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Tackle-related injury rates and nature of injuries in national Youth Week rugby union tournaments in South Africa (under-13 to under-18)

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Abstract

Objectives

The tackle situation is most often associated with the high injury rates in rugby union. Tackle injury epidemiology in rugby union has previously been focused on senior cohorts but less is known about younger cohorts. The aim of this study was to report on the nature and rates of tackle-related injuries in elite South African youth rugby union players.

Design

Observational cohort study.

Setting

Four South African Youth Week tournaments (under-13 Craven Week, under-16 Grant Khomo Week, under-18 academy Week, under-18 Craven Week).

Participants

Injury data were collected from 3652 youth rugby union players (population at risk) in 2011 and 2012.

Outcome measures

Tackle-related injury severity, type and location, injury rate per 1000 hours (including 95% confidence intervals). Injury rate ratios were calculated and modelled using a Poisson regression. A chi-squared analysis was used to detect linear trends between injuries and increasing match quarters.

Results

There was a higher probability of *'overall'* and *'time-loss'* tackle-related injuries occurring at

the under-13 Craven Week. The under-13 Craven Week had a significantly greater *'time-loss'* injury rate when compared to the 2012 under-18 Craven Week (IRR: 3.52; 95%CI: 1.54-8.00, p<0.05). The under-13 Craven Week also had the greatest proportion of broken bone/factures and muscular injuries for both *'overall'* (12% and 23%) and *'time-loss'* injuries (28% and 22%). The proportion of *'overall'* injuries increased significantly with each quarter of the match when all four tournaments were combined (p<0.05).

Conclusions

Age and match-related fatigue may affect the rates and nature of tackle-related injuries in youth rugby union. On-going injury surveillance is required to interpret these findings. Injury prevention strategies targeting the tackle may only be effective once rate and nature of the injuries have been determined.

Key words: youth; injury epidemiology; rugby union; tackle.

Strengths and limitations of this study

- This study is novel as it reports specifically on tackle-related injury rates and nature of injury in elite South African youth rugby union players
- Findings may help identify tackle injury prevention strategies for other youth rugby union players
- Findings may help prepare medical professionals for injury assessment and management at youth rugby union tournaments
- Only injuries reported to the tournament doctor were included in the analysis
- Findings in this study should not be generalised as the analysis involved a specific cohort of players at a week-long tournament

Introduction

Rugby union is a team sport played worldwide and characterised by frequent contact situations between players.[1-3] The ability to tolerate and contest these situations is a prerequisite for participation and success in the sport.[2,4,5] The high frequency of contact situations places rugby players at higher risk of injury when compared to other team sports.[6,7] In particular, the tackle is the contact event most often associated with this high rate of injury.[8-10]

The tackle is defined as "any event where one or more tacklers (player or players making the tackle) attempt to stop or impede the ball-carrier (player carrying the ball) whether or not the ball-carrier was brought to ground".[5,10] The tackle is an effective way to try and regain possession of the ball, and to prevent the attacking team from gaining field territory and advancing into a point-scoring position.[5]

Tackle-related injury rate has previously been reported for both league and tournament formats in professional English Premiership rugby[8] and at the Rugby World Cup,[11] respectively. The tackle is responsible for a high proportion of upper-body injuries in tacklers, particularly concussion, head/neck and shoulder injuries, and ball-carriers are more likely to sustain injuries to the lower-body, particularly thigh muscle and knee injuries.[8,9,12]

Despite the plethora of tackle injury studies with a focus on senior rugby union players,[9,10,14] less is known about youth cohorts. Therefore, the aim of this study was to report on the nature and rates of tackle-related injuries occurring at four elite youth rugby union tournaments which were hosted by the South African Rugby Union (SARU) in 2011 and 2012. It is noteworthy that this study is unique in comparison to previous research as these tournaments span for one week only.

The specific questions of this study, pertaining to tackle-related injuries at youth rugby union tournaments, are as follows; (1) are injury rates comparable across the age categories (13 to 18 years), (2) do injury type proportions differ across the age categories, (3) do injuries occur at different anatomical locations for ball-carriers and tacklers, and (4) does the rate of injury events increase with match time? The answers to these questions may contribute to the development and implementation of targeted injury prevention and management strategies in youth rugby.

Methods

SARU coordinates an injury-surveillance project, via the BokSmart National Rugby Safety Programme,[15] whereby information about all injuries that occur at their Youth Week tournaments are recorded and transcribed into an injury database. Authors were granted access to this database for analysis by SARU and the UCT Human Research Ethics Committee (HREC Ref: 438/2011). All players attending the Youth Week tournaments and their parents/legal guardians signed the SARU Medical and Anti-Doping informed consent form which has a section dedicated to explaining the details of the injury-surveillance project. When a player was injured, informed consent to analyse the recorded information was once again confirmed by the player or by the player's parent or guardian. The Youth Week tournaments are a showcase for South Africa's most talented schoolboy players and include the under-13 Craven Week, under-16 Grant Khomo Week, under-18 Academy Week and under-18 Craven Week tournaments. These tournaments are unique in that they only span the course of one week and thus place increased physical demands on players. Participating teams are formed through the selection of the top schoolboy players from within each of the country's 14 provincial rugby unions in addition to one Namibian and one Zimbabwean team. In the case of the two under-18 tournaments, Craven Week involves the best schoolboy players from each union, while the Academy Week involves the second tier of players from each union.

A SARU-appointed doctor was on duty at each tournament to assess every injury that occurred. Details about each injury were recorded on an injury collection form that was designed based on the Consensus Statement for injury surveillance.[16] Only data pertaining to the tackle event were analysed for the purposes of this study.

The injury definition for these tournaments, adapted from the Rugby Union injury Consensus Statement,[16] was stated as *'any physical complaint, which was caused by a transfer of energy that exceeded the body's ability to maintain its structural and/or functional integrity, that was sustained by a player during a rugby match and required attention from the SARU tournament doctor'*.

'*Time-loss*' and '*medical attention*' tackle-related injuries were reported for this study. A '*time-loss*' injury was an injury (based on the aforementioned definition) that resulted in the player being absent for more than one match in a tournament, or more than one day of normal/planned recreational activities during or after the tournament. Injuries were confirmed as *'time-loss'* injuries during the course of the tournament or via telephonic follow-up after the tournament. Weekly phone calls were made to assess the state of the injury until the player returned to practice. '*Medical attention*' injuries required treatment from the tournament doctor, but resulted in no loss in recreational, play or practice time. '*Overall'* injuries included both '*medical attention*' and '*time-loss*' injury events. Due to the short duration of each tournament and low absolute injury numbers, *'medical attention'* injuries were included during the analyses, as important information may have been overlooked if only *'time-loss'* injury data were considered.[7]

The '*type*' of injury was categorised as either concussion, spinal cord, broken bone/fracture, joint/ligament/tendon, muscle, bruise, laceration (including skin abrasion), or other by the

tournament doctor. If the tournament doctor was unable to diagnose the injury at the time, the injury '*type*' was recorded as '*unsure*'. The '*location*' of the injury was categorised into an anatomical group; head/neck, upper torso, upper limb, lower torso, lower limb, or '*unsure*'.

Statistical analysis

Player exposure time was calculated for all 2011 and 2012 tournaments based on the current injury collection consensus statement for rugby;[16]

$$Exposure\ time = \mathrm{N_M\ x\ P_M\ x\ D_M}$$

For this calculation, N_M is the number of matches, P_M is the number of players per match (i.e. 30 players from both sides), and D_M is the duration of the match in hours. This exposure time was used to determine the injury rate and corresponding 95% confidence intervals (95% CIs) for the number of tackle-related injuries per 1000 hours of match play regardless of whether a player was injured more than once.[17]

The injury rate ratios (IRR) and corresponding 95% CIs were calculated[18] to determine the difference in injury rates across the age categories (each year was analysed separately). The IRR was calculated by dividing the injury rate of one tournament, for example year '*A*' (numerator), by its total player exposure time, and then dividing this by the equivalent value for the specific tournament to which it was compared, for example year '*B*' (denominator);

$$IRR = \frac{injury\ rate_A / exposure_A}{injury\ rate_B / exposure_B}$$

The standard error (SE) of the log of the IRR was calculated by dividing the total number of tackle injuries of each of the two compared tournaments (*y*) by one, and finding the square root of their sum;

$$SElogIRR = \sqrt{\frac{1}{y_A} + \frac{1}{y_B}}$$

Confidence intervals (95%) were then calculated by using the log of the IRR and the SE of the log;

$$95\%\text{CI} = logIRR \pm 1.96 \text{ x } SElogIRR$$

The IRR was considered significantly greater for the numerator if both 95% CIs were greater than 1.0. Conversely, an IRR was considered significantly lower for the numerator if the both 95% CIs were less than 1.0.

