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Comparison of branded rugby headguards on their effectiveness in reducing impact on the head

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ABSTRACT

Aim To compare the available brands of rugby headguards and evaluate their impact attenuation properties at various locations on the cranium, with regard to concussion prevention.

Methods Seven different branded headguards were fitted onto a rigid headform and drop-tested in three different positions. An accelerometer measured the linear acceleration the headform experienced on impact with the ground. Each test involved dropping the headform from a height that generated 103.8 g on average when bare, which is the closest acceleration to the upper limit of the concussion threshold of 100 g. A mean peak acceleration for each drop position was calculated and compared with the bare baseline measurement.

Results Each headguard demonstrated a significant decrease in the mean peak acceleration from the baseline value (all $p \leq 0.01$). Overall the Canterbury Ventilator was the most effective headguard, decreasing the impact force on average by 47%. The least effective was the XBlades Elite headguard, averaging a force reduction of 27%. In five of the seven headguards, the right side of the headwear was the most effective at reducing impact force.

Conclusion Overall, the results indicate that it would be beneficial to wear a headguard during rugby in order to reduce the impact forces involved in head collisions. There was also a clear difference in performance between the tested brands, establishing the Canterbury headguard as the most effective. However, only one model of headguard from each brand was tested, so further research evaluating all other models should be considered.

Summary box

- ▶ All headguards reduced the linear acceleration experienced on impact.
- ▶ The Canterbury Ventilator was the most effective, while the XBlades Elite was the least effective.
- ▶ The headguards used may not prevent all concussive injuries, but there is the potential for them to reduce the incidence.

has been argued that the dramatic increase could be a result of improved awareness of the condition, reflecting previous underdiagnoses rather than a real rise in incidence.³ Regardless of the cause of this trend, steps need to be taken to protect players from head impact injury.

In addition to the immediate dangers posed by concussion, research into long-term sequelae of concussion is proposing a link between recurrent head collisions in contact sports and fatal conditions such as second impact syndrome⁴⁻⁸ and chronic traumatic encephalopathy (CTE).⁹⁻¹¹ The debate surrounding the long-term sequelae of concussion in contact sport is becoming a mainstream issue, with CTE even making it to Hollywood with the film, *Concussion*.¹² However, research into both conditions is in its early stages, and some have disputed their existence due to a limited case number.¹³⁻¹⁵

It is estimated that between 1.6 million and 3.8 million sports-related concussions occur each year, but this figure may be an underestimate due to the large number that goes unrecognised and unreported.¹⁶ Raised awareness of sports-related concussion has sparked a wave of research into the field, primarily in the USA within the American football setting. However, in most contact sports, such as American football, ice hockey and cycling, players use hard-shelled helmets during play, which differ dramatically from the foam-padded headguards used in rugby. While the American studies may not be a useful comparison for headgear, there were

INTRODUCTION

Rugby union (hereafter referred to as rugby) has one of the highest incidences of concussion in sport, and rates are continuing to rise.¹ The latest Injury Surveillance Project (2017) stated that for the sixth consecutive season the occurrence of match concussions within English rugby had increased, reaching a figure of 15.8 concussions per 1000 player-hours.² Since rugby became a professional sport in 1995, full-time training has allowed players to increase their strength, power and fitness, as well as their body mass. This increased physicality is thought to be the cause of the rise in concussion figures.¹ However, it



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some studies that attempted to determine a threshold force for concussion, which are useful for evaluating the effectiveness of rugby headgear.^{17–21} Studies within the field of rugby have investigated the epidemiology of head impacts and concussive injuries, such as King *et al*¹⁷ and Gardner *et al*.¹ Focusing more on rugby headguards, most of the limited on-pitch testing of headguards has revealed no change in concussion incidence,^{22–24} with the exception of Hollis *et al*, who demonstrated a decreased frequency of concussion in those who chose to wear a headguard.²⁵ Despite this, one of the studies that demonstrated no change in the frequency of concussion while wearing a headguard did highlight a decrease in severity of concussive symptoms in those wearing a headguard.²² Taking this further, a laboratory study highlighted that small alterations to the headguards' design could significantly improve their impact attenuation performance.²⁶

