

Changes in northern hemisphere male international rugby union players' body mass and height between 1955 and 2015

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ABSTRACT

Objectives We sought to establish the effects of professionalism, which officially began in 1995, on the body mass and height of northern hemisphere male international rugby union (RU) players. We hypothesised that mass would significantly increase following professionalism. We also investigated the changes in size of players according to their playing position, and we compared changes to rugby league (RL) players and the public.

Methods The body mass and height of players representing their international team for that country's first game of the Five Nations in 1955, 1965, 1975, 1985 and 1995 and, for 2005 and 2015, the Six Nations, were collected from matchday programmes. RL players' data were collected from the Challenge Cup final games played in the same years.

Results International RU player body mass has significantly increased since 1995. In 1955 mean (\pm SD) player body mass was 84.8 kg (\pm 8.2); in 2015, it was 105.4 kg (\pm 12.1), an increase of 24.3%. Between 1955 and 2015, the body mass of forwards increased steadily, whereas that of backs has mostly gone up since 1995. RU player body mass gain has exceeded that of RL, but the age-matched difference between RU players and the public has remained relatively constant.

Conclusions The factors influencing the gain in body mass of rugby players are legion; however, we believe that the interpretation of the law relating to the scrum put-in and changes allowing substitutions have, at least in part, contributed to the observed changes. Injury severity is increasing, and this may be linked to greater forces (caused by greater body mass) occurring in contact. RU law makers should adjust the rules to encourage speed and skill at the expense of mass.

INTRODUCTION

Isaac Newton's Second Law of Motion states that force applied is the product of mass and acceleration. In rugby union (RU), a sport in which words such as 'hit', 'collision' and 'smash' are commonly used to describe contact between players, these equations are important. Most humans cannot significantly increase their maximum running speed or their acceleration, but it is possible to modify

What are the new findings from this study?

- There has been a significant increase in the body mass of male international northern hemisphere rugby union players since the game officially turned professional in 1995.
- Forwards have steadily become heavier between 1955 and 2015, whereas almost all the weight gain observed in backs has occurred since 1995.
- In certain positions, for example, second row and hooker, changes in the laws of the game and refereeing interpretations appear to have driven changes in body size and/or shape.

body mass. Rugby players appear to be getting bigger although the extent to which this has occurred since the game became professional has not been described previously for northern hemisphere players.¹⁻³ The forces involved when players make contact with each other are thus increasing, and many players are now fitted with global positioning system (GPS) devices and acceleration sensors during matches.⁴ Indeed, it has been suggested that players may approach contact areas without checking their speed, in order to register high G-forces on impact and perhaps impress or satisfy their coaching staff.⁵ The advantages of size in a game where players wrestle and grapple the ball from one another and attempt to cross the gain line by outpacing, outsmarting or overpowering the opposition are clear. Heavier players have greater momentum, and any advantage gained in a tackle can afford greater opportunity to continue an attacking move or regain the ball.⁶ In addition, bigger players will generate greater force in scrums where the eight forward players from each team push against each other to try to win the ball as a means of restarting the game. Although not all players in RU are primarily selected to directly engage with the opposition and carry the ball into contact or to make tackles on opponents (eg, the scrum half, traditionally thought of

as small and nimble, is at least partly employed to pass the ball from a set piece engagement of forwards to the players in the back line), it makes sense that greater body mass will limit the discrepancy.⁷

We hypothesised that since RU turned professional in 1995, player body mass would significantly increase. In addition, we compared changes in body mass in international RU players to rugby league (RL) players, which has incorporated professionalism since 1895. We also sought to characterise the changes in body mass and height according to playing position on the field.

METHODS

Data were collected from matchday programmes. For RU matches, the body mass and height of players representing their international team for that country's first game of the Five Nations in 1955, 1965, 1975, 1985 and 1995, and for 2005 and 2015, the Six Nations, were recorded. The players' names are in online supplementary appendix A. In two cases, it was not possible to obtain the matchday programme of the team's first game (1955 France vs Scotland, 2005 Italy vs Ireland) so data from the next game the team(s) were involved in were used. One player, William O'Connell of Ireland, is not listed in the international programme; another player TE Reid is listed. O'Connell only played one international game in his career, and we have not been able to obtain his anthropometric data from other sources, so we have chosen to use Reid's data instead. To address issues regarding last-minute injuries and changes to team selection after the matchday programmes had gone to print, information was cross-referenced with the ESPN Rugby Union Archive (available at: <http://en.espn.co.uk/scrum/rugby/series/index.html>) and other internet-based sources, if required. For example, in the 1975 game between England and Ireland, the programme lists Roger Uttley as starting when in fact Bill Beaumont played at short notice due to an injury to Uttley. Beaumont's details were obtained from the 1976 programme when England played Scotland.