Significant findings from the IRR analysis were verified using VRP injury statistics software (University of North Carolina, Injury Prevention Research Center).[19] The IRR between any two tournaments was only considered to be significant if the VRP analysis yielded a p-value of less than 0.05.

A Poisson regression was modelled using STATA 11.1 (StataCorp LP, USA) to determine the probability of injury across the age categories (both years were combined and the under-18 Craven Week tournament was used as the reference i.e. denominator). The year

of the each tournament was factored into the model (2011 was used as the reference i.e. denominator) even though this was not part of the main analysis.

A chi-squared analysis was conducted using GraphPad Prism 5 (version 5.02 for Windows) to determine whether there were any significant linear trends ($p<0.05$) between the proportion of tackle-related injuries occurring in each match quarter for all tournaments across both years.

Results

Injury surveillance was conducted on 1804 players in 2011 and on 1848 players in 2012 (Table 1). Sixty per cent of '*overall*' injuries (Table 2) from 2011 and 2012 (n = 263 of 440 injuries) were tackle-related injuries. Sixty-one per cent of 'overall' tackle-related injuries were to the tackler and 39% were to the ball-carrier. Fifty-nine per cent of all 'time-loss' injuries (Table 2) from 2011 and 2012 (n = 104 of 176 injuries) were associated with the tackle. Sixty per cent of tackle-related 'time-loss' injuries were to the tackler and 40% were to the ball-carrier.

(Insert Tables 1 and 2)

The '*overall*' tackle-related injury rates at the 2011 tournaments were 29.2 injuries per 1000 exposure hours (95%CI: 16.8-41.6) at under-13 Craven Week, 24.7 injuries per 1000 exposure hours (95%CI: 13.9-35.5) at under-16 Grant Khomo Week, 34.4 injuries per 1000 exposure hours (95%CI: 24.6-44.3) at under-18 Academy Week, and 23.8 injuries per 1000 exposure hours (95%CI: 14.5-33.1) at under-18 Craven Week (Figure 1A). The '*overall*' tackle-related injury rates at the 2012 tournaments were 50.0 injuries per 1000 exposure

hours (95%CI: 33.7-66.3) at under-13 Craven Week, 36.7 injuries per 1000 exposure hours (95%CI: 24.2-49.2) at under-16 Grant Khomo Week, 34.4 injuries per 1000 exposure hours (95%CI: 24.6-44.3) at under-18 Academy Week, and 33.5 injuries per 1000 exposure hours (95%CI: 22.2-44.8) at under-18 Craven Week.

Analysis of tackle-related '*time-loss*' injury rates of the 2011 tournaments showed 11.1 injuries per 1000 exposure hours (95%CI: 3.4-18.8) at under-13 Craven Week, 9.9 injuries per 1000 exposure hours (95%CI: 3.0-16.7) at under-16 Grant Khomo Week, 18.3 injuries per 1000 exposure hours (95%CI: 11.1-25.5) at under-18 Academy Week, and 10.5 injuries per 1000 exposure hours (95%CI: 4.3-16.7) at under-18 Craven Week (Figure 1B). The tackle-related '*time-loss*' injury rates of the 2012 tournaments showed 22.2 injuries per 1000 exposure hours (95%CI: 11.3-33.1) at under-13 Craven Week, 13.3 injuries per 1000 exposure hours (95%CI: 5.8-20.9) at under-16 Grant Khomo Week, 11.0 injuries per 1000 exposure hours (95%CI: 5.4-16.6) at under-18 Academy Week, and 8.9 injuries per 1000 exposure hours (95%CI: 3.1-14.7) at under-18 Craven Week.

The Poisson regression model revealed no significant differences in *'overall'* and *'time-loss'* tackle-related injury rate across the age categories when both years were combined. However, there was a higher probability of *'overall'* tackle-related injury at the under-13 Craven Week when compared to the under-18 Craven Week (IRR: 1.38; 95%CI: 0.96-1.99, p=0.08). Tackle-related *'time-loss'* injury also had a higher probability of occurring at the under-13 Craven Week when compared to the under-18 Craven Week (IRR: 1.72; 95%CI: 0.95-3.12, p=0.07). There was a significantly higher chance of incurring an *'overall'* tackle-related injury in 2012 when compared to 2011 (IRR: 1.31; 95%CI: 1.03-1.67, p<0.05).

There were no significant differences when *'overall'* and *'time-loss'* tackle-related IRRs were calculated for the 2011 tournaments. However, there was a significantly greater tackle-related '*time-loss*' injury rate at the 2012 under-13 Craven Week tournament when compared to the 2012 under-18 Craven Week (IRR: 3.52; 95%CI: 1.54-8.00, p<0.05). This is consistent with the result from the Poisson regression (see above).

(Insert Figures 1A and 1B)

The largest proportion of '*overall*' tackle-related injuries were joint/ligament/tendon '*type*' injuries (29%), bruise/contusions (21%), muscle injuries (15%), concussions (11%), and lacerations (10%) when all tournaments in 2011 and 2012 were combined. The greatest proportion of tackle-related '*time-loss*' injuries were joint/ligament/tendon injuries (32%), concussions (27%), muscle injuries (12%), and broken bone/fractures (12%). The under-13 Craven Week tournament had the greatest proportion of broken bone/factures and muscle-related injuries for both '*overall*' (12% and 23% respectively) and '*time-loss*' injuries (28% and 22% respectively) when 2011 and 2012 were combined.

When observing anatomical injury locations, 40% of '*overall*' tackle-related injuries to the tackler across all four tournaments in both years, were head/neck injuries. Upper torso injuries (24%) were the next most frequent in tacklers followed by lower limb (17%) and upper limb (16%) injuries. The majority of tackle-related 'time-loss' injuries to tacklers across all four tournaments in both years, were head/neck (45%) followed by upper torso (26%), lower limb (19%) and upper limb (10%) injuries.

In contrast, the majority of ball-carrier '*overall*' tackle-related injuries were lower limb (44%) followed by head/neck (26%) and upper torso (22%) injuries. The highest proportion of

tackle-related *'time-loss'* injuries to ball-carriers were lower limb (41%) followed by upper torso (29%) and head/neck (26%) injuries.

When 2011 and 2012 *'overall'* tackle-related injuries were combined, the proportion of injuries increased significantly with each quarter of the match (chi-squared linear trend: $p<0.05$). Approximately 35% of *'overall'* tackle-related injuries across all tournaments in 2011 and 2012 occurred during the final quarter of the match. Twenty-four per cent of *'overall'* tackle-related injuries occurred in the third quarter followed by the second (23%) and first (17%) quarters. Thirty-three per cent of tackle-related *'time-loss'* injuries across all tournaments in both years occurred during the final quarter of the match followed by the second (24%), third (22%) and first (18%) quarters.

Discussion

This study is unique in that it reports exclusively on the nature and rates of tackle-related injuries in elite South African youth rugby union players at a week-long tournament, and it will add to the current literature on tackle injury epidemiology, which is well documented in senior rugby union cohorts.[9,10,14]

The high proportion of tackle-related injuries observed in this study (Table 2) is consistent with previous rugby union research.[8-10] The higher proportion of both '*overall*' and '*time-loss*' injuries occurring to the tackler during this study is consistent with some studies conducted in youth rugby union,[13,20,21] however this finding is also in contrast to other studies which found ball-carriers to be at greater risk.[12,22] A summary of the evidence suggests that both the tackler and the ball-carrier are proportionally at similar risk of injury during a tackle event.

This study showed a significant decrease in *'time-loss'* injuries between the under-13 and under-18 Craven Week tournaments in 2012. This decrease in injury rates with increasing age is in contrast to previous research.[3,13,14] There were no significant differences in the probability of *'overall'* and *'time-loss'* tackle-related injury between the age categories when both years were combined. However, there was a significantly greater probability of an *'overall'* tackle-related injury occurring in 2012 when compared to 2011, although this was not a part of the main analysis. On-going injury surveillance is necessary before these injury trends may be interpreted with confidence.

