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1 **Title page:**

2

3 **Title:**

4 Concussion and head injuries in English community rugby union match play

5

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21

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24 clubs who participated in this study.

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26

27 **Running title:**

28 Community rugby union head injuries

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31

32

33 **ABSTRACT**

34

35 **Background:** Previous research has described general injury patterns in
36 community level rugby union but specific information on time-loss head injuries
37 has not been reported.

38 **Objectives** To establish the incidence and nature of significant time-loss head
39 injuries in English community rugby match play, and to identify the injury risk
40 for specific contact events.

41 **Study design:** Descriptive epidemiology study.

42 **Methods** Over six seasons, injury information was collected from 46 (2009/10),
43 67 (2010/11), 76 (2011/12), 50 (2012/13), 67 (2013/14) and 58 (2014/15)
44 English community rugby clubs (RFU levels 3-9), over a total of 175,940 hours
45 of player match exposure. Club injury management staff reported information
46 for all head injuries sustained during match play whereby the player was absent
47 for 8 days or greater. Clubs were subdivided into semi-professional (mean
48 player age: 24.6 ± 4.7 years), amateur (24.9 ± 5.1 years) and recreational (25.6
49 ± 6.1 years) playing levels. Contact events from a sample of 30 matches filmed
50 over seasons 2009/10, 2010/11 and 2011/12, provided mean values for
51 frequency of contact events.

52 **Results:** The overall incidence for time-loss head injuries was 2.43 injuries per
53 1000 player match hours with a higher incidence for amateur (2.78; 95% CI
54 2.37-3.20) compared with recreational (2.20; 95% CI 1.86-2.53; $P = 0.032$) but
55 not different to semi-professional (2.31; 95% CI 1.83-2.79) playing levels.
56 Concussion was the most common time-loss head injury with 1.46 per 1000
57 player match hours. The tackle event was associated with 64% of all head

58 injuries and 73% of all concussions. There was also a higher risk of injury per
59 tackle (0.33 per 1000 events; 95% CI 0.30-0.37) compared with all other contact
60 events.

61 **Conclusions:** Concussion was the most common head injury diagnosis,
62 although it is likely that this injury was under-reported. Continuing education
63 programmes for medical staff and players are essential for the improved
64 identification and management of these injuries. With the majority of head
65 injuries occurring in the tackle, improved technique in this contact event through
66 coach and player education may be effective in reducing these injuries.

67

68 **What is known about this subject**

69 The limited number of existing injury epidemiology studies in community rugby
70 union have provided information showing that head injuries account a
71 significant proportion of the overall injury load. Concussions in particular
72 account for a considerable proportion of head injuries. However, specific
73 information relating to injured player position, injury causing event and
74 differentiation between playing levels for head injuries sustained during match
75 play is limited. In addition no studies have investigated the risk of injury for a
76 given contact event.

77

78 **What this study adds to existing knowledge**

79 This study describes the frequency and nature of head injuries at different
80 levels of English community rugby union match play over multiple seasons
81 and with a large study cohort. Specific information on the severity, injury event
82 and diagnosis has also been reported in this population for the first time.

83 Assessing the number of contact events per match has allowed the
84 calculation of head injury risk per contact event.

85

86

87 **CONCUSSION AND HEAD INJURIES IN ENGLISH COMMUNITY RUGBY**

88 **UNION MATCH PLAY**

89

90 **INTRODUCTION**

91 Head injuries are of particular interest in all sports because of the potential for
92 concussion and even severe traumatic brain injury. Rugby union is a contact
93 sport comprising bouts of physical collision, interspersed with intermittent high-
94 intensity running activity ²⁸. The majority of injuries in rugby are sustained in
95 contact events ^{25, 29}, many of which include the potential for impacts to the head.

96

97 There is general agreement in the available literature that head injuries
98 contribute to a considerable proportion of the overall injury rate, with
99 approximately 16% of all time-loss injuries in the elite game ³⁰. In community
100 rugby, head injuries account for 24% of all medical attendance injuries ²⁷ and
101 12 ²⁵ to 16% ¹⁸ of all time-loss injuries (one week or greater absence from match
102 play). Of all head injuries, concussion is the most commonly reported diagnosis
103 ^{4, 18}. While there are numerous studies which provide information on head
104 injuries and concussion in the elite men's game ^{1, 2, 4, 5, 7, 14}, there is only limited
105 information available in community rugby union. In a recent meta-analysis of
106 concussion in rugby union, only three studies from below the elite level
107 considered to report incidence according to appropriate methodological
108 standards were included to return a mean of 2.08 concussions per 1000 player
109 match hours ¹¹. Although some community level studies have reported the
110 overall incidence of head injuries with limited information for injury diagnosis,
111 there is no literature available which presents more detailed information such

112 as the severity and the match events specifically associated with head injuries
113 at this level of rugby. It should also be considered that there is a considerable
114 range of playing standards within men's community rugby and therefore
115 differentiation between these levels is warranted.

