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Head impact exposure from match participation in women's rugby league over one season of domestic competition

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ABSTRACT

Objectives: To quantify the magnitude, frequency, duration and distribution of head impact exposure in a women's rugby league competition.
Design: Prospective cohort study.
Methods: Twenty-one players had a wireless impact measuring device (X2Biosystems XPatch) behind their right ear during match participation. Head impact data were collected and downloaded for analysis. Median peak linear and rotational accelerations and impact locations between player positions were assessed using a Friedman repeated measures ANOVA on ranks with a Wilcoxon signed-rank test for post hoc analysis with a Bonferroni correction.
Results: A total of 1659 impacts to the head >10*g* were recorded (range 10*g*–91*g*) over the nine competition matches. There was a mean of 184 ± 18 impacts per-match resulting in a mean of 14 ± 12 impacts per-player per-match. The No. 8 prop recorded a mean of 29 ± 27 impacts per-match, the No. 12 second-row forward recorded the highest median peak resultant linear acceleration (16g) per-match and the No. 11 second-row forward recorded the highest median peak resultant rotational acceleration (3696 rad/s^2).
Conclusions: Our cohort of 21 female rugby league athletes were exposed to repetitive sub-concussive head impact exposure with an average of 14 impacts per-player per-match. Forwards were exposed to more impacts per-match than backs and these impacts were of higher magnitude. Most impacts occurred on the side of the head and were sustained during the second half of the game. Clinicians, coaches and players should be aware of the rates and magnitude of head impacts in female rugby league athletes.

1. Introduction

As an intermittent collision-based team sport, rugby league is played at junior, amateur (male and female), semi-professional and professional levels of competition.[1] Rugby league is a challenging contest for players to compete in, comprising intense frequent bouts of high-intensity activity (e.g. sprinting) and collisions (e.g. offensive ball carrying and defensive tackling), interspersed with short bouts of low-intensity activities (e.g. walking, jogging).[2] As a result of these activities, players can experience 29–74 physical collisions (tackles and ball-carries) per game.[3,4] From these physical collisions there is an inherent risk of injury, including concussion[5] to the players involved, as impacts to the body and head happen.[1] A pooled analysis of rugby league concussions[6] reported an incidence of 7.7 per 1000 match hours. Males had a higher incidence of concussion than females (7.7 vs 6.1 per 1000 match hours) and amateurs recorded the highest concussion incidence (19.1 per 1000 match hours) when compared with semi-professional (5.9 per 1000 match hours) and professional (7.1 per 1000 match hours) rugby league participants. To date there are no published studies reporting on head impacts in men's or women's rugby league.

Sports-related concussion is a common injury and many go unrecognised.[5] It has been reported that approximately 90% of concussions do not result in loss of consciousness.[5] Concussions are sometimes not detected or undiagnosed with underreporting rates estimated to be as high as 50%–90%.[5] Knowledge of the potential metabolic and ultrastructural consequences of impacts to the head has increased, placing a greater focus on the possible deleterious effects of repetitive concussive and sub-concussive impacts in some individuals.[7] Technology, such as accelerometers in the helmets of American football players,[8–10] mouth guards of amateur rugby union players[11] and patches on junior rugby union players[12] have

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increased the knowledge and analysis of injury biomechanics of the forces, accelerations, frequencies and velocities of head injuries.[13] Despite these studies, to date there are no published head impact studies reporting on women's contact sports such as rugby league. Therefore, this study quantified impacts to the head via an instrumented patch worn behind the ear for women rugby league players over a single domestic competition season in New Zealand.

2. Methods

A prospective cohort design examined the frequency, magnitude and duration of head impact exposure during women's rugby league matches. The researcher's Auckland University or Technology ethics committee (AUTEC 16/35) approved all procedures in the study and all players gave informed consent prior to participating in the study.

Twenty-one female rugby league players were enrolled into the study [mean (±SD) age of 29.2 ± 7.8 years]. The players competed in nine competition matches resulting in a match exposure of 155.6 h. Players were placed into three positional groups: (1) hit-up forwards (n = 4: 2 × prop, 2 × second row); (2) outside backs (n = 4: 2 × centre, 2 × wing); and (3) adjustables (n = 5: hooker, halfback, five-eight, loose forward and fullback).[14] Three players (prop, loose forward and centre) wore their own scrum caps during match participation. These were Canterbury Ventilator headguard (prop and centre) and Canterbury honeycomb headgear (loose forward).

Head impact exposure was measured with the XPatch (X2Biosystems, Seattle, USA). The XPatch is a 1 cm × 2 cm device that measures acceleration and is mounted with a single-use adhesive behind the right ear. Containing a triaxial accelerometer and a triaxial angular rate gyroscope to capture six degrees of freedom for linear acceleration and rotational velocity, the XPatch has a 4.2 V battery and a small memory chip measuring at 1 kHz for linear acceleration and 800 Hz for angular velocity[15] triggered when impacts greater than a pre-set level of 10*g* occur. This threshold was chosen based on a review of previously published studies[11,16] where it has been reported that running and jumping elicited a maximum of 9.54*g* of linear head acceleration.[17] The XPatches were synchronised and checked in the morning of the match. Prior to commencing their warm-up, the lead researcher applied the XPatch behind each player's right ear ensuring it was fitted over the mastoid process and loose hair was not in the adhesive. The patches were allocated to player positions and the players' names were recorded. Data collection was delimited to matches only—not team training sessions.