The type of tackle-related injuries did not differ greatly between the age categories. However, there were a higher proportion of skeletal and muscular tackle-related injuries at the under-13 Craven Week tournament. This may perhaps be attributed to the fact that the adolescent skeletal system takes time to adapt to the rapid increase in muscular strength experienced during puberty[20] and, as such, not all adolescents are able to tolerate frequent contact situations, potentially placing them at a greater risk. This is an important consideration as these types of contact injuries may affect growth and development.

The prevalence of concussion injuries at these tournaments, consistent with previous research in rugby union,[13,21] remains an area of concern and highlights the need for danger and symptom awareness amongst coaching staff, parents and players[3] as many concussion injuries go unreported.[23] In certain instances, symptoms may only manifest at a later stage.

The majority of injuries to the tackler were to the head/neck region while ball-carriers most frequently suffered a lower limb injury. Similar results have been found in senior cohorts,[9,14] although the current study's findings remain to be confirmed in other youth cohorts. These findings are not unexpected as the nature of the tackle situation in rugby union means that

the upper extremity of the tackler and lower extremity of the ball-carrier are usually the first points of contact.[24]

The finding that the frequency of tackle-related injuries increased as playing time progressed within the match is consistent with previous findings in rugby union.[1,20] This was significant for *'overall'* tackle-related injuries and may be attributed to the effect of fatigue which has been found to play a role in reducing tackle technique proficiency in professional rugby league.[25] This may expose players to a greater risk of injury in the tackle situation as playing time in the match progresses.

Multiple risk factors play a role in causing an injury during a tackle event. For example, technique has been found to be an associated risk factor in previous tackle-related injury epidemiology research.[13,24] This may, in part, explain the higher rates of tackle-related injuries observed in the youngest playing group (under-13 Craven Week). Older, more experienced players have been found to execute a greater proportion of effective tackles, and also miss fewer tackles and incur fewer tackle-breaks.[14,26] It has also been found that players may only learn proper tackle technique at an older age.[27]

These findings emphasise the need for coaches to teach correct contact technique from an early age.[27] Correct technique is not only necessary to prevent injury but it also increases the likelihood of a successful performance outcome.[5] Further research into which optimal movement patterns are required during tackle training is essential to help reduce injury rates.[28]

In addition to technique, it has also been suggested that the increased proportion of injuries associated with the tackle may be due to its open and unpredictable nature in comparison to

more structured and controlled situations such as the scrum, maul or lineout.[1,29] This may warrant research that involves explaining the role of complex, rapidly changing sport systems[30] in tackle-related injury events. Using video analysis in future studies may be one method with which to achieve this.

The injury rates associated with the tackle may, however, be attenuated by adopting and implementing a multidisciplinary approach.[21] The following points are examples that could be incorporated into an injury prevention plan; (1) education and coaching of safe and effective tackle techniques e.g. body height and position, head position, and falling technique,[20,22,24] (2) prompting players to become aware of their immediate surroundings,[29] (3) coaching tackle technique in both a fatigued and non-fatigued state,[25] and (4) stricter officiating.[10,22]

Data from this study should not be generalised as the injury surveillance was conducted on a select cohort of elite youth rugby players at specific week-long tournaments in South Africa. Comparison of injury rates between youth and senior cohorts, and tournament and league formats should be made with caution. There are physical growth and developmental differences between the age-group levels, and previous team sport injury epidemiological research has shown that injury rates at tournaments may be inflated in comparison to injury rates during a league season.[31] This may be due to the higher intensity of play involved with a knock-out competition, fatigue-related factors due to matches being played on consecutive days, or over-reporting of injuries due to the presence of numerous medical personnel. Injury intervention strategies and injury management protocols should be sensitive to these differences.[2,14,22]

A limitation of this study is the short duration and competitive nature of the tournaments. This may result in teams 'hiding' injuries from the tournament doctor to keep that player available

for the duration of the week. Players may also have been less likely to report injuries on the final day of the tournament as they might have preferred to see their own physician once they had returned home.[7]

Continued injury surveillance is required in youth rugby union cohorts so that patterns can be identified and better interpreted. A reduced injury risk and a subsequent decrease in injury rates in rugby union should hopefully result in an enhanced player experience, prolonged participation, and increased player numbers.

Conclusion

This study provides insight into the nature and rates of tackle-related injuries occurring amongst youth rugby union players in South Africa. The finding that tackle-related injury rates decreased with increasing age is in contrast to previous literature. On-going injury surveillance is required to determine if this finding is repeated in future tournaments. Skeletal and muscular injuries were more prominent in the youngest playing group and the long-term impact of these might need further exploration. Fatigue appears to play a role in the increasing tackle-related injury rates as match time progresses. Further research is required to determine the precise effect of fatigue on tackle technique proficiency and its relation to injury. One can only create an effective injury prevention strategy once the precise risk factors and aetiology of tackle event injuries have been properly determined.

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Contributors

NB was granted access to analyse the data, was involved in conceptualising the manuscript, conducted statistical analyses and wrote the initial drafts of the manuscript. NB, JB and SH collected and entered the data. All authors (ML, WV, JB, CR and SH) were involved in conceptualising and editing drafts of the paper, in the order that they appear on the author list.

Competing interests

The authors have no conflict of interest to declare.

Ethics approval

UCT Human Ethics Committee

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Data sharing statement

Owing to the sensitive nature of the information and appropriate medical ethics, access to a more detailed aspect of the available dataset will be reviewed upon request and on a discretionary basis. Sharing of only depersonalised and non-relatable data will be considered, once permission has been received from WV or CR (can be contacted through the corresponding author).

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Table 1. Tournament details, 2011 vs. 2012.

	Under-13 Craven Week		Under-16 Grant Khomo Week		Under-18 Academy Week		Under-18 Craven Week	
Year	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**
Teams	18	18	18	20	26	26	20	20
Matches	36	36	27	30	39	39	30	29
Match time (minutes)	40	40	60	60	70	70	70	70
Exposure time (hours)	720	720	810	900	1365	1365	1050	1015

Table 2. Proportion of *'overall'* and *'time-loss'* tackle-related injury events occurring in the four South African Rugby Union (SARU) Youth Week tournaments, 2011 vs. 2012.

	Under-13 Craven Week		Under-16 Grant Khomo Week		Under-18 Academy Week		Under-18 Craven Week	
Year	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**
Overall tackle injury %	68	58	54	59	68	65	48	56
Tackler	29	39	19	38	48	37	31	39
Ball-carrier	39	19	35	21	20	28	17	17
TL tackle injury %	73	80	50	52	74	65	37	47
Tackler	27	45	6	48	50	39	20	31
Ball-carrier	46	35	44	4	24	26	17	16

TL – time-loss

Figure legend:

Fig.1. (a) A comparison of injury rate (± 95%CIs) of 'overall' tackle-related injuries (including 'time-loss' injuries) at each South African Rugby Union (SARU) tournament in 2011 (white bars) and 2012 (shaded bars), and (b) a comparison of injury rate (± 95%CIs) of tackle-related 'time-loss' injuries between each South African Rugby Union (SARU) tournament in 2011 (white bars) and 2012 (shaded bars). (CW13 – under-13 Craven Week; GK16 – under-16 Grant Khomo Week; AW18 – under-18 Academy Week; CW18 – under-18 Craven Week)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4-5
Methods			
Study design	4	Present key elements of study design early in the paper	5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6, 9
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	5-6
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7
Bias	9	Describe any efforts to address potential sources of bias	N/A
Study size	10	Explain how the study size was arrived at	N/A
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-9
		(*b*) Describe any methods used to examine subgroups and interactions	N/A
		(*c*) Explain how missing data were addressed	N/A
		(*d*) If applicable, explain how loss to follow-up was addressed	N/A
		(*e*) Describe any sensitivity analyses	N/A
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	5, 9
		(b) Indicate number of participants with missing data for each variable of interest	N/A
		(c) Summarise follow-up time (eg, average and total amount)	N/A
Outcome data	15*	Report numbers of outcome events or summary measures over time	9
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9-12
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	12-14
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	17