116

117 Previous studies have investigated the propensity for specific contact events to
118 cause injury in both elite ⁹ and community level rugby ²⁶. These studies
119 demonstrated that illegal tackles returned the highest injury risk per event but
120 also that (legal) tackles accounted for the greatest loss of match time ^{9, 26}.
121 However, information was only reported for all injury diagnoses combined and
122 therefore the community match play contact event with the greatest risk for
123 head injury is yet to be determined.

124

125 The primary aim of this study was to investigate the incidence, nature and
126 severity of time-loss head injuries in community rugby union match play, with
127 particular reference to concussion. A secondary aim was to determine the risk
128 of head injury for specific match events.

129

130 **METHODS**

131

132 **Participants**

133 Senior male first team squads at English community-level clubs participating in
134 the Rugby Football Union (RFU) league structure within playing levels 3-9 were
135 invited to participate in the study. Player demographics for the playing
136 population are presented in Table 1. Data were collected over six seasons
137 [2009/10, n=46 clubs (61 clubs at start of season); 2010/11, n=67 (90 clubs at
138 start of season); 2011/12, n=76 clubs (104 clubs at start of season); 2012/13,
139 n=50 club (106 clubs at the start of the season); 2013/14, n=67 (120 clubs at
140 the start of the season); 2014/15, n=58 (102 clubs at the start of the season)].
141 Each season, some clubs dropped out from the study if staff left the club or
142 decided to discontinue with data collection during the season. All matches were
143 played over the normal English rugby union season, lasting between
144 September and the following April. To facilitate comparisons across playing
145 levels, clubs were classified as 'Semi-professional' at RFU levels 3 and 4, the
146 highest level of English community rugby; 'Amateur' at RFU levels 5 and 6; and
147 'Recreational' at RFU levels 7, 8 and 9. It is accepted that these definitions are
148 approximate and there will be varied practice/approaches across clubs. Having
149 been provided with information about the study, individual players could opt-out
150 from participation by informing club medical staff who omitted information on
151 that player. Injury management staff did not provide any details of players who
152 opted out. The study had institutional ethics approval.

153

154 INSERT TABLE 1 NEAR HERE

155

156 **Injury reporting**

157 Injury management staff (holding an accredited sports therapist qualification as
158 a minimum) at participating clubs completed and returned injury forms. Any
159 head injury incurred during a first team match resulting in an absence from
160 participation in match play for one week or more from the day of the injury was
161 defined as a “time-loss” head injury. This time-loss definition was used because
162 in most community level teams, the players have infrequent contact with their
163 injury management staff which may compromise the reporting of injuries of less
164 than one week. For the purposes of the current study, concussions were
165 reported by the club injury manager based on their own understanding and
166 diagnosis of a concussion. The date of the first match following the injury on
167 which the player was fit enough to be available for selection (whether or not he
168 actually played) was recorded as the return to play date, and injury severity was
169 defined by the number of weeks missed. Therefore, the least severe injuries
170 are ‘moderate’ (8-28 days absence) according to the consensus statement for
171 injury definitions and data collection procedures for studies of injuries in rugby
172 ¹⁰. Guidelines for the return to play protocols following concussion, throughout
173 the data collection period, are included in Table 2.

174

175 INSERT TABLE 2 NEAR HERE

176

177 For all time-loss injuries, information was recorded on the type, injury event,
178 treatment, time of injury and severity (number of weeks missed through injury)
179 using a standard report form. Details on the type of injury were recorded using

180 the Orchard Sports Injury Classification System version 8²³ by the injury
181 management personnel in discussion with the player with regard to the inciting
182 event. For 0.5% of all injuries, the inciting event was unknown. Only head
183 injuries incurred during match play at the participating clubs were recorded and
184 therefore absences from match play due to injuries incurred through any other
185 activity (including rugby training) were not included.

186

187 **Match Analysis**

188

189 Footage from 30 community rugby matches (10 matches from each group)
190 filmed over seasons 2009/10, 2010/11 and 2011/12, was analysed to determine
191 mean values for the number of contact events occurring within match play at
192 the playing levels described for this study. This match footage was obtained
193 from the same playing levels as those from which the injuries were reported but
194 the specific matches were not related. This analysis was made with the purpose
195 of combining the number of injuries and values for the mean number of contact
196 events per match to determine values for the risk of injury per contact event.