In response to growing pressures, World Rugby have made reducing the incidence of concussion one of their main priorities. They have focused on education, creating many online resources providing information on recognising and managing concussion within the game of rugby.²⁷ They have also changed the laws of the game to punish reckless head collisions.²⁸ However, one area World Rugby have not used to prevent concussion is protective headgear. Their laws enforce tight limits on the thickness and density of the material used,²⁹ emphasising their purpose is to prevent superficial head injuries which they have proven to do.^{24 30} World Rugby argue that wearing headgear would give players a 'false sense of security' and encourage 'risk taking behaviour', resulting in an increase rather than a decrease in head injuries.^{31 32} However, research into the effectiveness of headguards has shown the tackle style and frequency do not change when comparing players wearing a headguard with those who are not.²³

The primary aim of this research was to investigate the efficiency of several branded rugby headguards at reducing the forces transferred to the head on impact. Headguards are the only form of head protection available to rugby players, and there is limited research comparing the efficiency of different brands which are approved by World Rugby. It was hoped the results would point towards a brand of headguard that provided the best protection for players.

METHODS

Selection of branded headguards

Three UK-based online rugby stockists (Rugby Store,³³ Lovell Rugby³⁴ and Pro:Direct³⁵) were searched to identify the brands producing a rugby headguard available to players in the UK. From these searches seven different brands were identified: Adidas, Canterbury, Gilbert, Impact, Kooga, Optimum and XBlades. Some of these brands produced more than one model of headguard; where that was the case, the mid-range (price) design was chosen. The seven headguards selected for testing are shown in figure 1.

Composition of the test rig

To evaluate the headguards, a drop test mechanism was designed. This involved a test rig which was developed and constructed in the Tayside Orthopaedic and Rehabilitation Technology Services Centre. It was constructed by attaching a polyvinyl chloride tube via a pivot mechanism onto a wooden base to create a swinging arm. A resin headform built to EN960 specification was screwed into the non-pivoted end of the piping of the test rig. It was chosen due to the negligible fatigue effects of its solid structure. The dimensions of the testing rig are shown in figure 2³⁶ for completeness. Attached to the top of the headform was a uniaxial accelerometer which recorded the linear acceleration during each test drop, as the testing rig movement was constrained to one plane. The targeted drop height was a height that would generate a force as close to 100 g as possible, as this figure is at the upper limit of the proposed concussion threshold.^{17–21} The chosen drop height of 27.9 cm resulted in the headform experiencing 103.8 g when bare. All drops were carried out onto 4G artificial surface. This was selected due to the popularity of artificial pitches within rugby, highlighted by almost 30 artificial rugby pitches in existence in Scotland³⁷ and the Rugby Football Union's recent campaign to provide 100 of them for the grassroot game across England.³⁸

Testing the headguards

Each headguard was placed on the same headform and tested in three different positions: front, back and side. The position of the headguard referred to the surface of the headguard that would experience the impact with the artificial surface during testing. To initiate the impact, the block of wood was triggered causing the headform to fall onto the artificial grass surface. The data output from the accelerometer was sampled at 100 kHz and recorded via the PicoScope 3204 software. This process was carried out 12 times in each of the three positions, producing 60 drops for each headguard. The bare headform was drop-tested five times to establish a baseline impact force from the chosen drop height.

Analysing the collected data

The peak acceleration from each drop test carried out was extracted from the accelerometer recording to generate a peak impact force. The results then underwent statistical analysis using the Statistical Package for Social Sciences (SPSS) V.22 software. Initially, a one-sample t-test was carried out to determine whether there was a significant difference between the baseline value and the values generated by each position of each of the headguards. Once this was established, post-hoc analysis of variance testing using Fisher's least significant difference was carried out to compare the different headguards as well as the different surfaces of the headguards.



Figure 1 Headguards selected for testing (left to right): Adidas Rugby headguard (£34.95), Canterbury Ventilator headguard (£42.00), Gilbert Evolution headguard (£34.99), Impact RWC Tartan headguard (£39.99), Kooga Combat headguard (£28.99), Optimum Hedweb Classic headguard (£24.99) and XBlades Elite headguard (£34.99).

RESULTS

Results by brand

The mean peak force demonstrated during testing of each brand of headguard is shown in [table 1](#), along with the maximum, minimum, SD and average reduction values. The mean peak acceleration gives a picture of each headguard's overall impact attenuation properties by combining the tests in all positions. A statistically significant reduction ($p < 0.001$) in linear acceleration was seen in all seven headguards when compared with baseline. The most effective headguard was the Canterbury

Ventilator, which on average produced a 46.7% reduction in impact force, and the least effective was the XBlades Elite headguard, which produced a 27.4% reduction.