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

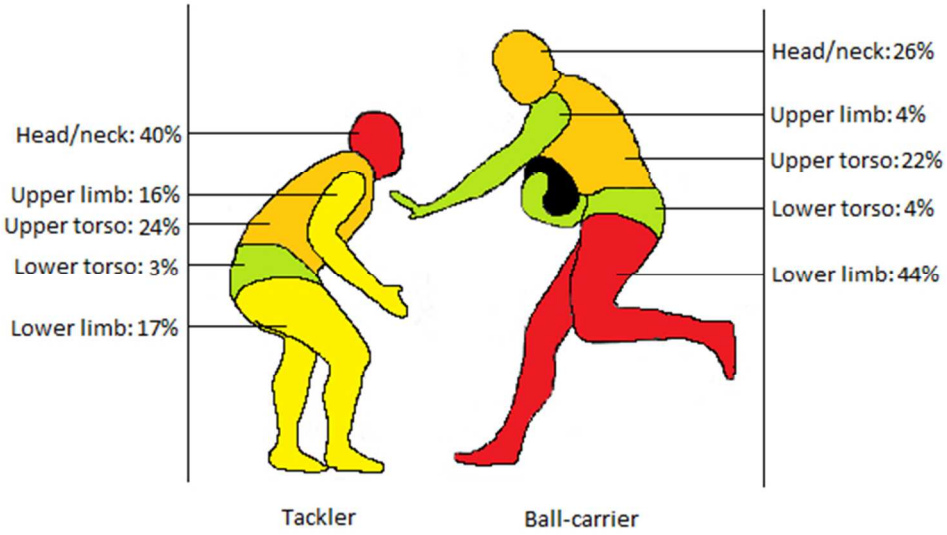
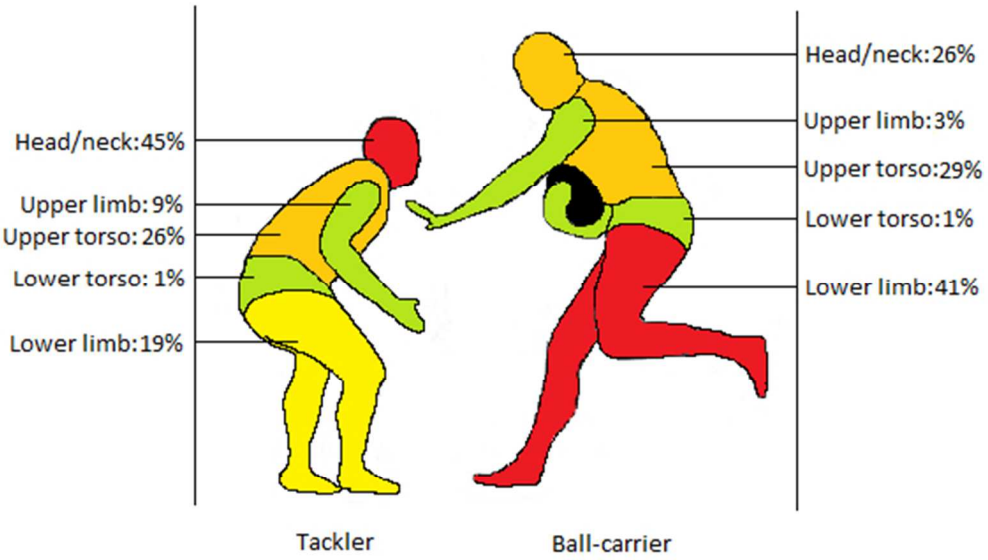


Fig. (a) A comparison of anatomical location of 'overall' tackle-related injuries in tacklers versus ball-carriers at each South African Rugby Union (SARU) tournament.



(b) a comparison of anatomical location of tackle-related 'time-loss' injuries in tacklers versus ball-carriers at each tournament.

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Tackle-related injury rates and nature of injuries in South African Youth Week tournament rugby union players (under-13 to under-18): an observational cohort study

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Tackle-related injury rates and nature of injuries in South African Youth Week tournament rugby union players (under-13 to under-18): an observational cohort study

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Abstract

Objectives

The tackle situation is most often associated with the high injury rates in rugby union. Tackle injury epidemiology in rugby union has previously been focused on senior cohorts but less is known about younger cohorts. The aim of this study was to report on the nature and rates of tackle-related injuries in South African youth rugby union players representing their provinces at national tournaments.

Design

Observational cohort study.

Setting

Four South African Youth Week tournaments (under-13 Craven Week, under-16 Grant Khomo Week, under-18 Academy Week, under-18 Craven Week).

Participants

Injury data were collected from 3652 youth rugby union players (population at risk) in 2011 and 2012.

Outcome measures

Tackle-related injury severity (*'time-loss'* and *'medical attention'*), type and location, injury rate per 1000 hours (including 95% confidence intervals). Injury rate ratios were calculated and modelled using a Poisson regression. A chi-squared analysis was used to detect linear trends between injuries and increasing match quarters.

Results

The 2012 under-13 Craven Week had a significantly greater *'time-loss'* injury rate when compared to the 2012 under-18 Academy Week (IRR: 4.43; 95%CI: 2.13-9.21, p<0.05) and under-18 Craven Week (IRR: 3.52; 95%CI: 1.54-8.00, p<0.05). The Poisson regression also revealed a higher probability of *'overall'* (*'time-loss'* and *'medical attention'* combined) and *'time-loss'* tackle-related injuries occurring at the under-13 Craven Week. The proportion of

'overall' and *'time-loss'* injuries increased significantly with each quarter of the match when all four tournaments were combined ($p<0.05$).

Conclusions

There was a difference in tackle-related injury rate between the under-13 tournament and the two under-18 tournaments, and tackle-related injury rate was higher in the final quarter of matches. On-going injury surveillance is required to better interpret these findings. Injury prevention strategies targeting the tackle may only be effective once rate and nature of the injuries have been accurately determined.

Strengths and limitations of this study

- This study is novel as it reports specifically on tackle-related injury rates and nature of injury in high-level South African youth rugby union players.
- Findings may help identify tackle injury prevention strategies for other youth rugby union players.
- Findings may help prepare medical professionals for injury assessment and management at youth rugby union tournaments.
- Only injuries reported to the tournament doctor were included in the analysis
- Data regarding height and weight for both injured and un-injured players were not gathered therefore player mismatch could not be analysed as a potential injury risk factor.
- Findings in this study should be generalised with caution as the analysis involved a specific cohort of players at a week-long tournament in which the match load was high compared to the recovery period.

Introduction

Rugby union is a team sport played worldwide and characterised by frequent contact and collision situations between players.[1-3] The ability to tolerate and contest these situations is a prerequisite for participation and success in the sport.[2,4,5] The high frequency of collisions places rugby players at higher risk of injury when compared to other non-collision team sports such as soccer and cricket.[6,7] In particular, the tackle is the contact event most often associated with this high rate of injury.[8-10]

The tackle is defined as "any event where one or more tacklers (player or players making the tackle) attempt to stop or impede the ball-carrier (player carrying the ball) whether or not the ball-carrier was brought to ground".[5,10] The tackle is an effective way to try and regain possession of the ball, and to prevent the attacking team from gaining field territory and advancing into a point-scoring position.[5]

Tackle-related injury rate has previously been reported for both league (professional English Premiership[8] and community level rugby[11]), and tournament (Rugby World Cup[12]) formats. The tackle is responsible for a high proportion of upper-body injuries in tacklers, particularly concussion, head/neck and shoulder injuries, and ball-carriers are more likely to sustain injuries to the lower-body, particularly thigh muscle and knee injuries.[8,9,13]

Despite the plethora of tackle injury studies with a focus on senior rugby union players,[9,10,14] less is known about youth cohorts. Therefore, the aim of this study was to report on the nature and rates of tackle-related injuries occurring at four national youth rugby union tournaments which were hosted by the South African Rugby Union (SARU) in 2011 and 2012. It is noteworthy that this study is unique in comparison to previous research as these tournaments span for one week only and have a high match load compared to recovery period.

The specific questions of this study, pertaining to tackle-related injuries at youth rugby union tournaments, are as follows; (1) what is the injury rate of the tournaments, (2) do injury rates differ across the tournaments, (3) what are the injury type proportions at the tournaments, (4) do injuries occur at different anatomical locations for ball-carriers and tacklers, and (5) does the rate of injury events increase with match time? The answers to these questions may contribute to the development and implementation of targeted injury prevention and management strategies in youth rugby.