197

198 Matches were filmed from an elevated position using one video camera (Sony
199 DCR-TRV900E, Japan) mounted on a tripod. The ball was kept in the centre of
200 the view with an approximate radius of 10 m. Match footage was captured to
201 analysis software (SportsCode Pro 7.0.150, Sportstec, Australia). Every
202 contact event (tackle: tackler stops the progress of the ball carrier with the use
203 of his arms; (illegal) collision tackle: tackler stops the progress of the ball carrier
204 without the use of his arms; ruck: one or more players from each team

205 contesting with the ball on the ground; maul: ball carrier in contact with at least
206 two other players on their feet; lineout: a minimum of two players from each
207 team contesting a ball thrown in by one team to re-start play and scrum: eight
208 players from each team pushing against each other in a crouched position and
209 contesting the ball fed in by one team to re-start play) was identified and
210 recorded.

211

212 **Data Analysis**

213 Playing positions were grouped as forwards and backs, then subdivided into
214 front row (props and hooker), second row, back row (flankers and No. 8), scrum
215 halves, inside backs (fly half and centres) and outside backs (wingers and full
216 backs). Data were combined for all seasons. Injury incidence was recorded as
217 the number of injuries per 1000 player hours of match exposure. Player hours
218 of match exposure was calculated by the number of matches x number of
219 players per team x match duration (hours).

220

221 For the propensity (risk per event) calculations, the total number of match play
222 contact events (over the 8797 matches from which the injury data was reported)
223 was estimated by multiplying the mean number over the 30 recorded matches
224 by the number of matches (8797). In addition, the number of injuries was
225 multiplied by 1.93 to account for the fact that two teams were always exposed
226 to the risk of injury from the contact events (which would have resulted in a
227 multiplication factor of 2), but on a small number of occasions two participating
228 teams within this study played each other and therefore the injuries for both
229 teams would be reported ²⁶. Propensity of a contact event to cause a head

230 injury was therefore expressed as the number of injuries for each type of
231 contact per 1000 events.

232

233 Differences between groups were determined using a two-tailed Z test for
234 comparison of rates. Differences were deemed to be statistically significant if P
235 ≤ 0.05 , and 95% confidence intervals (CI) were recorded for calculated
236 variables. Player demographic data was non-normally distributed with unequal
237 group sizes and therefore differences between groups were determined using
238 the Kruskal-Wallis-test with post-hoc analysis using the Mann-Whitney test.

239

240 **RESULTS**

241 **Overall incidence and severity**

242 In total, 8797 team games were included in this study, with a mean of 24 games
243 per club per season. Overall, there was a total of 427 head injuries over 175,940
244 hours of player match exposure. For Semi-professional, Amateur and
245 Recreational playing levels, there were 38,120 (1906 matches), 62,200 (3110
246 matches) and 75,620 (3781 matches) player match hours resulting in 88, 173
247 and 166 injuries, respectively. The overall incidence of time-loss head injuries
248 was 2.43 injuries per 1000 player match hours and was higher for Amateur
249 (2.78; 95% CI 2.37-3.20) compared with Recreational (2.20; 95% CI 1.86-2.53;
250 $P = 0.032$) playing levels and neither were different to Semi-professional (2.31;
251 95% CI 1.83-2.79) playing levels. (Table 3). There were 256 reported
252 concussions with an overall incidence of 1.46 injuries per 1000 player match
253 hours with no difference between playing levels (Table 3). The mean number
254 of weeks missed per head injury for all playing levels combined was 4.8 (95%
255 CI 4.3 to 5.2) (median of 3) for all head injuries, and 3.6 (95% CI 3.2 to 4.0)
256 (median of 3) weeks for concussions. There was no difference between playing
257 levels for the number of weeks missed due to all head injuries or concussions.
258 Of all reported concussion injuries, 24% returned after two weeks, 35%
259 returned after three weeks and 35% of cases missed more than 3 weeks. No
260 return to play date was reported for 6% of all concussions. There was one head
261 injury in every 21 team games, or every 10 matches involving two teams. There
262 was one concussion in every 34 team games or one in every 17 matches. There
263 was a higher incidence in season 2014/15 compared with all other seasons for
264 both all head injuries and concussions (all $P < 0.05$) and in 2013/14 compared

265 with 2011/12 for all head injuries ($P = 0.038$) and compared with 2010/11 for
266 concussions ($P = 0.023$) (Table 4).

267

268 TABLE 3 NEAR HERE

269 TABLE 4 NEAR HERE

270

271 **Injury diagnoses**

272 Concussion was the most commonly reported time-loss head injury, accounting
273 for 60% of all head injuries, followed by fractures (15%) and then
274 lacerations/abrasions (12%) (Table 5). The most severe injuries (i.e. those
275 resulting in the highest mean number of weeks missed) were fractures. When
276 combining the incidence of injuries and weeks missed (injury burden), 5.2 and
277 3.5 weeks per 1000 player match hours were missed for concussion and
278 fractures, respectively. For 88% of all time-loss head injuries, the player was
279 removed from play at the time of the injury, while players diagnosed with
280 concussion were removed at the time of injury for 90% of injuries. Four percent
281 of all concussions were reported as recurrences of previous concussion injuries
282 although the time delay between the injuries was not available for analysis.