For RL players, without a regular international event equivalent to the Five/Six Nations, we chose to collect data from the two teams who played in the Challenge Cup final in the years listed above (online supplementary appendix B). In 1955 not all the Workington Town players had body mass recorded in the final programme (Ike Southward, Bill Wookey and Bill Lymer), and it has not been possible to obtain these data from other sources. Likewise, the 1995 Challenge Cup final programme did not contain the mass or heights of the Wigan and Leeds players and neither did the semifinal programmes. The body mass values were obtained from other programmes during that or the preceding year's Super League fixtures, except for six Leeds players for whom reliable data could not be obtained. We used published data from the Health Survey for England 1993–2016 on the changes in body mass of men within a similar age range from the general

public, and the body mass of Army recruits between 1955 and 1974 were also used.^{8,9}

Statistics

GraphPad Prism V.7.00 for Windows (GraphPad Software, La Jolla, California USA, www.graphpad.com) was used for statistical analysis and graph creation. Data were checked for normality using the Shapiro-Wilk test. Repeated measures data are presented as mean and range, non-parametric data as median, IQR (box) and range (whiskers). For unpaired data, one-way analysis of variance (ANOVA) was used with post hoc Dunnett's multiple comparison test for parametric data and the Kruskal-Wallis test with Dunn's post hoc analysis for non-parametric data. Non-parametric repeated measures data were analysed using the Friedman test with Dunn's post hoc analysis. To investigate differences between adjacent Trek and Rest days, data were analysed by two-way ANOVA with Sidak's multiple comparison test. Statistical significance was set at $p < 0.05$.

RESULTS

We collected data on 516 northern hemisphere international RU players between 1955 and 1965. Nine players were counted twice (England: Johnny Williams: 1955 and 1965, Rory Underwood: 1985 and 1995, Rob Andrew: 1985 and 1995; Wales: Gethin Jenkins: 2005 and 2015; Ireland: Willie-John McBride: 1965 and 1975, Brendan Mullin: 1985 and 1995, Anthony Foley: 1995 and 2005, Paul O'Connell: 2005 and 2015; France: Phillipe Sella: 1985 and 1995).

The median age (\pm IQR) of the players in 1955 was 24.8 years (23.6–25.5), in 1965 was 25.8 years (23.4–27.9), in 1975 was 26.6 years (25.0–28.3), in 1985 was 27.1 years (24.8–29.9), in 1995 was 27.8 years (24.3–30.3), in 2005 was 27.2 years (25.3–30.5) and in 2015 was 27.1 years (24.9–29.0).

Impact of professionalism on body mass and height

The body mass of RU players has increased significantly ($p < 0.0001$) since 1995 when the game turned professional but remained steady in the four decades (1955–1985) prior to this (figure 1). The mean (\pm SD) mass of a player in 1955 was 84.8 kg (\pm 8.2) and in 2015 was 105.4 kg (\pm 12.1), an increase of 24.3%. The pattern of body mass gain over time is preserved when the data are analysed by country (figure 2). Players in 2015 were on average, heavier than players in 1955, 1965, 1975, 1985 and 1995. Further interrogation of the data show that in 1955 only one out of 75 players weighed more than 100 kg (n his player profile, it was noted that Bernard Chevalier of France had 'gained 19 lb weight in the past two seasons'); in 2015, this number had increased to 49 out of 75. Player height did not increase between 1955 and 1985 but then increased significantly from 1995 to 2015 ($p < 0.0001$). The mean (\pm SD) height of a player in 1955 was 1.80 m (\pm 0.05) and in 2015 was 1.88 m (\pm 0.07), an increase of 4.3%. Body mass index (BMI) also increased ($p < 0.0001$)

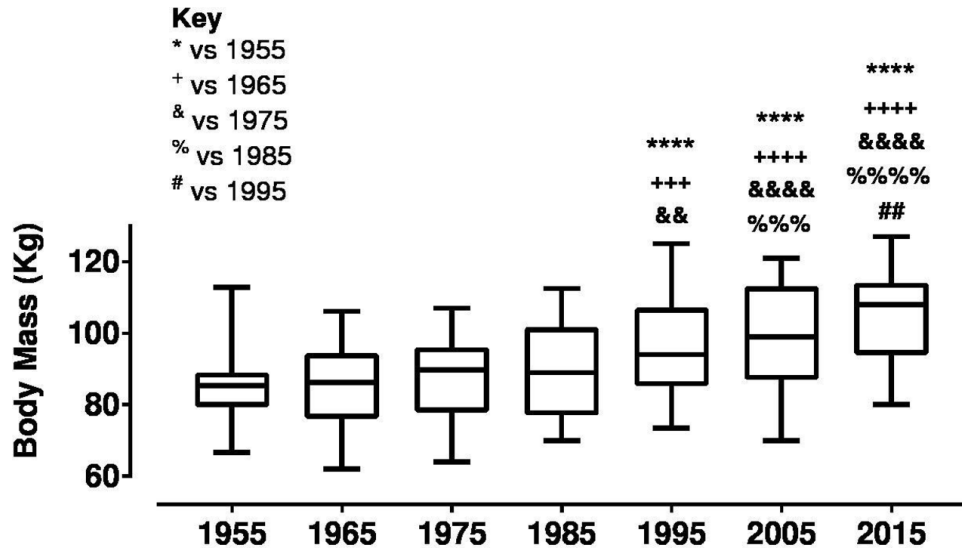


Figure 1 Median, IQR and range of body mass international rugby union players taking part in the opening matches of the Five or Six Nations tournament in 1955, 1965, 1975, 1985, 1995, 2005 and 2015 (n=75 comprising 15 players representing England, Wales, Ireland, Scotland and France). Significance levels calculated by the Kruskal-Wallis test with Dunn's post hoc analysis show p<0.01 (two icons); p<0.001 (three icons); p<0.0001 (four icons).