Methods

SARU coordinates an injury-surveillance project, via the BokSmart National Rugby Safety Programme,[15] whereby information about all injuries that occur at their Youth Week tournaments are recorded and transcribed into an injury database. Authors were granted access to this database for analysis by SARU and the UCT Human Research Ethics Committee (HREC Ref: 438/2011). All players attending the Youth Week tournaments and their parents/legal guardians signed the SARU Medical and Anti-Doping informed consent form which has a section dedicated to explaining the details of the injury-surveillance project. No player was allowed to participate in the SARU Youth Week Tournaments if this form was not completed and signed by the player and his parent/legal guardian and submitted to the Team Manager. Assent was given by the player at the time of the injury to analyse the recorded information. The Youth Week tournaments are a showcase for South Africa's most talented schoolboy players and include the under-13 Craven Week, under-16 Grant Khomo Week, under-18 Academy Week and under-18 Craven Week tournaments. These tournaments are unique in that they only span the course of one week and may place increased physical demands on players. Participating teams are formed through the selection of the top schoolboy players from within each of the country's 14 provincial rugby unions in addition to one Namibian and one Zimbabwean team. In the case of the two under-18 tournaments, Craven Week involves the best schoolboy players from each union, while

the Academy Week involves the second tier of players from each union. Each team included 22 players with each player required to start and complete at least one match at the tournament unless forced off the field of play due to injury.

The structure of each week varied across the different tournaments (Table 1). 'Match days' (Ms) are defined as days on which all teams played an official tournament match on the same day. For the under-18 Craven Week, when only half the teams played in an alternating fashion for the first four days, one M would span two days to include all the team matches. These days were termed 'tournament match days' (TM) i.e. any day in which official rugby matches were played. This was done for the purpose of comparing the daily load on the tournament medical staff. These terms should be contrasted to 'rest days' (Rs), on which teams were able to partake in other sporting or recreational activities. Exposure was only calculated using Ms (not Rs).

A SARU-appointed doctor was on duty at each tournament to assess every injury that occurred. Details about each injury were recorded on an injury collection form that was designed based on the Consensus Statement for injury surveillance.[16] Only data pertaining to the tackle event were analysed for the purposes of this study.

The injury definition for these tournaments, adapted from the Rugby Union injury Consensus Statement,[16] was stated as *'any physical complaint, which was caused by a transfer of energy that exceeded the body's ability to maintain its structural and/or functional integrity, that was sustained by a player during a rugby match and required attention from the SARU tournament doctor'*.

'*Time-loss*' and '*medical attention*' tackle-related injuries were reported for this study. A '*time-loss*' injury was an injury (based on the aforementioned definition) that resulted in the player being absent for more than one match in a tournament, or more than one day of normal/planned recreational activities during or after the tournament. Injuries were confirmed as *'time-loss'* injuries during the course of the tournament or via telephonic follow-up after the tournament. Weekly phone calls were made to assess the state of the injury until the player returned to practice. '*Medical attention*' injuries required treatment from the tournament doctor, but resulted in no loss in recreational, play or practice time. '*Overall'* injuries included both '*medical attention*' and '*time-loss*' injury events. Due to the short duration of each tournament and low absolute injury numbers, *'medical attention'* injuries were included during the analyses in addition to *'time-loss'* injury data to gain insight into the rate and nature of tackle-related injuries.

The '*type*' of injury was categorised as either concussion, spinal cord, broken bone/fracture, joint/ligament/tendon, muscle, bruise, laceration (including skin abrasion), or other by the tournament doctor. If the tournament doctor was unable to diagnose the injury at the time, the injury '*type*' was recorded as '*unsure*'. The '*location*' of the injury was categorised into an anatomical group; head/neck, upper torso, upper limb, lower torso, lower limb, or '*unsure*'.

Statistical analysis

Player exposure time was calculated for all 2011 and 2012 tournaments based on the current injury collection consensus statement for rugby;[16]

$$Exposure\ time = \mathrm{N_M\ x\ P_M\ x\ D_M}$$

For this calculation, N_M is the number of matches, P_M is the number of players per match (i.e. 30 players from both sides), and D_M is the duration of the match in hours. This exposure time was used to determine the injury rate and corresponding 95% confidence intervals (95% CIs) for the number of tackle-related injuries per 1000 hours of match play regardless of whether a player was injured more than once.[17]

The injury rate ratios (IRR) and corresponding 95% CIs were calculated[18] to determine the difference in injury rates at the different tournaments (each year was analysed separately). The two under-18 tournaments were analysed separately because they are two different levels of play i.e. tier-one (under-18 Craven Week) and tier-two (Academy Week), they have different tournament structures, and therefore have different exposure times (Table 1). The IRR was calculated by dividing the injury rate of one tournament, for example tournament '*A*' (numerator – may be representative of any tournament from either year), by its total player exposure time, and then dividing this by the equivalent value for the specific tournament to which it was compared, for example tournament '*B*' (denominator – must be representative of another tournament from the same year);

$$IRR = \frac{injury\ rate_A / exposure_A}{injury\ rate_B / exposure_B}$$

The standard error (SE) of the log of the IRR was calculated by dividing the total number of tackle injuries of each of the two compared tournaments (*y*) by one, and finding the square root of their sum;

$$SElogIRR = \sqrt{\frac{1}{y_A} + \frac{1}{y_B}}$$

Confidence intervals (95%) were then calculated by using the log of the IRR and the SE of the log;

$$95\%\text{CI} = logIRR \pm 1.96 \text{ x } SElogIRR$$

The IRR was considered significantly greater for the numerator if both 95% CIs were greater than 1.0. Conversely, an IRR was considered significantly lower for the numerator if the both 95% CIs were less than 1.0.

Significant findings from the IRR analysis were verified using VRP injury statistics software (University of North Carolina, Injury Prevention Research Center).[19] The IRR between any two tournaments was only considered to be significant if the VRP analysis yielded a p-value of less than 0.05.

A Poisson regression was modelled using STATA 11.1 (StataCorp LP, USA) to determine the probability of injury at the tournaments (both years were combined and the under-18 Craven Week tournament was used as the reference i.e. denominator).

A chi-squared analysis was conducted using GraphPad Prism 5 (version 5.02 for Windows) to determine whether there were any significant linear trends ($p<0.05$) between the proportion of tackle-related injuries occurring in each match quarter for all tournaments across both years.

Results

Injury surveillance was conducted on 1804 players in 2011 and on 1848 players in 2012 (Table 1). Sixty per cent of '*overall*' injuries from 2011 and 2012 (n = 260 of 436 injuries) were tackle-related injuries. Sixty-one per cent of 'overall' tackle-related injuries (n = 158 of 260 injuries) were to the tackler and 39% (n = 102 of 260 injuries) were to the ball-carrier. Sixty-one per cent of all 'time-loss' injuries from 2011 and 2012 (n = 104 of 171 injuries) were associated with the tackle. Fifty-five per cent of tackle-related 'time-loss' injuries (n = 57 of 104 injuries) were to the tackler and 45% (n = 47 of 104 injuries) were to the ball-carrier. Injury rates were calculated for each tournament in both years (Table 2).

(Insert Tables 1 and 2)

The Poisson regression model revealed no significant differences in *'overall'* and *'time-loss'* tackle-related injury rate at the different tournaments when both years were combined. However, there was a higher probability of *'overall'* tackle-related injury at the under-13 Craven Week when compared to the under-18 Craven Week (IRR: 1.38; 95%CI: 0.96-1.99, p=0.08). Tackle-related *'time-loss'* injury also had a higher probability of occurring at the under-13 Craven Week when compared to the under-18 Craven Week (IRR: 1.79; 95%CI: 0.99-3.23, p=0.05).

There were no significant differences when *'overall'* and *'time-loss'* tackle-related IRRs were calculated for the 2011 tournaments. However, there was a significantly greater tackle-related '*time-loss*' injury rate at the 2012 under-13 Craven Week tournament when compared to the 2012 under-18 Academy Week (IRR: 4.43; 95%CI: 2.13-9.21, p<0.05) and

under-18 Craven Week (IRR: 3.52; 95%CI: 1.54-8.00, p<0.05). This is consistent with the result from the Poisson regression (see above).