283

284 TABLE 5 NEAR HERE

285

286 **Injury event**

287 All head injuries were attributed to contact events. In total, 64% were sustained
288 in the tackle (1.56 injuries per 1000 player match hours; 95% CI 1.38-1.75),

289 including both being tackled (0.60, 95% CI 0.49 to 0.72) and tackling another
290 player (0.78, 95% CI 0.65 to 0.91), along with illegal collision tackles (0.18, 95%
291 CI 0.12 to 0.24). Foul play, including punching, head butting and eye gouging,
292 was associated with 11% of head injuries. Most concussions were associated
293 with, tackling (38%) and being tackled (36%) (both legal and illegal collision
294 tackles).

295

296 **Player position**

297 There was no difference between forwards and backs in the incidence of either
298 all head injuries (forwards: 2.63, 95% CI 2.30 to 2.96; backs 2.19, 95% CI 1.87
299 to 2.51) or concussions (forwards: 1.48, 95% CI 1.24 to 1.73; backs 1.42, 95%
300 CI 1.17 to 1.68). For specific positional groups, back row forwards (3.47, 95%
301 CI 2.85 to 4.08) incurred a higher incidence of any head injury compared with
302 front rows (2.19, 95% CI 1.70 to 2.86; $P = 0.002$), second rows (2.05, 95% CI
303 1.47 to 2.63; $P = 0.002$), inside backs (2.07, 95% CI 1.60 to 2.55; $P < 0.001$)
304 and outside backs (2.27, 95% CI 1.78 to 2.77; $P = 0.001$). Back row forwards
305 (2.05, 95% CI 1.57 to 2.52) also incurred significantly more concussions
306 compared with front row forwards (1.14, 95% CI 0.78 to 1.49; $P = 0.003$),
307 second row forwards (1.15, 95% CI 0.72 to 1.59; $P = 0.003$) and inside backs
308 (1.22, 95% CI 0.86 to 1.59; $P = 0.008$).

309

310 **Timing of injuries**

311 There were significantly fewer head injuries in the 1st and 3rd match quarters,
312 compared with the 2nd and 4th quarters (Table 6). There were also fewer
313 concussions in the 1st match quarter compared with the 2nd and 4th quarters.

314 There was no difference in the severity of injuries between different match
315 quarters. There was no difference in the incidence of concussions over the
316 course of the season.

317

318 TABLE 6 NEAR HERE

319

320 **Risk of injury by match contact event**

321 There was an overall injury risk of 0.25 injuries per 1000 contact events and a
322 significantly greater risk in Amateur matches (0.29 injuries per 1000 events;
323 95% CI 0.26 to 0.32) compared with Semi-professional (0.22 injuries per 1000
324 events; 95% CI 0.19 to 0.26; P = 0.008) but no difference compared with
325 Recreational (0.25 injuries per 1000 events 95% CI 0.22 to 0.28). The overall
326 risk of concussion per contact event was 0.15 concussions per 1000 contact
327 events, with no difference between the different playing levels.

328

329 For all groups combined, the propensity for a contact event to result in injury
330 was greatest for collision tackles (Table 7) at 4.90 head injuries per 1000
331 collisions tackles with the risk being highest for the tackled player in the
332 collision. There was a significantly greater risk of injury per legal tackle
333 compared with all other contact events (apart from collision tackles) but the risk
334 was not different for the tackled or tackling player (Table 7).

335

336 TABLE 7 NEAR HERE

337

338 **DISCUSSION**

339 We investigated the incidence, severity and nature of time-loss head injuries in
340 community-level rugby with a specific focus on concussion injuries. The
341 incidence of match-related time-loss head injuries of 8 days or greater absence
342 was found to be 2.43 per 1000 player match hours (12% of all injuries), with a
343 mean severity of 4.8 weeks absence. Reported concussions accounted for 60%
344 (1.46 per 1000 player match hours) of all time-loss head injuries with a mean
345 of 3.6 weeks absence. Most head injuries were incurred in the tackle, with the
346 illegal collision tackle in particular, being the highest risk contact event in terms
347 of injuries per event.

348

349 The overall incidence of 2.43 head injuries per 1000 player match hours in the
350 current study is comparable with that of 1.7 per 1000 players hours in Australian
351 amateur grade rugby²⁰ but lower than previous studies reporting head injuries
352 in professional¹⁶ and international rugby³⁰. This finding supports the largely
353 accepted view that in rugby union, overall injury rates are higher for higher
354 playing levels^{3, 22, 25}; a pattern which was also identified previously between
355 playing levels in English community rugby for both overall time-loss²⁵ and
356 match play medical attention injuries²⁷. While these different injury patterns
357 have been attributed to a greater frequency^{9, 26} and intensity of contact events
358 in higher-level rugby³, in the current study there was a higher incidence of time-
359 loss head injuries in Amateur compared with Semi-professional playing levels
360 despite there being fewer contact events during the match. This finding may be
361 due in part to players at a higher level having greater technical proficiency in

362 the tackle, better physical conditioning, and possibly better access to medical
363 support to facilitate an earlier return to play.