Results by position

[Table 2](#) shows the peak acceleration results by position. In comparison with the other two surfaces, the back of the headguards produced less of a reduction in the impact forces (36%). There was not much variation between the other two positions, but the front produced the lowest

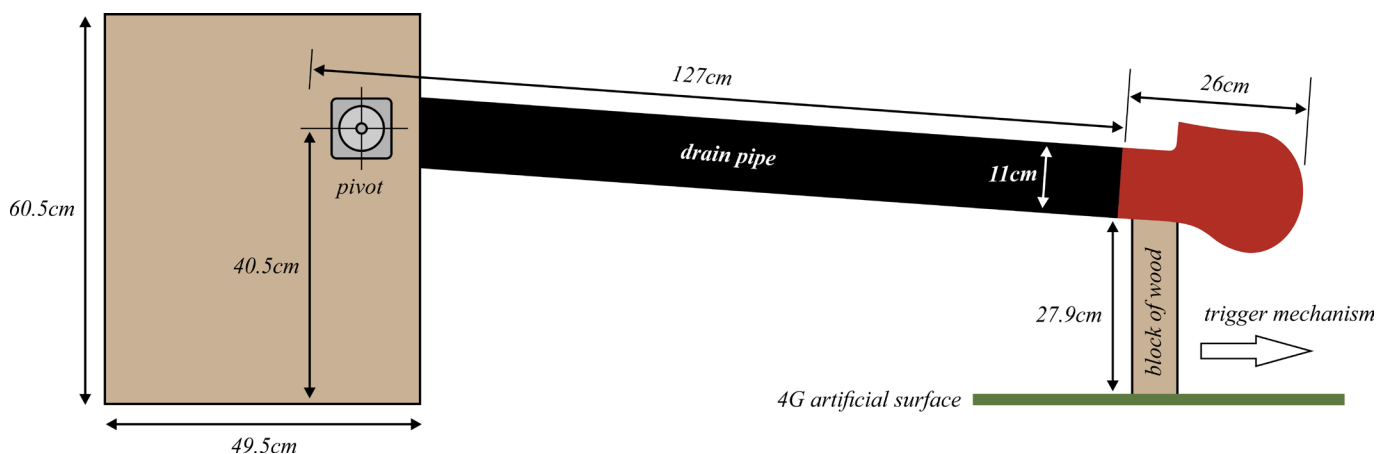


Figure 2 Dimensions of the test rig used in the drop testing of the headguards.¹⁷

Table 1 Mean peak acceleration (g) recorded during headguard testing by brand

Brand	Test drops (n)	Mean (g)	Minimum (g)	Maximum (g)	SD	Average reduction from baseline (%)
Baseline	5	103.80	98.48	106.08	3.03	–
Canterbury Ventilator	36	55.31	40.40	70.08	6.74	46.7
Impact RWC Tartan	36	59.42	45.84	80.41	8.56	42.8
Optimum Hedweb Classic	36	60.11	43.20	72.88	7.79	42.1
Adidas Rugby	36	60.22	41.60	80.73	9.37	42.0
Kooga Combat	36	60.71	43.28	80.01	6.61	41.5
Gilbert Evolution	36	71.72	45.84	91.53	11.65	30.9
XBlades Elite	36	75.31	54.16	89.61	9.12	27.4

mean peak acceleration during testing, reducing linear acceleration by 40%.

Further breakdown of results

Figure 3 allows comparison of the efficiency of the different branded headguards at each of the three surfaces tested. The highest mean peak acceleration was seen when the XBlades Elite headguard was tested on the right surface, which averaged 81.12 g, while the lowest was obtained from testing the right side of the Canterbury Ventilator headguard, which averaged 52.80 g. Overall, the Canterbury and Impact headguards tended to be the most efficient at the different surfaces, while the least efficient was always either the Gilbert or XBlades headguard.

DISCUSSION

Comparison of the different branded headguards

The aim of this research was to evaluate and compare the efficiency of various branded rugby headguards at reducing the forces transferred to the head on impact. All the headguards involved in testing demonstrated a decrease in linear acceleration experienced during impact when compared with the bare headform (all $p < 0.01$). There was also variation between the headguards, with post-hoc analysis demonstrating that for each of the three positions the most effective headguard was significantly different from the least effective headguard (all $p \leq 0.001$).