(Insert Figures 1A and 1B)

The largest proportion of '*overall*' tackle-related injuries were joint/ligament/tendon '*type*' injuries (29%, n = 76 of 260 injuries), bruise/contusions (22%), muscle injuries (15%), concussions (10%), and lacerations (10%) when all tournaments in 2011 and 2012 were combined. The greatest proportion of tackle-related '*time-loss*' injuries were joint/ligament/tendon injuries (34%, n = 35 of 104 injuries), concussions (25%), broken bone/fractures (13%), and muscle injuries (12%).

When observing anatomical injury locations, 40% of '*overall*' tackle-related injuries (n = 63 of 158 injuries) to the tackler across all four tournaments in both years, were head/neck injuries. Upper torso injuries (24%) were the next most frequent in tacklers followed by lower limb (17%) and upper limb (16%) injuries. The majority of tackle-related 'time-loss' injuries to tacklers across all four tournaments in both years, were head/neck (44%; n = 25 of 57 injuries) followed by upper torso (30%), lower limb (18%) and upper limb (9%) injuries.

In contrast, the majority of ball-carrier '*overall*' tackle-related injuries were lower limb (44%; n = 45 of 102 injuries) followed by head/neck (25%) and upper torso (22%) injuries. The highest proportion of tackle-related *'time-loss'* injuries to ball-carriers were lower limb (40%; n = 19 of 47 injuries) followed by upper torso (28%) and head/neck (23%) injuries.

When 2011 and 2012 *'overall'* tackle-related injuries were combined, the proportion of injuries increased significantly with each quarter of the match (chi-squared linear trend:

p<0.05). Approximately 35% (n = 91 of 260 injuries) of *'overall'* tackle-related injuries across all tournaments in 2011 and 2012 occurred during the final quarter of the match. Twenty-four per cent of *'overall'* tackle-related injuries occurred in the third quarter followed by the second (23%) and first (17%) quarters (1% were unknown). Significantly more tackle-related *'time-loss'* injuries occurred in the final quarter of matches when both years were combined (p<0.05). Thirty-seven per cent (n = 38 of 104 injuries) of tackle-related *'time-loss'* injuries across all tournaments in both years occurred during the final quarter of the match followed by the second, third and first quarters (all 20%, 3% were unknown).

Discussion

This study is unique in that it reports exclusively on the nature and rates of tackle-related injuries in high-level South African youth rugby union players at a week-long tournament, and it will add to the current literature on tackle injury epidemiology, which is well documented in senior rugby union cohorts.[9,10,14]

The high proportion of tackle-related injuries observed in this study is consistent with previous rugby union research.[8-10] The higher proportion of both '*overall*' and '*time-loss*' injuries occurring to the tackler during this study is consistent with some studies conducted in youth rugby union,[20,21] however this finding is also in contrast to other studies which found ball-carriers to be at greater risk.[13,22,23] Therefore, based on these data, evidence is equivocal as to whether the tackler or ball-carrier is at greatest risk during the tackle situation.

The rate of *'overall'* tackle-related injuries at the Youth Week tournaments ranged from 23.8 injuries per 1000 exposure hours (95%CI: 14.5-33.1) at the 2011 under-18 Craven Week tournament to 50.0 injuries per 1000 exposure hours (95%CI: 33.7-66.3) at the 2012 under-

13 Craven Week tournament (Table 2). These injury rates are similar to those observed in English Premiership rugby union (33.9 injuries per 1000 exposure hours (30.3-37.9))[8] and at the Rugby World Cup (tackling 20.2 injuries per 1000 exposure hours (95%CI: 13.9-26.5)[12] and being tackled 18.7 injuries per 1000 exposure hours (95%CI: 12.6-24.7)). However they are much higher than those rates seen in English community-level rugby union (8.4 injuries per 1000 exposure hours (96%CI: 7.8-9.0)).[11] This may be due to the higher intensity and level of competition associated with high-level youth and professional senior rugby union in comparison to sub-elite levels of play. It is noteworthy that the English community-level rugby study took place over three seasons in comparison to the compressed tournament structure observed at the SARU Youth Week tournaments and at the Rugby World Cup.

This study showed that there were significantly more *'time-loss'* tackle-related injuries at the 2012 under-13 Craven Week in comparison to the two under-18 tournaments (Academy Week and Craven Week) in 2012. There were no significant differences in the probability of *'overall'* and *'time-loss'* tackle-related injury between the tournaments when both years were combined. However, there was a higher probability of an *'overall'* and *'time-loss'* tackle-related injury occurring at the under-13 Craven Week. On-going injury surveillance is necessary before these injury trends may be interpreted with confidence.

The type of tackle-related injuries did not differ greatly between the tournaments. The majority of injuries to the tackler were to the head/neck region while ball-carriers most frequently suffered a lower limb injury. Similar results have been found in senior cohorts,[9,14] although the current study's findings remain to be confirmed in other youth cohorts. These findings are not unexpected as the nature of the tackle situation in rugby union means that the upper extremity of the tackler and lower extremity of the ball-carrier are usually the first points of contact.[24]

The finding that the frequency of tackle-related injuries increased as playing time progressed within the match is consistent with previous findings in rugby union.[1,20] This was significant for both *'overall'* and *'time-loss'* tackle-related injuries and may be attributed to the effect of fatigue which has been found to play a role in reducing tackle technique proficiency in professional rugby league.[25] This may expose players to a greater risk of injury in the tackle situation as playing time in the match progresses. Therefore, each coach should make use of their entire squad and ensure that players are substituted and rotated in relation to their levels of fatigue. This is important at the Youth Week tournaments as matches are played on consecutive days and players have less time to recover. Coaches should also condition their players to tackle correctly under fatigued conditions. It is important to train, progress and reinforce tackle safety elements under fatigued and game-like conditions, where decision-making becomes important. By coaching and training these safety elements while fatigued, players will be more likely to execute a safer and more effective tackle under highly pressurised situations in dynamic environments.

Multiple risk factors play a role in causing an injury during a tackle event. For example, technique has been found to be an associated risk factor in previous tackle-related injury epidemiology research.[14,24] This may, in part, explain the higher rates of tackle-related injuries observed in the youngest playing group (under-13 Craven Week). Older, more experienced players have been found to execute a greater proportion of effective tackles, and also miss fewer tackles and incur fewer tackle-breaks.[14,26] It has also been found that players may only learn proper tackle technique at an older age.[27]

These findings emphasise the need for coaches to teach correct contact technique from an early age.[27] Correct technique is not only necessary to prevent injury but it also increases the likelihood of a successful performance outcome.[5] Further research into which optimal

movement patterns are required during tackle training is essential to help reduce injury rates.[28]

In addition to technique, it has also been suggested that the increased proportion of injuries associated with the tackle may be due to its open and unpredictable nature in comparison to more structured and controlled situations such as the scrum, maul or lineout.[1,29] This may warrant research that involves explaining the role of complex, rapidly changing sport systems[30] in tackle-related injury events. Using video analysis in future studies may be one method with which to achieve this.

The injury rates associated with the tackle may, however, be attenuated by adopting and implementing a multidisciplinary approach.[21] The following points are examples that could be incorporated into an injury prevention plan; (1) education and coaching of safe and effective tackle techniques e.g. body height and position, head position, and falling technique,[20,22,24] (2) prompting players to become aware of their immediate surroundings,[29] (3) coaching tackle technique in both a fatigued and non-fatigued state,[25] and (4) stricter officiating.[10,22]

Data from this study should be generalised with caution as the injury surveillance was conducted on a select cohort of high-level youth rugby players at specific week-long tournaments in South Africa. Comparison of injury rates between youth and senior cohorts, and tournament and league formats should also be made with caution. There are physical growth and developmental differences between the age-group levels, and previous team sport injury epidemiological research has shown that injury rates at tournaments may be inflated in comparison to injury rates during a league season.[31] This may be due to the higher intensity of play involved with a knock-out competition, fatigue-related factors due to matches being played on consecutive days, or over-reporting of injuries due to the presence

of numerous medical personnel. Injury intervention strategies and injury management protocols should be sensitive to these differences.[2,14,22]

A limitation of this study is the short duration and competitive nature of the tournaments. This may result in teams 'hiding' injuries from the tournament doctor to keep that player available for the duration of the week. Players may also have been less likely to report injuries on the final day of the tournament as they might have preferred to see their own physician once they had returned home.[7]

Continued injury surveillance is required in youth rugby union cohorts so that patterns can be identified and better interpreted. A reduced injury risk and a subsequent decrease in injury rates in rugby union should hopefully result in an enhanced player experience, prolonged participation, and increased player numbers.