from 26.1 (±2.1) kg/m² in 1955 to 29.8 (±2.9) kg/m² in 2015, and this was reflected in significant changes in both forwards and backs. BMI was significantly increased between different preprofessionalism (1955–1985) and postprofessionalism (1995–2015) and significantly greater even between 1995 and 2015 (p=0.007).

Changes in body mass and height according to playing position

Interestingly, the combined body mass of the forwards (or 'pack') increased steadily during selected timeframe 1955–2015, whereas the backs body mass only started to increase in 1995 (figure 3). The average weight of the pack increased by more than 200 kg from 1955 to 2015 (711.1 kg to 912.2 kg).

Subdividing by position, certain positions (centres and hookers in particular) have gained body mass at an extraordinary rate since the game became professional (table 1). In 1955, 1965, 1975, 1985 and 1995, none of the centres weighed more than 100 kg; in 2005, one did; and in 2015 six of the centres weighed more than 100 kg. Similarly, before professionalism (1955–1985), no hookers were heavier than 100 kg, in 1995 four and in 2005 two hookers weighed more than 100 kg; in 2015 all the hookers weighed more than 100 kg.

Also, of interest is that while the mass of second row forwards has increased each decade since 1955, their height increased most in the period before professionalism between 1955 and 1995. The mass required to

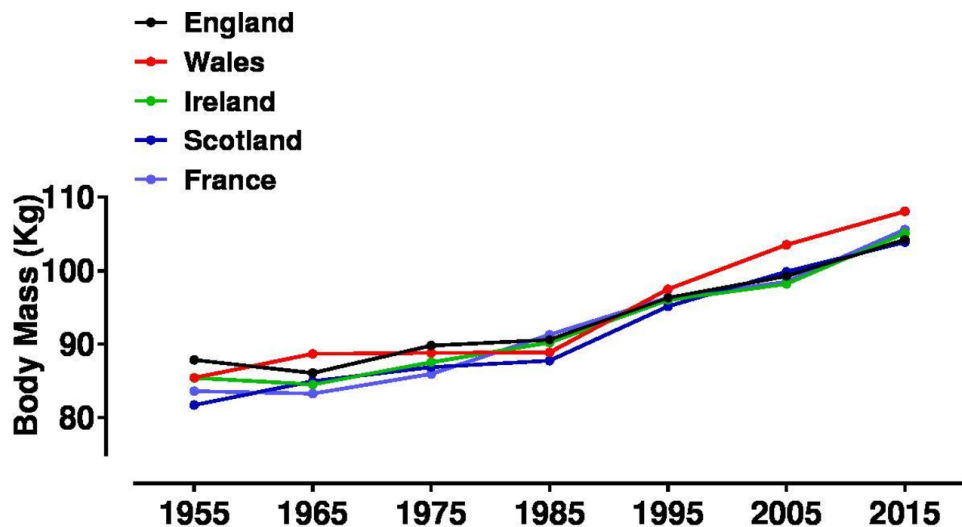


Figure 2 Mean body mass of international rugby union players taking part in the opening matches of the Five or Six nations tournament in 1955, 1965, 1975, 1985, 1995, 2005 and 2015 (n=15 at each time point comprising players representing England, Wales, Ireland, Scotland and France).

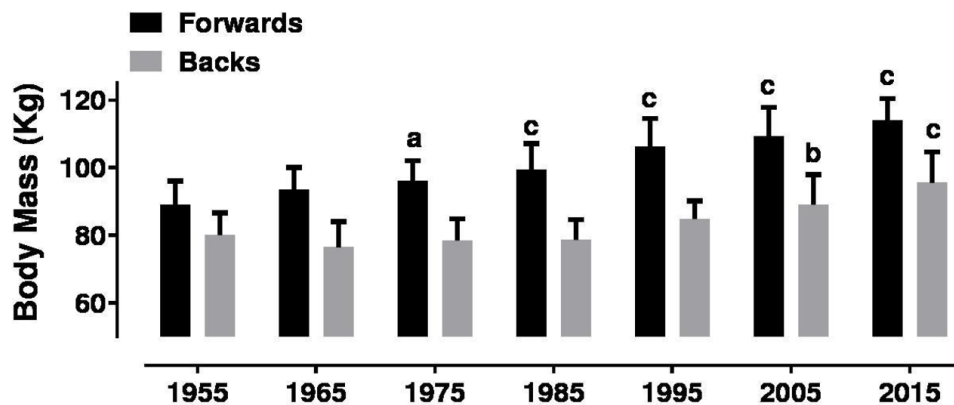


Figure 3 Mean and SD of body mass international rugby union players taking part in the opening matches of the Five or Six nations tournament in 1955, 1965, 1975, 1985, 1995, 2005 and 2015 divided according to whether they were forwards or backs (n=45 forwards and 40 backs representing England, Wales, Ireland, Scotland and France). Significance levels calculated by the Kruskal-Wallis test with Dunn's post hoc analysis compared with 1955 show: a= $p < 0.01$; b= $p < 0.001$ and c= $p < 0.0001$.