364

365 The most common head injury diagnosis in the current study was concussion,
366 accounting for 60% of all head injuries and an incidence of 1.46 per 1000 player
367 match hours. This incidence is slightly lower compared with other community
368 rugby studies with equivalent concussion time-loss injury definitions of 2.2 ²⁹
369 and 1.7 ¹⁸ but higher than another study for male senior players reporting 0.8
370 per 1000 player match hours ²⁰. In a study of Australian non-professional
371 players, concussion (defined as mild Traumatic Brain Injury) was shown to be
372 7.97 per 1000 player game hours when the definition included non time-loss
373 injuries ¹². The variation in concussion incidence in studies of community rugby
374 can be attributed to a number of factors including the diverse levels of play,
375 variations in the medical support provided to players between studies and the
376 concussion definition ¹¹.

377

378 It is likely that the concussion incidence in the current study is a minimum
379 estimate with the possibility that these injuries are under-reported in community
380 rugby union through lack of player awareness and/or unwillingness of players
381 to report symptoms to club staff. Evidence for this includes a study of 172
382 players who were asked to retrospectively self-report sustained concussions
383 over a season, with 45% reporting at least one concussion ⁶. However, only
384 47% of these concussions were reported to club medical staff, suggesting that
385 data collected in prospective studies that rely on data capture by medical staff

386 are prone to under-reporting of this specific injury. A previous study has shown
387 that compliance with return to play regulations was low in community rugby
388 union players ¹³ and therefore it cannot be discounted that for some players,
389 the concussion may have been recognised but that the player returned to play
390 in the next match. We have shown previously that the incidence of match play
391 medical attendances for head laceration, contusion and neural injuries
392 combined was 45 attendances per 1000 player hours ²⁷. This finding is
393 noteworthy in the current context because it demonstrates a large discrepancy
394 between the incidence of seemingly minor (usually non time-loss) injuries and
395 those injuries captured in the current study (eight days or greater absence),
396 thus highlighting the fact that pitch side medical staff should be vigilant to the
397 signs of concussion. It should also be considered that in some cases, the
398 outward signs of injuries such as lacerations or fractures may conceal the less
399 obvious signs of neurological disturbance related to concussion.

400

401 Incidence of reported concussion in professional rugby has increased in recent
402 seasons (5.1 per 1000 match hours in 2011/12 to 10.7 per 1000 match hours
403 in 2013/14) ¹⁷, and this has been largely attributed to increased awareness of
404 issues surrounding concussion ⁵. Concussion incidence in the most recent
405 season of the current study was significantly higher than all earlier seasons and
406 coincides with recent media interest and increased educational activity through
407 the RFU 'Headcase' programme, which was launched in January 2013 to
408 promote concussion education and resources across all levels of the English
409 game ²⁴. Given the raised level of awareness, this finding is most likely to be
410 due to better understanding and diagnosis by both players and medical staff,

411 for example, the player not having to lose consciousness to be diagnosed.
412 While it is possible that a change in the physical demands of the game may
413 also be responsible for an increased concussion risk, this explanation is more
414 difficult to assess given that there is no evidence to support a change in the
415 match demands at this level of rugby over one season. Ongoing work will be
416 required to identify whether incidence of reported concussion continues to
417 increase in future seasons and should try to determine whether this is due to
418 greater awareness or changes in the risk associated with playing the game.

419

420 The overall mean of 3.6 weeks missed and 3 weeks or more absence for 70%
421 of concussions in the current study relates closely to the recommended stand
422 down time of three weeks mandated by the International Rugby Board (the
423 international federation for rugby, now World Rugby) until 2010. Another 24%
424 of all concussed players returned after two weeks (14 days) which is feasible
425 within the regulations in force for much of the current study period which
426 permitted the player to return at any point if they were symptom free and had
427 followed the graduated return to play protocol ¹⁹. However guidelines
428 introduced in March 2014 ²⁴ state that the earliest that an adult player can return
429 to play is 19 days following the concussion unless the player has access to an
430 enhanced care setting which is normally only available to professional players.
431 Therefore, it would be expected that in future seasons, the proportion of
432 community level players returning to play in less than 19 days will be small.
433 Ongoing work will assess whether concussion education programmes such as
434 the 'Recognise and remove' campaign promoted through RFU Headcase ²⁴ and

435 World Rugby Player Welfare ¹⁵ influence both the incidence and the duration of
436 player absences for concussion in future seasons.

