
</tr>
<tr>
<td>Lower leg</td>
<td>90</td>
<td>1.70 (1.27–2.13)</td>
<td>26</td>
</tr>
<tr>
<td>Ankle</td>
<td>339</td>
<td>6.40 (5.57–7.23)</td>
<td>31</td>
</tr>
</tbody>
</table>

Table 2: Frequency and rate of game injury to the head region in two full contact sports

<table>
<thead>
<tr>
<th>Injury site</th>
<th>North American Football</th>
<th>Rugby Union</th>
<th>Rate Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of injuries</td>
<td>Rate of injury per 1000 player-games (95% CI)</td>
<td>Rate of injury per 1000 player-games (95% CI)</td>
</tr>
<tr>
<td>Intracranial</td>
<td>116</td>
<td>2.19 (1.70–2.68)</td>
<td>22</td>
</tr>
<tr>
<td>Scalp</td>
<td>4</td>
<td>0.08 (0.00–0.17)</td>
<td>15</td>
</tr>
<tr>
<td>Face</td>
<td>6</td>
<td>0.11 (0.00–0.22)</td>
<td>16</td>
</tr>
<tr>
<td>Mouth/teeth/jaw</td>
<td>3</td>
<td>0.06 (0.00–0.14)</td>
<td>2</td>
</tr>
<tr>
<td>Eye</td>
<td>0</td>
<td>0.00 –</td>
<td>15</td>
</tr>
<tr>
<td>Ear</td>
<td>0</td>
<td>0.00 –</td>
<td>8</td>
</tr>
<tr>
<td>Injury type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concussion</td>
<td>112</td>
<td>2.11 (1.63–2.59)</td>
<td>18</td>
</tr>
<tr>
<td>Laceration</td>
<td>1</td>
<td>0.02 (0.00–0.06)</td>
<td>35</td>
</tr>
<tr>
<td>Contusion/haematoma</td>
<td>6</td>
<td>0.11 (0.00–0.22)</td>
<td>9</td>
</tr>
<tr>
<td>Fracture</td>
<td>4</td>
<td>0.08 (0.00–0.17)</td>
<td>5</td>
</tr>
<tr>
<td>Other</td>
<td>6</td>
<td>0.11 (0.00–0.22)</td>
<td>7</td>
</tr>
</tbody>
</table>

a Rate ratio using rugby as the referent.
Neck injuries were very different between the two sports. Football players sustained a much lower incidence of sprains/strains to the neck than rugby players, 1.02 per 1000 (95% CI: 0.69–1.35) compared to 6.02 (95% CI: 2.87–9.17). Of all football injuries to the neck, 40% involved the nervous system. These brachial plexus injuries, or ‘stingers’, typically result from a forced lateral movement of the neck and are often associated with sharp pain, numbness, and loss of motor control, particularly in the arm. No injuries of this type were reported by the rugby players.

**Group 3: Unprotected**

Two of the Group 3 sites, the ankle and the knee, had RR above 0.60. Both these lower limb joints are subject to significant biomechanical stresses as players accelerate, turn, and sustain body contact in the course of normal play in both games. Sprains accounted for 95% of ankle injuries in football and 71% in rugby. For both sports, the most common type of knee injury was sprains and strains (72% of all knee injuries in football and 49% in rugby). The lower leg was the other site classified as unprotected. Surprisingly, the football rate was considerably lower than the rugby rate (Table 1).

**Higher severity injuries**

To further explore these relationships, an analysis was conducted of the high severity injuries, defined as those resulting in ≥7 days of lost participation from the sport. The general pattern seen for all injuries, of decreasing risk with increasing level of protection, was also observed in the higher severity injuries. For the head region (protected), the RR was 0.09 (95% CI: 0.04–0.21). The RR for the partly protected sites ranged from 0.26 for the upper leg (95% CI: 0.10–0.73) to 0.72 for the shoulder (95% CI: 0.30–1.76); there were too few rugby hand/wrist injuries of high severity, n = 1, to permit meaningful analysis of this site. The RR for injury to the neck was 0.61 (95% CI: 0.14–2.64). The proportion of all neck injuries classified as high severity was similar between the two sports (26% in football and 29% in rugby). The RR for unprotected sites were 0.89 for the lower leg (95% CI: 0.15–5.16), 0.94 for the ankle (95% CI: 0.41–2.16), and 1.28 for the knee (95% CI: 0.65–2.54).

**Discussion**

Overall, the results had a consistent pattern and were supportive of our primary hypothesis. Football, which mandates use of hard-shell helmets and pads, had an injury rate approximately one-third the rate in rugby, which prohibits use of these protective items. Furthermore, those body sites with a higher level of protection in football tended to exhibit lower rates of injury relative to the same body site in rugby. This effect was most apparent for the head, a well-protected site in football, which had an injury rate nearly one-tenth of the rugby rate. The pattern of decreasing risk with increasing level of protective equipment across body site was also observed when the analysis was restricted to the more severe injuries.