play as an international centre is reflected in comparing them with back-row forwards, because both positions exist on a similar spectrum requiring running, ball-handling and tackling skills. However, back-row players would typically be bigger, reflecting the need for greater muscular strength for them to win ball at the breakdown and enforce turnover of possession in tackles. In 1955, the average Five Nations back-row forward weighed 85.7 kg and was 1.82 m tall; by 1995, centres had overtaken this (mean mass: 86.7 kg, height: 1.83 m). The 40 years for this 'catch-up' to take place between centres and back-row players between 1955 and 1995 has been halved in the professional era. In 1995, the mean back-row player body mass was 102.7 kg (and 1.91 m tall); in 2015, centres weighed an average of 100.9 kg (although slightly shorter at 1.87 m).

Changes in body mass compared with RL players and the public

RL players have also gained body mass between 1955 and 2015 ($p < 0.0001$, figure 4) with multiple comparison tests showing significant differences between 2015 and 1955, 1965, 1975 and 1985 (all at least $p < 0.01$). The mean (\pm SD) mass of a player in 1955 was 85.9 kg (± 9.6) and in 2015 was 97.7 kg (± 7.4), an increase of 13.8%. Although RL players weighed more than RU players in 1955, RU had overtaken by 1975; however, it is only in 2015 that the body mass difference between RU and RL becomes statistically significantly ($p < 0.05$).

Comparing rugby players (RU and RL) with the average British man, it is apparent that 'normal'-sized individuals from the public would be far smaller than the average

Table 1 Mean and SD of body mass (in kilograms) and height (in metres) of international rugby union players taking part in the opening matches of the Five or Six Nations tournament in 1955, 1965, 1975, 1985, 1995, 2005 and 2015 divided by position (n=5 for hookers; n=10 for props, second rows, half-backs; n=15 for back-row, centres and back three)

Year	1955	1965	1975	1985	Change 1955-1985 (%)	1995	2005	2015	Change 1995-2015 (%)
Body mass									
Prop	90.3 (6.1)	94.9 (4.0)	97.3 (4.1)	103.4 (3.5)	14.5	106.1 (2.9)	114.2 (6.8)	116.9 (4.9)	10.2
Hooker	84.8 (7.8)	85.7 (6.5)	90.1 (4.6)	89.1 (5.7)	5.1	98.9 (5.0)	101.2 (8.2)	110.2 (3.3)	11.4
Second row	94.3 (7.5)	99.9 (3.6)	103.0 (3.6)	106.1 (4.5)	12.5	115.3 (6.1)	116.0 (2.8)	119.7 (4.0)	3.8
Back-row	85.7 (5.2)	90.7 (5.4)	92.3 (3.9)	95.9 (6.0)	11.9	102.7 (8.0)	104.3 (6.9)	109.6 (5.6)	6.7
Half-back	76.0 (7.9)	74.6 (5.9)	74.8 (4.7)	76.3 (5.8)	0.0	79.1 (3.9)	83.3 (6.8)	88.8 (4.4)	12.3
Centre	82.0 (5.6)	79.4 (7.5)	80.9 (6.1)	80.1 (7.3)	-2.3	86.7 (3.1)	92.9 (8.1)	100.9 (12.4)	16.4
Back 3	81.6 (5.3)	75.6 (8.6)	79.3 (6.8)	79.2 (4.8)	-2.9	87.4 (4.4)	90.4 (8.9)	96.3 (6.4)	10.2
Height									
Prop	1.80 (0.02)	1.81 (0.02)	1.81 (0.05)	1.81 (0.03)	0.6	1.80 (0.03)	1.85 (0.04)	1.85 (0.04)	2.8
Hooker	1.78 (0.05)	1.82 (0.03)	1.79 (0.02)	1.78 (0.02)	0.6	1.79 (0.04)	1.82 (0.04)	1.83 (0.02)	2.2
Second row	1.87 (0.02)	1.93 (0.05)	1.95 (0.03)	1.95 (0.05)	4.3	2.00 (0.04)	1.99 (0.03)	2.00 (0.04)	0.0
Back-row	1.82 (0.04)	1.85 (0.04)	1.88 (0.05)	1.91 (0.04)	3.3	1.93 (0.04)	1.91 (0.05)	1.91 (0.03)	-1.0
Half-back	1.75 (0.03)	1.72 (0.07)	1.74 (0.06)	1.78 (0.06)	-0.6	1.77 (0.03)	1.77 (0.05)	1.81 (0.05)	2.3
Centre	1.80 (0.04)	1.77 (0.05)	1.81 (0.07)	1.80 (0.05)	0.6	1.83 (0.02)	1.84 (0.05)	1.87 (0.05)	2.2
Back 3	1.80 (0.04)	1.78 (0.07)	1.80 (0.06)	1.79 (0.05)	0.0	1.81 (0.05)	1.84 (0.08)	1.87 (0.05)	3.3