437

438 The tackle was the primary contact event associated with head injuries and
439 specifically concussions, which is a common finding in the literature ^{3, 18}. This
440 is not surprising given that this is also the most common contact event during
441 match play ²⁶, but our analysis also shows that the risk of injury per tackle
442 (injuries per 1000 events) was higher than any other contact event. It is beyond
443 the scope of the current study to identify which specific aspects of the tackle
444 result in head injury but a previous study showed that head/neck injuries in elite
445 level players were most likely when this was the principal site of contact in the
446 tackle ⁸ and particularly when the tackler's head contacted the ball carrier's
447 lower leg ²¹. These findings suggest that players adopting the appropriate head
448 position in the tackle (to the side, allowing shoulder to make contact) should be
449 an effective measure for reducing the risk of head injuries ²¹. It is of note that
450 by far the greatest risk of head injury per event in the current study was
451 specifically for ball carriers in collision tackles, which are instances when the
452 tackling player stops the ball carrier without use of the arms. These tackles are
453 illegal, and our data highlight the need for strict officiating in relation to these
454 high risk events. Using a sample of 30 matches to estimate the number of
455 match events for all matches may potentially to introduce some bias. However
456 it would be expected that this sample provides an acceptable representation of
457 match events at this level of community rugby given that the confidence
458 intervals for all contact events were small for all groups combined and were

459 sufficient to show differences between playing levels (Supplementary Data:
460 Table 9).

461

462 Conclusions

463 This study shows that concussions account for the majority of time-loss head
464 injuries in English community rugby. Concussion regulations introduced at the
465 end of the currently studied period state that the minimum stand down period
466 for a player outside of the enhanced care setting is now 19 days and therefore
467 future studies should demonstrate a substantial reduction from the 26% of
468 players returning within this period in the current study. Given that the current
469 incidence is likely to be a minimum estimate and the potential short, medium
470 and long-term neurological implications for repeated concussion injuries,
471 continued education for medical staff, coaches and players on the identification
472 and management for head injuries, particularly concussion, is essential. With
473 most head injuries associated with the tackle, good technique in this event may
474 be effective in reducing these injuries.

475

476

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565 **TABLES**

566

567 Table 1. Player demographics (mean, range and number) for participants at different

568 playing levels. Values are derived from only seasons 2012/13 – 2014/15

569

Level	Age	Mass	Height
All Players	25.8 (17-55) (n=2916)	94.2 (56-154) (n=3629)	182.0 (150-213) (n=3676)
Semi-professional	24.7 ^{ab} (17-41) (n=420)	96.7 ^{bd} (69-145) (n=499)	183.4 ^{be} (158-212) (n=495)
Amateur	25.6 ^c (17-46) (n=1042)	95.1 ^b (56-154) (n=1209)	181.8 (150-210) (n=1255)
Recreational	26.3 (17-55) (n=1454)	93.1 (56-150) (n=1921)	181.8 (150-213) (n=1926)

570

571 ^aP = 0.007 *versus* Amateur; ^bP < 0.001 *versus* Recreational; ^cP = 0.025 *versus*

572 Recreational; ^dP = 0.005 *versus* Amateur; ^eP < 0.001 *versus* Amateur.

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580 Table 2. Return to play guidelines following a concussion throughout the study data

581 collection period

Date	Guidelines
Until 2010	International Rugby Board* recommended a three-week stand down period
2010 to March 2014	International Rugby Board did not prescribe a stand down period and every case was judged on its own merits with GRTP (Graduated Return to Play) started once the player was symptom free. Therefore a player could have returned within 6 days.
March 2014 to present	Any player outside of the enhanced care setting (accounting for the vast majority of community level players) could not return to play in less than 19 days.

582 *Now World Rugby

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586 Table 3. Number of injuries, incidence and severity of injuries for all groups
587 combined and for each playing group. *Incidence per 1000 player match hours
588 (95% CI).

	Total Number of Injuries	Incidence* (95% CI)	Severity (Weeks Missed) (95% CI)
Head Injuries			
All Players	427	2.43 (2.20-2.66)	4.8 (4.3-5.3)
Semi-professional	88	2.31 (1.83-2.79)	4.2 (3.4-5.2)
Amateur	173	2.78 (2.37-3.20) ^a	5.2 (4.5-6.1)
Recreational	166	2.20 (1.86-2.53)	4.6 (3.9-5.3)
Concussion			
All Players	256	1.46 (1.28-1.63)	3.6 (3.2-4.0)
Semi-professional	62	1.63 (1.22-2.03)	3.3 (2.6-4.3)
Amateur	98	1.58 (1.26-1.89)	3.8 (3.1-4.6)
Recreational	96	1.27 (1.02-1.52)	3.5 (2.9-4.3)

589

590 ^aP = 0.032 *versus* Recreational

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594 Table 4. Number and incidence of all head injuries and concussions over the
 595 six seasons with all playing levels combined. Incidence per 1000 player match
 596 hours (95% CI).