Conclusion

This study provides insight into the nature and rates of tackle-related injuries occurring amongst youth rugby union players in South Africa. Tackle-related injury rate was highest at the 2012 under-13 Craven Week tournament, and a there was a higher probability for a tackle-related injury to occur at the under-13 Craven Week when both years were combined. On-going injury surveillance is required to determine if this finding is repeated in future tournaments. Tackle-related injury type did not differ across the tournaments for both *'overall'* and *'time-loss'* injuries. Fatigue appears to play a role in the increasing tackle-related injury rates as match time progresses. Further research is required to determine the precise effect of fatigue on tackle technique proficiency and its relation to injury. This evidence, along with information detailing the precise risk factors and aetiology of tackle event injuries, may help guide the formation of effective injury prevention strategies.

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Contributors

NB was granted access to analyse the data, was involved in conceptualising the manuscript, conducted statistical analyses and wrote the initial drafts of the manuscript. NB, JB and SH collected and entered the data. All authors (ML, WV, JB, CR and SH) were involved in conceptualising and editing drafts of the paper, in the order that they appear on the author list.

Competing interests

The authors have no conflict of interest to declare.

Ethics approval

UCT Human Ethics Committe

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Data sharing statement

Owing to the sensitive nature of the information and appropriate medical ethics, access to a more detailed aspect of the available dataset will be reviewed upon request and on a

discretionary basis. Sharing of only depersonalised and non-relatable data will be considered, once permission has been received from WV or CR (can be contacted via email through the corresponding author - nicholas.burger@uct.ac.za).

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514 **Table 1. Tournament details, 2011 vs. 2012.**

	Under-13 Craven Week		Under-16 Grant Khomo Week		Under-18 Academy Week		Under-18 Craven Week	
Year	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**
Teams	18	18	18	20	26	26	20	20
Matches	36	36	27	30	39	39	30	29
Match time (minutes)	40	40	60	60	70	70	70	70
Tournament structure	M, M, R, M, M		M,M,R,M		M,M,R,M		TM, TM, TM, TM, R, M	
Exposure time (hours)	720	720	810	900	1365	1365	1050	1015

515 **M – match day, R – rest day, TM – tournament match day**

516

517 **Table 2. *'Overall'* and *'time-loss'* tackle-related injury rates occurring in the four South**

518 **African Rugby Union (SARU) Youth Week tournaments, 2011 vs. 2012.**

	Under-13 Craven Week		Under-16 Grant Khomo Week		Under-18 Academy Week		Under-18 Craven Week	
Year	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**
Overall tackle injuries (n)	21	36	20	33	47	44	25	34
Overall injury rate	29.2	50.0	24.7	36.7	34.4	32.2	23.8	33.5
95% CI	16.8 - 41.6	33.7 - 66.3	13.9 - 35.5	24.2 - 49.2	24.6 - 44.3	22.7 - 41.8	14.5 - 33.1	22.2 - 44.8
TL tackle injuries (n)	9	16	8	13	25	13	11	9
TL injury rate	12.5	22.2	9.9	14.4	18.3	9.5	10.5	8.9
95% CI	4.3 - 20.7	11.3 - 33.1	3.0 - 16.7	6.6 - 22.3	11.1 - 25.5	4.3 - 14.7	4.3 - 16.7	3.1 - 14.7

519 **Injury rate per 1000 exposure hours; 95% CI – 95% confidence intervals; TL – time-**

520 **loss**

Figure legend:

Fig.1. (a) A comparison of injury rate (± 95%CIs) of 'overall' tackle-related injuries (including 'time-loss' injuries) at each South African Rugby Union (SARU) tournament in 2011 (white bars) and 2012 (shaded bars), and (b) a comparison of injury rate (± 95%CIs) of tackle-related 'time-loss' injuries between each South African Rugby Union (SARU) tournament in 2011 (white bars) and 2012 (shaded bars). (CW13 – under-13 Craven Week; GK16 – under-16 Grant Khomo Week; AW18 – under-18 Academy Week; CW18 – under-18 Craven Week)

Fig.1. (b) A comparison of injury rate (± 95%CIs) of tackle-related 'time-loss' injuries between each South African Rugby Union (SARU) tournament in 2011 (white bars) and 2012 (shaded bars). (CW13 – under-13 Craven Week; GK16 – under-16 Grant Khomo Week; AW18 – under-18 Academy Week; CW18 – under-18 Craven Week)

Tackle-related injury rates and nature of injuries in South African ~~national~~ Youth Week tournament rugby union players ~~tournaments in South Africa~~ (under-13 to under-18): an observational cohort study

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Abstract

Objectives

The tackle situation is most often associated with the high injury rates in rugby union. Tackle injury epidemiology in rugby union has previously been focused on senior cohorts but less is known about younger cohorts. The aim of this study was to report on the nature and rates of tackle-related injuries in South African youth rugby union players representing their provinces at national tournaments ~~in elite South African youth rugby union players.~~

Design

Observational cohort study.

Setting

Four South African Youth Week tournaments (under-13 Craven Week, under-16 Grant Khomo Week, under-18 ~~academy~~ Academy Week, under-18 Craven Week).

Participants

Injury data were collected from 3652 youth rugby union players (population at risk) in 2011 and 2012.

Outcome measures

Tackle-related injury severity (*'time-loss'* and *'medical attention'*), type and location, injury rate per 1000 hours (including 95% confidence intervals). Injury rate ratios were calculated and modelled using a Poisson regression. A chi-squared analysis was used to detect linear trends between injuries and increasing match quarters.

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Results

The 2012 under-13 Craven Week had a significantly greater *'time-loss'* injury rate when compared to the 2012 under-18 Academy Week (IRR: 4.43; 95%CI: 2.13-9.21, p<0.05) and under-18 Craven Week (IRR: 3.52; 95%CI: 1.54-8.00, p<0.05). ~~There was~~ The Poisson regression also revealed a higher probability of *'overall'* (*'time-loss'* and *'medical attention'* combined) and *'time-loss'* tackle-related injuries occurring at the under-13 Craven Week. ~~The under-13 Craven Week had a significantly greater *'time-loss'* injury rate when compared to the 2012 under-18 Craven Week (IRR: 3.52; 95%CI: 1.54-8.00, p<0.05). The under-13 Craven Week also had the greatest proportion of broken bone/factures and muscular injuries for both *'overall'* (12% and 23%) and *'time-loss'* injuries (28% and 22%).~~ The proportion of *'overall'* and *'time-loss'* injuries increased significantly with each quarter of the match when all four tournaments were combined (p<0.05).

Conclusions

~~Age~~ There was a difference in tackle-related injury rate between the under-13 tournament and the two under-18 tournaments and tackle-related injury rate increased as match time progressed~~match-related fatigue may affect the rates and nature of tackle-related injuries in youth rugby union~~. On-going injury surveillance is required to better interpret these findings. Injury prevention strategies targeting the tackle may only be effective once rate and nature of the injuries have been accurately determined.

Key words: youth; injury epidemiology; rugby union; tackle.

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Strengths and limitations of this study

- This study is novel as it reports specifically on tackle-related injury rates and nature of injury in ~~elite~~ high-level South African youth rugby union players.
- Findings may help identify tackle injury prevention strategies for other youth rugby union players.
- Findings may help prepare medical professionals for injury assessment and management at youth rugby union tournaments.
- Only injuries reported to the tournament doctor were included in the analysis
- Data regarding height and weight for both injured and un-injured players were not gathered therefore player mismatch could not be analysed as a potential injury risk factor.
- Findings in this study should ~~not~~ be generalised with caution as the analysis involved a specific cohort of players at a week-long tournament in which the match load was high compared to the recovery period.