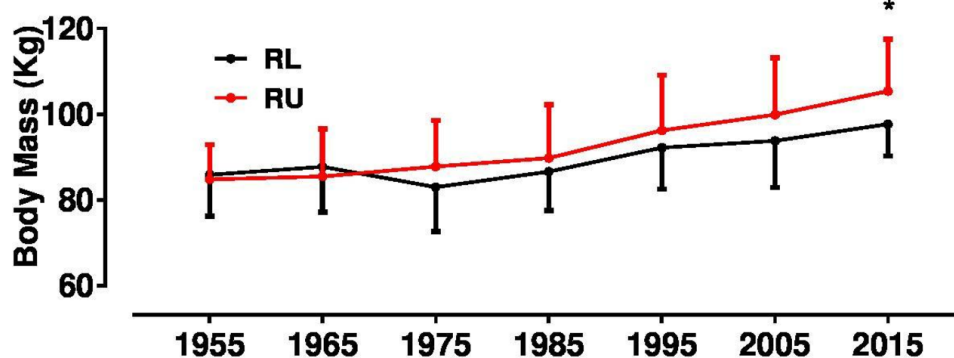


Figure 4 Mean and SD of body mass international rugby union (RU) players taking part in the opening matches of the Five or Six nations tournament, and rugby league (RL) players competing in the Challenge Cup final match in 1955, 1965, 1975, 1985, 1995, 2005 and 2015 (n=75 RU; n=26 RL, apart from 1955 where n=23 and 1995 when n=20). *p<0.05 by two-way analysis of variance.

elite rugby player (table 2). Interestingly, this difference between the public (or military recruits) and top-level rugby players is reasonably consistent, with rugby players typically around 25% heavier than average.

DISCUSSION

We have found that the body mass of international RU players has increased significantly between 1955 and 2015. This body mass gain has mostly occurred in the last 20 years since the game turned professional. RU players are now heavier than RL players. We chose to use matchday programmes because it was our experience that internet-based databases and Wikipedia do not give a time-specific body mass and is therefore not possible to determine when in a players' career their body mass was calculated. RU has traditionally been considered a game for people of all shapes and sizes; our data show that at international level that is no longer the case.

Changes in body mass and comparison with other data

It has been reported that there were no statistically significant differences in the anthropometric measurements of backs and forwards at the 2011 and 2007 Rugby World Cups (RWC) when compared with 2015.¹⁰ Analysis of English professional RU players over 10 years between 2002 and 2011 showed that only fly-halves and back-row players had statistically significant gains in body mass.¹¹

Our data show a significant difference between 2005 and 2015 in mean body mass; these divergent results may reflect the shorter reporting period of 8 years between 2007 and 2015 compared with the deciles used in our study, and it may be that the RWC data (which include 16 teams) is skewed because some of the teams include players who are not fully professional.

The data for UK adults and Army recruits show that the average body mass of the public is steadily increasing (indeed many Western countries are now amid an obesity 'crisis'). Reasons for this include better public health and nutrition. It might be argued that the change in RU players body mass are influenced by players who have a Polynesian ethnicity; however, this includes only two players from the 2015 Six Nations. Other causes of increased body mass may include resistance training and the use of anabolic steroids.¹ The observed increase in body mass of international players over time may also be attributed to coaches preferentially selecting bigger players, especially when they have a large pool to select from. Olds¹ suggested that a competitive Darwinian selection pressure for increased size has manifested greater body mass, in a so-called physique arms-race. Indeed, an old boxing adage says that a 'good bigun will always beat a good littleun' and this, perhaps derived from Golding's *Lord of the Flies*, appears to be symbolically and

Table 2 Mean (and SEM where available) body mass in kilogram in military recruits and the general public, Five or Six Nations rugby union and Challenge Cup final rugby league players and the per cent difference between them

Year	Source	UK men	Rugby union	Rugby league	% Difference between UK men	
					Union	League
1955	Military recruits (aged 20–24 years)	65.6	84.8 (0.9)	85.9 (2.0)	29.3	30.9
1965		68.1	85.5 (1.3)	87.7 (2.1)	25.6	28.8
1974/1975*		69.6	87.8 (1.2)	83.0 (2.0)	26.1	19.3
1995	General public (aged 16–24 years)	73.6 (0.4)	96.2 (1.5)	92.2 (2.2)	30.7	25.3
2005		74.3 (0.7)	99.9 (1.5)	93.8 (2.1)	34.5	26.3
2015		79.0 (1.5)	105.4 (1.4)	97.7 (1.5)	33.3	23.6

*Only data from 1974 was available for military recruits.

metaphorically true in the decision-making processes of rugby selectors. Interestingly, it has been shown that the forwards of World Cup-winning teams are significantly heavier than the forwards of the other teams in the competition.¹²

It is important not to directly compare RL and RU; they are different games requiring different skills, in RL, there is less emphasis on set-piece areas (scrums and line-outs) and more running. Nevertheless, it is intriguing to note that RL, a game that has been professional for more than 100 years, shows a steady increment in body mass, whereas RU players, especially the backs, have rapidly gained body mass since the game was officially professional in 1995. The reasons for this are not clear.