When an impact above this pre-set level occurs, the device saves 10-ms prior to the impact and 90-ms after the impact providing X, Y and Z coordinates of acceleration at 1-ms intervals (see Fig. 1). Peak linear acceleration (PLA) was measured and peak rotational acceleration (PRA) was then calculated. The time stamp of the match was synchronised with the X2 XPatch prior to every game. The frequency, location, PLA, PRA and duration of all head impacts ≥10*g* threshold of linear acceleration were recorded by the XPatch for each match and stored on the device until uploaded. The XPatch has a strong correlation with peak linear acceleration (PLA: $r^2 = 0.93$) with a normalised root square error of 18%, but may over predict PLA and PRA by 15*g* ± 7*g* and 2500 ± 1200 rad/s^2, respectively.[18] The XPatch has also been reported[15] to have good agreement with PLA, can underestimate PRA by at least 25% and has a significant statistical correlation with the Head Impact telemetry System (HITS) for PLA (r = 0.144; p < 0.001), PRA (r = 0.15; p < 0.001) and Head Impact Telemetry severity profile (HITsp) (r = 0.34; p < 0.001).[19]

Before the statistical analysis was conducted, the raw data were reduced as follows. Data contained on the XPatch were uploaded to the Impact Management System (IMS) provided by X2Biosystems. The data were then downloaded and filtered through the IMS to remove any spurious linear acceleration that did not meet the proprietary algorithm for a head impact.[20] The X2Biosystems proprietary algorithm is unavailable. The data underwent a second filtering waveform parameter proprietary algorithm during data exporting to remove spurious linear acceleration data with additional layers of analysis.[20] This included the area under the curve, the number of points above threshold and filtered versus unfiltered peaks.[20] Press[21] estimated that approximately 80% of the impacts recorded may have been removed through the analysis that X2Biosystems provide as part of the IMS program. This may be similar for the current study, however, we were unable to obtain the details of the proprietary algorithm or the raw data. The remaining data were exported onto an Excel spreadsheet (version 2013; Microsoft Corporation, Redmond, WA) for visual examination. The data were then reviewed by impact time stamps (h:min:s) to identify identical and sequential patterns for each player. Time stamps with multiple (≥2) linear accelerations having the same h:min:s time stamp in quick succession milliseconds after the preceding impact were removed. These were removed by the authors by utilising Microsoft Excel conditional formatting and duplicate values to screen for linear accelerations with the same h:min:s time stamp in quick succession following downloading the impacts from the IMS. The data were then screened for player number and if there were any duplicate impacts on the h:min:s time stamp with the same player number these were removed. No incidence of this was identified in the final screening of the data prior to analysis in the Microsoft Excel. Once the review was completed, the data estimates were adjusted to estimates of the Hybrid III headform criterion standard. All impacts <10*g* were removed (n = 185) from the database following the completion of the adjusted calculations in line with previous results[22] that showed the XPatch over-estimates linear accelerations when compared with the centre of gravity of the headform criterion.

All filtered data on the Microsoft Excel spreadsheet were analysed with SPSS V.23.0.0. To test for normality, one-sample Kolmogorov–Smirnov and one sample *t*-test were conducted. The impact variables were not normally distributed ($D_{(1659)} = 0.23$; $p < 0.0001$; $t_{(1658)} = 67.0$; $p < 0.0001$), therefore data were expressed as median [IQR] and 95th percentile. Three measures of impact frequency were computed for each player: (1) *player position impacts*, the total and median number of head impacts recorded for the playing position for all matches; (2) *player group impacts*, the total and median number of recorded head impacts for the playing group (hit-up forwards, adjustables and outside backs) for all matches; and (3) *impacts per match*, the total and median number of impacts per match for all matches.

Player head impacts exposure were assessed utilising previously published levels for injury tolerance[23–25] (linear >95*g* and rotational acceleration >5500 rad/s^2), and impact severity[26–28] (linear mild <66*g*, moderate 66–106*g*, severe >106*g*) and rotational acceleration (mild <4600 rad/s^2, moderate 4600–7900 rad/s^2, severe >7900 rad/s^2). Two additional risk equations were included in the analysis of the head impact exposure data. The Head Impact Telemetry Severity profile (HIT_{SP})[29] is weighted composite score including linear and rotational accelerations, impact duration, as well as impact location. The Risk Weighted Exposure Combined Probability (RWE_{CP})[30] is a logistic regression equation and regression coefficient of injury risk prediction of an injury occurring based on previously published analytical risk functions. The RWE_{CP} combines the resultant linear and rotational accelerations to elucidate individual player and team-based head impact exposure. As a value of 63 is a 75% indicator for a concussive injury[29,31] the HIT_{SP} values were evaluated by limits of less than 25% risk (<21), 25%–75% risk (21–63) and >75% risk (>63). The RWE_{CP} values were evaluated by the same values of 25% risk (<0.25) 25%–75% risk (0.25–0.75)