This study established the Canterbury Ventilator headguard as the most effective headguard at reducing linear

acceleration during collisions to the head. It produced the largest overall reduction of the impact force (46.7%) and was consistently in the most efficient half when comparing the headguards in each drop position. It generated the largest mean reduction in acceleration in two of the three positions: the right (49%) and back (47%).

The XBlades Elite headguard was consistently poorer at reducing the impact transferred to the headform compared with the other headguards. Its overall mean peak acceleration was only 27.4% lower than the baseline and was 20 g higher than the best performing Canterbury Ventilator headguard. The XBlades Elite headguard also produced the highest peak acceleration values at two of the three positions (right and front). The poorest performing headguard when testing the back position was the Gilbert Evolution headguard, which was also the second most ineffective overall.

Comparison of the different surfaces of the headguards

Different locations on the headguards were tested to determine the best protected parts of the cranium during a collision. Looking at the results from the three positions tested, the highest mean result was the back with 66.24 g, while the lowest was the front with 61.22 g. The slightly higher mean result for the back of the headguards when compared with the front and side is most likely due to the headwear design. The back region of the headguards features the tightening mechanism so as a result has less foam padding, reducing the headguards' impact attenuation properties in this area.

Table 2 Mean peak acceleration (g) recorded during headguard testing by position

Position	Test drops (n)	Mean (g)	Minimum (g)	Maximum (g)	SD	Average reduction from baseline (%)
Baseline	5	103.80	98.48	106.08	3.03	–
Front	84	61.22	40.80	81.77	9.41	41.0
Right	84	62.32	40.40	91.53	13.41	40.0
Back	84	66.24	43.04	84.57	8.92	36.2

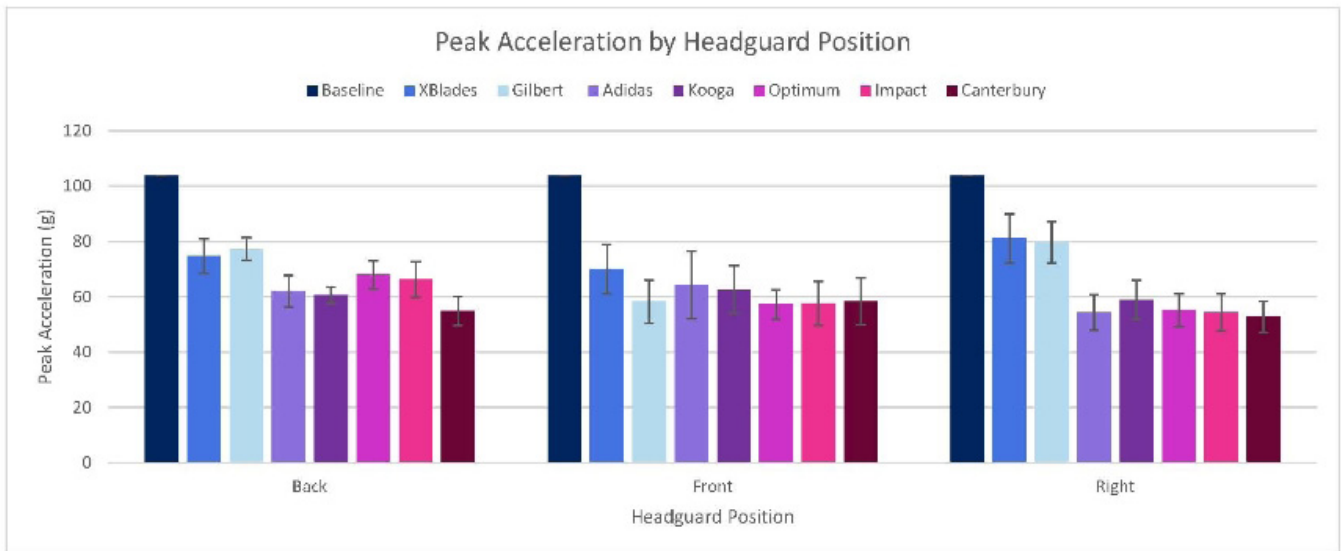


Figure 3 Mean peak acceleration (g) recorded in each headguard position.