How RU laws have influenced changes in body mass

It has been suggested that law changes occurring since the game turned professional have been driven by the need for the game to compete aesthetically with other sports in order to maintain and increase the number of spectators.^{13 14} Nevertheless, we suggest that the laws of RU have, at least in part, facilitated the current situation of huge players competing against similarly vast individuals. We cite three examples where law changes may have led to changes in player shape.

1. Historically at a scrum, the ball was fed straight down an imaginary line between the two front rows. Both hookers would strike for the ball with their legs. Although the team whose scrum-half was putting the ball into the scrum was at an advantage because their hooker was closer to the ball, it was possible for the other team to win a scrum 'against the head'. To do this, the opposition hooker had to swing forward between the two props to strike for the ball. This meant that hookers needed to be smaller than the props because the props had to support the body mass of their hooker while pushing against their opposite man. In the past, referees would penalise scrum-halves with a free kick for not putting the ball straight into the scrum. For the last 20 years though, we have observed that scrum-halves feeding the ball crookedly towards their own team are rarely punished.¹⁵ This has made it impossible for the opposition hooker to successfully strike for the ball. This means that the chances of winning a scrum against the head are much lower; only occurring when there is a mistake over timing of the ball being placed into the scrum or when one pack of forwards pushes the other completely off the ball. It seems likely that the change in the way the scrum is refereed is at least why hookers now have similar body shapes to props; their primary scrummaging role is no longer to win the possession as the ball is fed into the scrum but to push.
2. Since 1996, tactical substitutions have been allowed in RU with up to seven or eight changes of personnel permitted during an 80 min game. Prior to this, changes were only allowed if a player was injured and unable to continue. This has been cited as a possible reason

for increased injuries—fresh players coming onto the pitch towards the end of the game, facing players who are fatigued, fractionally slower in thought and deed and thus perhaps more susceptible to injury in contact situations. The ability to make substitutes during the game has also led to the term 'impact player', which typically refers to someone of powerful physique being brought on towards the end of the game¹⁶ taking advantage of tired opposition players to break the gain line.¹⁷ An early example was South African prop, Ollie Le Roux (weighing 136 kg) who played 54 tests between 1994 and 2002, appearing as a substitute in 43 of them. Typically heavier, forwards fatigue faster than backs.^{6 18} This may relate to the greater body fat generally found in forwards that leads to a reduced lean mass to total body mass ratio, leading to greater metabolic demands with reduced oxidative capacity per unit value of body mass.¹⁹ Forwards also do more total work during a game, which may also underpin the tendency to replace more forwards than backs. The widespread use of substitutes means that larger players, carrying greater mass, can be removed from play before their relative lack of endurance translates into mistakes or can be exploited by the opposition. This is, in effect, a rule-based incentive to select heavier players for roles where power and force are important. Perhaps at the amateur level, where teams may struggle to find 15 players, this is less of an issue. At elite or international levels problems with player availability do not exist, and full squads are always available.

3. Second-row players have important roles in set-piece situations. They are sometimes described as the 'engine room' of the scrum, pushing to ensure the advantage is maintained when their team place the ball in the scrum and competing for the ball when they do not. In line-outs, where the ball is thrown in to restart the game when the ball has gone into touch, the second rows traditionally tried to outjump their opponent. In 1999, the International Rugby Board (IRB) introduced a law allowing other players to lift and support a jumping player. This meant that absolute height (and jumping ability) were no longer a prime consideration for second row selection. Consequently, second rows are the only position not to increase in height following professionalism (2.00 m in 1995 and 2015). In addition, the body mass of second rows stabilised after the 1999 law change (only a 3.8% increase between 1995 and 2015, compared with 16.4% for centres) with the lowest sum of SD of body mass in professional era, suggesting a more uniform body type. The lack of body mass gain likely reflects the achievement of player mass (and height), which can most effectively be lifted and compete for the ball at line-out while providing enough power for scrummaging.

Effects of greater player body mass on injuries

The growth in size of players inevitably leads to questions about whether the greater mass of players and

forces involved in collisions lead to more injuries. Media headlines suggest that more injuries are also occurring with frequent references to injury crises.²⁰ Increases in body mass, player speed and fitness are not, to the best of our knowledge, matched by parallel increases in the tensile strength of bone, tendons and ligaments. Head injuries are rightly currently the focus of much attention in RU, causing a spate of early retirements from the professional game and considerable concern regarding long-term neuropsychiatric health and player welfare.²¹⁻²² Shoulder injuries also occur frequently, and dislocations are a cause of significant absence from playing, and it has been suggested that players with greater BMI have greater injury incidence and severity.²³⁻²⁶