**Prevention of injury to the head**

The hard-shell helmets used in football, originally designed to prevent catastrophic injuries, also appear to be effective in preventing a wide range of more minor injuries to the head, such as lacerations, contusions, and facial fractures. It is probable that many of these injuries could be prevented through the use of headgear without a hard shell, similar to the rugby headgear currently being manufactured and marketed. The rules of game were changed in 1998 to permit the use of soft, thin (≤1 cm depth when uncompressed) headgear. Research on the effectiveness of this form of head protection in rugby is needed.11

**Potential sources of bias**

Ecologic sources are ideal for examining exposures where either most or all of the variation occurs at the level of the group, such as regulations and policies.12–15 However, they are prone to bias from a number of sources.12,16,17 The major concerns in this study, where there is a high degree of homogeneity of equipment usage within each sport, are the potential for group-level information bias, bias due to confounding by group, and effect-measure modification by group.

Group-level information bias may have arisen from the methodological complications inherent in comparing data from two different sources. The NCAA football data were reported by athletic trainers whereas the RIPP data were player self-report. Because the rugby data were reviewed by research staff in consultation with sports physicians, the effect of this bias, if any, is expected to be slight. In addition, the definition of a reportable injury was slightly different between the two data sources. The NCAA ISS includes only injuries which required medical attention and restricted participation for at least 1 day, whereas RIPP included all injuries requiring medical attention or causing a player to miss at least one scheduled game or team practice. The effect of this difference is expected to be minor given that 91% of RIPP injuries included in this study received medical attention. Finally, RIPP collected data for only one season, whereas the NCAA ISS is an on-going surveillance system. Therefore, the potential for elevated rates in the rugby data due to a ‘Hawthorne effect’ (increased awareness and reporting of injury purely as a result of participation in a research study) cannot be excluded.

Group-level confounding and/or effect-measure modification could result from any of the following: differences in exposure to competition, differences in playing surfaces, differences in body contact and other injury producing situations on the field of play, and differences in attitudes and behaviours concerning prevention and treatment of injuries. The primary method for controlling for differences in exposure was to use an incidence density measure (injury rate per athlete-exposure) rather than a cumulative incidence measure (number of injuries per 100 players per season). We did not, however, control for any differences in the average playing time per game, and some members of a football team have very limited playing time during competition (e.g. field goal kickers). Playing surface is also a potential confounder in this study. Of the football games in this study, 30% were played on artificial surfaces, whereas New Zealand rugby is played exclusively on natural turf. Since it appears that the increased risk of injury associated with artificial surfaces is slight, and mainly confined to the lower leg, this difference is unlikely to account for the results observed in this study.18–20

Some degree of group-level confounding and effect-measure modification due to differences in the nature of the body contact between the two sports is undoubtedly present in the data, but it is unlikely that this source of bias would account...
for the pattern of decreasing risk with increasing protection reported in Table 1. Differences in body contact could confound our results if, for example, impacts to the head were far less frequent in football than in rugby. While detailed biomechanical data on the number and nature of impacts to the head region for the two sports are not available, it seems very unlikely that these differences would be sufficient to generate a ten-fold difference in the injury rate. Group-level effect-measure modification might arise if the use of body pads and hard-shell helmets influenced the style of play so that body contact and body impact were less frequent in football than in rugby. However, a contact athlete wearing protective equipment is unlikely to try to avoid, consciously or unconsciously, contact at that body site. If anything, the reverse has been observed; players tend to assume that protective equipment confers an unwarranted degree of invulnerability.

In a similar fashion, we cannot exclude bias from differences between the two sports in attitudes and behaviours concerning the prevention and treatment of injuries. Anecdotally, however, both sports require athletes who are willing to accept a reasonably high level of injury risk and engage in body contact.

Because we lack individual data on potential group-level confounders and effect modifiers, we are unable to fulfill the requirements for an ecologic study to be completely free of bias. Given the strength, consistency, and direction of our findings, however, it seems unlikely that differences between the two populations on factors other than their usage of protective equipment could explain the differences observed in this study. In particular, the pattern observed in Table 1, of decreasing risk with increasing level of protection, is strong support for study hypotheses and unlikely to be the result of uncontrolled confounding.

Conclusions

We conclude that a portion of the differential in injury rates between the two sports is due to differences in the regulation of protective equipment. This effect was particularly apparent for injuries to the head. The issue of head protection in rugby warrants further attention.

Acknowledgements

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KEY MESSAGES

- Injury rates in US collegiate football were compared to New Zealand club Rugby Union.
- The injury rate in football was approximately one-third the rugby rate.
- The rate of injury to the head region in football was approximately one-tenth the rugby rate.
- Regulations mandating protective equipment appear to reduce the rate of injury.
- Research is needed into head protection for rugby players.

References