Season	Total match exposure	All head injuries		Concussion	
		Number	Incidence (95% CI)	Number	Incidence (95% CI)
2009/10	22,540	44	1.95 (1.45-2.62)	25	1.11 (0.75-1.64)
2010/11	33,060	70	2.12 (1.68-2.68)	32	0.97 (0.68-1.37) ^b
2011/12	37,100	74	1.99 (1.59-2.51) ^a	51	1.37 (1.04-1.81)
2012/13	24,040	50	2.08 (1.58-2.74)	25	1.04 (0.70-1.54)
2013/14	32,180	89	2.77 (2.25-3.40)	52	1.62 (1.23-2.12)
2014/15	27,020	100	3.70 (2.98-4.43) ^c	71	2.63 (2.02-3.24) ^c

597

598 ^aP = 0.038 and ^bP = 0.023 *versus* 2013/14. ^cP < 0.05 *versus* all other seasons.

599

600 Table 5. The number of injuries, incidence and severity of different injury
 601 diagnoses. *Incidence per 1000 player match hours (95% CI).

Diagnosis	Number (% of all head injuries)	Incidence* (95% CI)	Mean severity (weeks missed) (95% CI)
Concussion	256 (60)	1.46 (1.28-1.63) ^a	3.6 (3.2-4.0)
All fractures	62 (15)	0.35 (0.26-0.44) ^{bcd^e}	9.8 (7.6-12.6)
<i>Nose fracture</i>	23 (5)	0.13 (0.08-0.18)	5.5 (3.6-8.2)
<i>Skull fracture</i>	2 (1)	0.01 (0.00-0.03)	8.0 (2.0-32.0)
<i>Mandible fracture</i>	9 (2)	0.05 (0.02-0.08)	16.5 (8.6-31.7)
<i>Maxilla, zygoma, orbit frac</i>	24 (6)	0.14 (0.08-0.19)	10.4 (7.0-15.5)
<i>Unspecified fracture</i>	4 (1)	0.02 (0.00-0.04)	19.1 (6.2-59.1)
Lacerations/abrasions	53 (12)	0.30 (0.22-0.38) ^{bcd^e}	5.5 (4.2-7.2)
Bruising	18 (4)	0.10 (0.06-0.15)	3.7 (2.3-5.9)
Eye injury	16 (4)	0.09 (0.05-0.14) ^{d^e}	3.5 (2.1-5.7)
Jaw dislocation/sprain	5 (1)	0.03 (0.00-0.05)	3.5 (1.5-8.4)
Dental	7 (2)	0.04 (0.01-0.07)	8.8 (4.2-18.5)
Other head Injuries	10 (2)	0.06 (0.02-0.09)	2.7 (1.3-5.7)

602
 603 ^aP < 0.001 *versus* all other diagnoses; ^bP < 0.001 *versus* bruising; ^cP < 0.001
 604 *versus* eye injury; ^dP < 0.001 *versus* jaw dislocation/sprain; ^eP < 0.001 *versus*
 605 dental.
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608 Table 6. The number and severity of all time-loss head injuries combined and
 609 concussion injuries associated with match quarter.

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Match quarter	All head injuries		Concussion	
	Incidence (95% CI)	Severity (Weeks Missed) (95% CI)	Incidence (95% CI)	Severity (Weeks Missed) (95% CI)
0-20	1.68 (1.30-2.07)	5.9 (4.7-7.4)	1.05 (0.74-1.35)	3.8 (2.8-5.1)
21-40+	2.73 (2.24-3.22) ^{ab}	4.2 (3.6-5.1)	1.57 (1.20-1.94) ^c	3.3 (2.6-4.2)
41-60	2.07 (1.64-2.49)	4.5 (3.7-5.5)	1.23 (0.90-1.56)	3.5 (2.7-4.6)
61-80+	2.77 (2.28-3.27) ^{ab}	4.8 (4.0-5.7)	1.68 (1.30-2.07) ^c	3.8 (3.1-4.8)
Unknown	0.45 (-.26-0.65)	4.5 (2.9-6.9)	0.30 (0.13-0.46)	2.8 (1.7-4.9)

611 ^aP < 0.001 *versus* 0-20; ^bP < 0.05 *versus* 41-60; ^cP < 0.05 vs 0-20

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618 Table 7. Incidence of head injuries per 1000 contacts events for all groups
619 combined.