The England Professional Rugby Injury Surveillance Project has not identified an increased incidence of injuries (apart from concussion); however, it is important to note that this has only been collecting data systematically since 2002.²⁷ Bathgate *et al*²⁸ showed that the injury rate in elite Australian players before professionalism (in 1995) was 47 injuries/1000 player hours of game play, and after that, between 1996 and 2000, the injury rate increased to 74 injuries/1000 hours game play. Others have suggested that injuries have doubled since professionalism.²⁹ Data from the Rugby World Cup, which occurs every 4 years, show that while injury frequency has not changed between 2015, 2011 and 2007, the severity of injury sustained and subsequent duration of absence through injury has sequentially increased.¹⁰ There is conflicting evidence for whether more injuries occur in the second half of games when tactical substitutions tend to occur.^{10 28} Our analysis of the available literature suggest that it is likely that an increased incidence of injury, and more significant sequelae, have occurred following 'professionalism'. This encompasses greater time during which the ball is in play, higher fitness levels, pressure to play when carrying pre-existing injuries and greater forces involved during collisions.³⁰ Teasing out the extent to which increased body mass affects this is challenging. What is clear is that (unsurprisingly) most injuries occur during tackling and contact.²⁹ Analysis of games between Australia versus New Zealand show an increased number of rucks (more than 100) and tackles in 2004 compared with 1995.³ Furthermore, there are more injuries in international and professional players than in amateurs, and these players are heavier.^{14 31} Some investigators have found a link between higher injury rates in heavier players, while others have not.^{22 31-33} Interestingly, although not a universal finding, one study has found centres and hookers, the players we have identified as increasing mass disproportionately since professionalism, have the greatest risk of injury.³⁴ In another study, again midfield backs (centres) had the greatest absence through injury³¹; the reason cited was high-speed tackles, which brings us back to Newton's laws of motion and the forces involved when big people run very fast into each other.

Limitations

There are notable limitations to this study. We have only obtained player details at 10-year intervals (limited by the availability of programmes); more frequent sampling may show some or all our data to be outlying from a trend of lesser body mass gain. We do not know the source of the body mass data published in the matchday programmes. It may be that players or teams exaggerate their size, perhaps to intimidate the opposition. This was highlighted recently when, in the prematch build up to the Wales versus Scotland match on 3 February 2018, Martin Johnson, the former England captain and coach, said, 'I don't think Hamish Watson is as big as his programme weight says'.

The future

Where might this end? One opportunity is to study the extreme changes in body mass that have occurred in American football over the last 40 years. Some positions (such as offensive linemen and defensive tackle) now average more than 300 lb (136 kg), where grappling and preventing opponents from getting past are important. However, in other positions (such as defensive end and running back), body mass appears to have peaked and, in some cases fallen, due to changes in tactics and the requirement for greater speed.³⁵ It is possible that this will occur in RU where, in our opinion, at times bulk seems to be prioritised over skill. We hope that as skill levels continue to improve, RU players will outwit and outpace rather than outmuscle their opponents.

Summary

We have shown that the body mass of male RU players has significantly increased since the game officially turned professional in 1995. Between 1955 and 2015, the body mass of forwards increased steadily, whereas that of backs has mostly gone up since 1995. RU player body mass gain has exceeded that of RL, but the age-matched difference between RU players and the public has remained relatively constant. We hypothesise that some of the change observed in body mass have been driven by law changes. Although it is not possible to conclude that body mass gain is directly causing a greater frequency and severity of injuries, this remains a possibility. We hope that the World Rugby will make law changes that will discourage players to gain body mass, preferring instead speed and skill; this in turn may lead to fewer injuries.