When analysing the test drops on the front of the headwear, there is not much variation between the different brands. The post-hoc analysis showed no significant difference between the headguards when dropped on the front, with one exception: the XBlades Elite. The results from the front testing of this headguard were significantly different from almost all the other headguards. The narrow range in the results on front testing is most likely due to the similarity in the design of the headwear. Each headguard has an oblong-shaped foam block on the forehead aspect of the headgear. Therefore, any difference in the results between drops on the front is more likely due to the material compositions of the headguards rather than the design implemented.

Only one side of the headguards was tested as all seven headguards had a symmetrical design. The right side was chosen as previous research has shown the right side of the head to be the most common site for head collisions during rugby match play.¹⁷ There was a large range in effectiveness between the headguards when testing their right side; both the highest and lowest mean peak acceleration produced resulted from testing on the right side. The Canterbury Ventilator averaged 52.80 g when dropped, while the XBlades averaged almost 30 g higher at 81.12 g; these results made the right side the Canterbury headguard's strongest site, while it was the XBlades' weakest.

Potential for the headguard to reduce incidence of concussion

One of the main objectives of this research was to determine if the headguards available to players have the potential to reduce the incidence of concussion in rugby. When comparing the overall mean peak acceleration values for each headguard generated in this research against the 80–100 g concussion threshold proposed by current research,^{17–21} there is strong evidence that

headguards may reduce the incidence of concussion. This is demonstrated by each headguard producing a mean peak acceleration lower than the 80 g value. However, analysis of the individual drop test results suggests concussion may not always be prevented by headguard use. While the Canterbury, Impact and Optimum headguards did not produce a single drop test which exceeded the suggested 80 g threshold value, the other headguards did. Although the Kooga and Adidas headguards only saw one drop test go over 80 g, the Gilbert and XBlades headguards had a much larger figure: 19% of the Gilbert test drops and 31% of the XBlades test drops exceeded 80 g. Furthermore, when the XBlades Elite headguard was tested on the right side, two-thirds of the results surpassed 80 g.

However, as has been previously acknowledged, the threshold for concussion is still widely debated, and accepting a specific value must be done with caution. Furthermore, research has demonstrated incidents of concussion occurring from forces as small as 54.9 g,¹⁷ which is lower than the overall mean peak acceleration generated by each of the headguards tested in this study. Additionally, there are other variables which will influence whether an impact during play will result in concussion. These include cerebrospinal fluid levels and musculoskeletal strength, which can influence the body's ability to disperse head impact forces.²¹ While these factors are important to consider, in reducing the forces involved in collisions, it seems rational to suggest that this could lead to decreased concussion rates.

Limitations

This study relied on lab testing; prior research in this field indicates positive testing of headguards in the lab does not always translate into reduction in concussion rates on the rugby field.³⁹ The testing rig was set up to simulate

head collisions with the ground. However, prior research has demonstrated that 53% of concussive injuries that occur during rugby matches result from tackling.⁴⁰ Therefore, further research into the biomechanics involved in this kind of head impact may provide a more accurate way of evaluating the headguards. Data collection also only involved linear acceleration measurements despite research pointing towards angular acceleration playing an important role in concussive injuries. However, in a recent study, data from drop testing within a laboratory setting were compared with data from real-life American football head collisions, and it found that angular acceleration values from the laboratory were 46% lower when compared with pitch impacts.⁴¹ Drop testing is therefore not an accurate way to simulate and assess the angular component of concussive impacts and so only linear measurements were collected during this study.

Recommendations for future research

Recommendations in this area primarily involve wider testing of the headguards. Only one model from each brand was selected for testing, but it may be beneficial to investigate if other models from the tested brands demonstrate the same pattern in efficiency. There was also a slight decline in impact attenuation over serial drops with the same headguard, although this was attributed to the compression of the grass surface with repeated impact and therefore losing some of its cushioning effect. Further analysis of the performance deficit of the headgear over time could therefore be considered. It may also be worth carrying the research forward into live testing to identify if there is a difference in concussion incidence while wearing different branded headguards.

CONCLUSION

All headguards included in this study were shown to decrease the linear acceleration forces experienced during impact but with varying efficiency. The most effective brand was Canterbury. While the mean peak acceleration for each headguard was lower than the proposed injury threshold, there were individual drop tests which surpassed it. This suggests that while the headguards may not always be effective at preventing concussion, they may be effective at reducing the incidence of the injury. Until World Rugby make effective headguard development a priority, this research demonstrates current headguards are worth considering as they do decrease linear acceleration experienced on impact.

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