	Injuries per 1000 events (95% CI)	
	All Head injuries	Concussion
All match contact events	0.25 (0.24-0.27)	0.15 (0.14-0.17)
All tackles (legal & collision)	0.33 (0.30-0.37)	0.29 (0.26-0.32)
All tackles (legal)	0.29 (0.26-0.32) ^{bcde}	0.27 (0.24-0.30) ^{bcde}
<i>Tackled (legal)</i>	0.17 (0.14-0.19) ^{bcdef}	0.12 (0.10-0.14) ^{bcde}
<i>Tackling (legal)</i>	0.21 (0.19-0.24) ^{bcdef}	0.15 (0.13-0.17) ^{bcde}
All collision tackles	4.90 (3.82-6.29) ^a	2.45 (1.72-3.48) ^a
<i>Collision tackled</i>	4.44 (3.42-5.77) ^{bcde}	2.14 (1.47-3.12) ^{bcde}
<i>Collision tackling</i>	0.46 (0.20-1.04) ^{bcde}	0.31 (0.11-0.83) ^{bcde}
Ruck	0.09 (0.07-0.11) ^{defg}	0.05 (0.04-0.07) ^{defg}
Maul	0.08 (0.05-0.12) ^{defg}	0.02 (0.01-0.05) ^{efg}
Scrum	0.03 (0.01-0.06) ^{fg}	0.01 (0.00-0.03) ^{fg}
Lineout	0.01 (0.00-0.04) ^{fg}	0.00 (0.00-0.00) ^{fg}

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621 ^aP < 0.001 *versus* all other events; ^bP < 0.001 *versus* ruck; ^cP < 0.001 *versus*622 maul; ^dP < 0.001 *versus* scrum; ^eP < 0.001 *versus* lineout, ^fP < 0.001 *versus*623 all types of collision tackles; ^gP < 0.001 *versus* all types of tackles

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627 **Supplementary Data:** Table 8. The number and severity of all time-loss head
 628 injuries combined and concussion injuries associated with specific match
 629 events.

Event	Number (% of all head/concussion injuries)	Incidence	Mean severity (Weeks missed) (95% CI)
All head injuries combined			
All tackles (legal & collision)	275 (64)	1.56 (1.38-1.75)	4.6 (4.1-5.2)
All Tackles (legal)	243 (57)	1.38 (1.21-1.55)	4.5 (4.0-5.1)
<i>Tackled</i>	106 (25)	0.60 (0.49-0.72) ^{bcd}	4.5 (3.7-5.4)
<i>Tackling</i>	137 (32)	0.78 (0.65-0.91) ^a	4.6 (3.9-5.4)
All collision tackles	32 (8)	0.18 (0.12-0.24)	5.4 (3.8-7.6)
<i>Tackled collision</i>	29 (7)	0.16 (0.10-0.22)	4.8 (3.3-6.9)
<i>Tackling collision</i>	3 (1)	0.02 (0.00-0.04)	11.0 (3.5-34.1)
Accidental Collision	29 (7)	0.16 (0.10-0.22)	3.1 (2.1-4.4)
Ruck/Maul	54 (13)	0.31 (0.23-0.39)	5.0 (3.8-6.6)
Punched	35 (8)	0.20 (0.13-0.26)	6.9 (5.0-9.6)
Concussion			
All tackles (legal & collision)	187 (73)	1.06 (0.91-1.22)	3.7 (3.2-4.2)
All Tackles (legal)	171 (67)	0.97 (0.83-1.12)	3.7 (3.2-4.3)
<i>Tackled</i>	77 (30)	0.44 (0.34-0.54) ^{bcd}	3.9 (3.1-4.8)
<i>Tackling</i>	94 (37)	0.53 (0.43-0.64) ^{bcd}	3.6 (3.0-4.4)
All collision tackles	16 (6)	0.09 (0.05-0.14)	2.9 (1.8-4.8)
<i>Tackled collision</i>	14 (6)	0.08 (0.04-0.12)	2.9 (1.7-4.9)
<i>Tackling collision</i>	2 (1)	0.01 (0.00 – 0.03)	3.0 (0.8-12.0)
Accidental Collision	14 (6)	0.08 (0.04-0.12)	3.5 (2.1-6.0)
Ruck/Maul	29 (11)	0.16 (0.10-0.22)	3.7 (2.6-5.4)
Punched	10 (4)	0.06 (0.02-0.09)	3.3 (1.8-6.1)

630

631 ^aP < 0.001 versus all other events; ^bP < 0.001 versus collision; ^cP < 0.001
 632 versus ruck/maul; ^dP < 0.001 versus punched.

633

634 **Supplementary data:** Table 9. Number of contacts events per match.

	Events per match (Mean ± 95% CI)
All Groups - All events	370.1 (363.8-377.6)
<i>Group A - All events</i>	399.3 (387.1-411.9) ^a
<i>Group B - All events</i>	374.0 (362.2-386.2) ^b
<i>Group C - All events</i>	338.7 (327.5-350.3)
All tackles (legal & collision)	142.3 (138.1-146.6)
All tackles (legal)	140.9 (136.7-145.2)
All collision tackles	1.4 (1.1-1.9)
Ruck	115.0 (111.2-118.9)
Maul	23.4 (21.7-25.2)
Scrum	32.2 (30.2-34.3)
Lineout	25.6 (23.9-27.5)

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636 ^aP < 0.05 *versus* Group B and Group C; ^bP < 0.001 *versus* Group C.

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