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REFERENCES

- Olds T. The evolution of physique in male rugby union players in the twentieth century. *J Sports Sci* 2001;19:253–62.
- Stephens D, Fourie J. Morphological evolution of Springbok rugby players: Implications for racial transformation in South African rugby. *South African Journal for Research in Sport, Physical Education and Recreation* 2017;39:145–61.
- Quarrie KL, Hopkins WG. Changes in player characteristics and match activities in Bledisloe Cup rugby union from 1972 to 2004. *J Sports Sci* 2007;25:895–903.
- Technology in rugby: GPS systems continue to grow in importance. 2018. Available from: <http://www.the42.ie/gps-technology-rugby-1113025-Oct2013/> [Accessed 15 Apr 2018].
- Allan Massie: Rugby must ban the big hitters. 2018. Available from: <https://www.scotsman.com/sport/rugby-union/allan-massie-rugby-must-ban-the-big-hitters-1-4220082> [Accessed 15 Apr 2018].
- Quarrie KL, Handcock P, Waller AE, et al. The New Zealand rugby injury and performance project. III. Anthropometric and physical performance characteristics of players. *Br J Sports Med* 1995;29:263–70.
- Quarrie KL, Handcock P, Toomey MJ, et al. The New Zealand rugby injury and performance project. IV. Anthropometric and physical performance comparisons between positional categories of senior A rugby players. *Br J Sports Med* 1996;30:53–6.
- Health Survey for England. 2018. Available from: <https://discover.ukdataservice.ac.uk/series/?sn=2000021#format> [Accessed 15 Apr 2018].
- Rosenbaum S, Crowdy JP. British Army recruits: 100 years of heights and weights. *J R Army Med Corps* 1992;138:81–6.
- Fuller CW, Taylor A, Kemp SP, et al. Rugby world cup 2015: world rugby injury surveillance study. *Br J Sports Med* 2017;51:51–7.
- Fuller CW, Taylor AE, Brooks JH, et al. Changes in the stature, body mass and age of English professional rugby players: a 10-year review. *J Sports Sci* 2013;31:795–802.
- Sedeaud A, Marc A, Schipman J, et al. How they won Rugby World Cup through height, mass and collective experience. *Br J Sports Med* 2012;46:580–4.
- Austin D, Gabbett T, Jenkins D. The physical demands of Super 14 rugby union. *J Sci Med Sport* 2011;14:259–63.
- Duthie G, Pyne D, Hooper S. Applied physiology and game analysis of rugby union. *Sports Med* 2003;33:973–91.
- Brian Moore: Rugby union referees have a lot to answer for as scrums develop into farce. 2018. Available from: <http://www.telegraph.co.uk/sport/rugbyunion/8157529/Brian-Moore-Rugby-union-referees-have-a-lot-to-answer-for-as-scrums-develop-into-farce.html> [Accessed 15 Apr 2018].
- Tracking the trends of the modern game. 2018. Available from: <http://playerwelfare.worldrugby.org/?documentid=156> [Accessed 15 Apr 2018].
- The Rugby Debate: Should the number of substitutions allowed be reduced to five?. 2018 Available from: <http://www.telegraph.co.uk/rugby-union/2017/03/21/rugby-debateshould-number-substitutions-allowed-reduced-five/> [Accessed 15 Apr 2018].
- Tee JC, Lambert MI, Coopoo Y. Impact of fatigue on positional movements during professional rugby union match play. *Int J Sports Physiol Perform* 2017;12:554–61.
- Smart D, Hopkins WG, Quarrie KL, et al. The relationship between physical fitness and game behaviours in rugby union players. *Eur J Sport Sci* 2014;14(Suppl 1):S8–S17.
- The story of rugby's injury crisis from the players, a coach and a doctor. 2018. Available from: <http://www.bbc.co.uk/sport/rugby-union/41544641> [Accessed 15 Apr 2018].
- Kiwi rugby concussion study goes global. 2018. Available from: www.nzherald.co.nz/sport/news/article.cfm?c_id=4&objectid=11813573 [Accessed 15 Apr 2018].
- Rafferty J, Ranson C, Oatley G, et al. On average, a professional rugby union player is more likely than not to sustain a concussion after 25 matches. *Br J Sports Med* 2018;bjsports-2017-098417.
- Lee AJ, Myers JL, Garraway WM. Influence of players' physique on rugby football injuries. *Br J Sports Med* 1997;31:135–8.
- Headey J, Brooks JH, Kemp SP. The epidemiology of shoulder injuries in English professional rugby union. *Am J Sports Med* 2007;35:1537–43.
- Moore IS, Ranson C, Mathema P. Injury risk in international rugby union: three-year injury surveillance of the Welsh national team. *Orthop J Sports Med* 2015;3:2325967115596194.
- Usman J, McIntosh AS, Quarrie K, et al. Shoulder injuries in elite rugby union football matches: Epidemiology and mechanisms. *J Sci Med Sport* 2015;18:529–33.
- England Rugby, 2018. News. Available from: <http://www.englandrugby.com/news/professional-game-action-plan-player-injuries-released-with-2016-professional-rugby-injury-surveillance-project-report/#> [Accessed 15 Apr 2018].
- Bathgate A, Best JP, Craig G, et al. A prospective study of injuries to elite Australian rugby union players. *Br J Sports Med* 2002;36:265–9.
- Kaplan KM, Goodwillie A, Strauss EJ, et al. Rugby injuries: a review of concepts and current literature. *Bull NYU Hosp Jt Dis* 2008;66:86–93.
- Brooks JH, Kemp SP. Recent trends in rugby union injuries. *Clin Sports Med* 2008;27:51–73.
- Quarrie KL, Alsop JC, Waller AE, et al. The New Zealand rugby injury and performance project. VI. A prospective cohort study of risk factors for injury in rugby union football. *Br J Sports Med* 2001;35:157–66.
- Archbold HA, Rankin AT, Webb M, et al. RISUS study: rugby injury surveillance in Ulster schools. *Br J Sports Med* 2017;51:600–6.
- Chalmers DJ, Samaranayaka A, Gulliver P, et al. Risk factors for injury in rugby union football in New Zealand: a cohort study. *Br J Sports Med* 2012;46:95–102.
- Brooks JH, Fuller CW, Kemp SP, et al. Epidemiology of injuries in English professional rugby union: part 1 match injuries. *Br J Sports Med* 2005;39:757–66.
- Sports Reference, 2018. How much bigger are players now? Available from: <https://www.pro-football-reference.com/blog/index7255.html?p=493> [Accessed 15 Apr 2018].