Introduction

Rugby union is a team sport played worldwide and characterised by frequent contact and collision situations between players.[1-3] The ability to tolerate and contest these situations is a prerequisite for participation and success in the sport.[2,4,5] The high frequency of ~~contact situations~~collisions places rugby players at higher risk of injury when compared to other non-collision team sports such as soccer and cricket.[6,7] In particular, the tackle is the contact event most often associated with this high rate of injury.[8-10]

The tackle is defined as "any event where one or more tacklers (player or players making the tackle) attempt to stop or impede the ball-carrier (player carrying the ball) whether or not the ball-carrier was brought to ground".[5,10] The tackle is an effective way to try and regain possession of the ball, and to prevent the attacking team from gaining field territory and advancing into a point-scoring position.[5]

Tackle-related injury rate has previously been reported for both league ~~and tournament formats in~~ (professional English Premiership ~~rugby~~[8] and community level rugby[11]), and ~~at the~~ tournament ~~(~~Rugby World Cup[12]~~,)~~[11] ~~respectively~~ formats. The tackle is responsible for a high proportion of upper-body injuries in tacklers, particularly concussion, head/neck and shoulder injuries, and ball-carriers are more likely to sustain injuries to the lower-body, particularly thigh muscle and knee injuries.[8,9,~~12~~ 13]

Despite the plethora of tackle injury studies with a focus on senior rugby union players,[9,10,~~14~~ 15]less is known about youth cohorts. Therefore, the aim of this study was to report on the nature and rates of tackle-related injuries occurring at four ~~elite~~ national youth rugby union tournaments which were hosted by the South African Rugby Union (SARU) in 2011 and 2012. It is noteworthy that this study is unique in comparison to previous research as these

tournaments span for one week only and have a high match load compared to recovery period.~~.~~

The specific questions of this study, pertaining to tackle-related injuries at youth rugby union tournaments, are as follows; (1) what is the injury rate of the tournaments, (~~1~~2) ~~are~~ do injury rates ~~comparable~~ differ across the ~~age categories~~tournaments ~~(13 to 18 years)~~, (~~2~~3) ~~do~~ what are the injury type proportions at the tournaments ~~differ across the age categories~~, (~~3~~4) do injuries occur at different anatomical locations for ball-carriers and tacklers, and (~~4~~5) does the rate of injury events increase with match time? The answers to these questions may contribute to the development and implementation of targeted injury prevention and management strategies in youth rugby.

Methods

SARU coordinates an injury-surveillance project, via the BokSmart National Rugby Safety Programme,[~~15~~ 16] whereby information about all injuries that occur at their Youth Week tournaments are recorded and transcribed into an injury database. Authors were granted access to this database for analysis by SARU and the UCT Human Research Ethics Committee (HREC Ref: 438/2011). All players attending the Youth Week tournaments and their parents/legal guardians signed the SARU Medical and Anti-Doping informed consent form which has a section dedicated to explaining the details of the injury-surveillance project. When a player was injured, informed consent to analyse the recorded information was ~~once~~ ~~again~~ confirmed either by the player or by the player's parent or guardian if present at the time of the injury assessment. At this point, the player or parent/guardian had the option to deny access to their personal information or details regarding the injury event. The Youth Week tournaments are a showcase for South Africa's most talented schoolboy players and include the under-13 Craven Week, under-16 Grant Khomo Week, under-18 Academy Week

and under-18 Craven Week tournaments. These tournaments are unique in that they only span the course of one week and ~~thus~~ may place increased physical demands on players. Participating teams are formed through the selection of the top schoolboy players from within each of the country's 14 provincial rugby unions in addition to one Namibian and one Zimbabwean team. In the case of the two under-18 tournaments, Craven Week involves the best schoolboy players from each union, while the Academy Week involves the second tier of players from each union. Each team included 22 players with each player required to start and complete at least one match at the tournament unless forced off the field of play due to injury.

The structure of each week varied across the different tournaments (Table 1). 'Match days' (Ms) are defined as days on which all teams played an official tournament match on the same day. For the under-18 Craven Week, when only half the teams played in an alternating fashion for the first four days, one M would span two days to include all the team matches. These days were termed 'tournament match days' (TM) i.e. any day in which official rugby matches were played. This was done for the purpose of comparing the daily load on the tournament medical staff. These terms should be contrasted to 'rest days' (Rs), on which teams were able to partake in other sporting or recreational activities. Exposure was only calculated using Ms (not Rs).

A SARU-appointed doctor was on duty at each tournament to assess every injury that occurred. Details about each injury were recorded on an injury collection form that was designed based on the Consensus Statement for injury surveillance.[~~16~~ 17] Only data pertaining to the tackle event were analysed for the purposes of this study.

The injury definition for these tournaments, adapted from the Rugby Union injury Consensus Statement,[16 17] was stated as *'any physical complaint, which was caused by a transfer of energy that exceeded the body's ability to maintain its structural and/or functional integrity, that was sustained by a player during a rugby match and required attention from the SARU tournament doctor'*.

'*Time-loss*' and '*medical attention*' tackle-related injuries were reported for this study. A '*time-loss*' injury was an injury (based on the aforementioned definition) that resulted in the player being absent for more than one match in a tournament, or more than one day of normal/planned recreational activities during or after the tournament. Injuries were confirmed as *'time-loss'* injuries during the course of the tournament or via telephonic follow-up after the tournament. Weekly phone calls were made to assess the state of the injury until the player returned to practice. '*Medical attention*' injuries required treatment from the tournament doctor, but resulted in no loss in recreational, play or practice time. '*Overall'* injuries included both '*medical attention*' and '*time-loss*' injury events. Due to the short duration of each tournament and low absolute injury numbers, *'medical attention'* injuries were included during the analyses~~, as important information may have been overlooked if only~~ in addition to *'time-loss'* injury data ~~were considered.~~[7] to gain insight into the rate and nature of tackle-related injuries.

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The '*type*' of injury was categorised as either concussion, spinal cord, broken bone/fracture, joint/ligament/tendon, muscle, bruise, laceration (including skin abrasion), or other by the tournament doctor. If the tournament doctor was unable to diagnose the injury at the time, the injury '*type*' was recorded as '*unsure*'. The '*location*' of the injury was categorised into an anatomical group; head/neck, upper torso, upper limb, lower torso, lower limb, or '*unsure*'.

Statistical analysis

Player exposure time was calculated for all 2011 and 2012 tournaments based on the current injury collection consensus statement for rugby;[16 17]

$$Exposure\ time = N_M \text{ x } P_M \text{ x } D_M$$

For this calculation, N_M is the number of matches, P_M is the number of players per match (i.e. 30 players from both sides), and D_M is the duration of the match in hours. This exposure time was used to determine the injury rate and corresponding 95% confidence intervals (95% CIs) for the number of tackle-related injuries per 1000 hours of match play regardless of whether a player was injured more than once.[17 18]

The injury rate ratios (IRR) and corresponding 95% CIs were ~~calculated~~[18] calculated[19] to determine the difference in injury rates ~~across the age categories~~at the different tournaments (each year was analysed separately). The two under-18 tournaments were analysed separately because they are two different levels of play i.e. tier-one (under-18 Craven Week) and tier-two (Academy Week), they have different tournament structures, and therefore have different exposure times (Table 1). The IRR was calculated by dividing the injury rate of one tournament, for example ~~year~~ tournament '*A*' (numerator – may be representative of any tournament from either year), by its total player exposure time, and then dividing this by the equivalent value for the specific tournament to which it was compared, for example ~~year~~

tournament '*B*' (denominator – must be representative of another tournament from the same year);

$$IRR = \frac{injury\ rate_A / exposure_A}{injury\ rate_B / exposure_B}$$

The standard error (SE) of the log of the IRR was calculated by dividing the total number of tackle injuries of each of the two compared tournaments (*y*) by one, and finding the square root of their sum;

$$SElogIRR = \sqrt{\frac{1}{y_A} + \frac{1}{y_B}}$$

Confidence intervals (95%) were then calculated by using the log of the IRR and the SE of the log;

$$95\%\text{CI} = logIRR \pm 1.96 \text{ x } SElogIRR$$

The IRR was considered significantly greater for the numerator if both 95% CIs were greater than 1.0. Conversely, an IRR was considered significantly lower for the numerator if the both 95% CIs were less than 1.0.

Significant findings from the IRR analysis were verified using VRP injury statistics software (University of North Carolina, Injury Prevention Research Center).[19 20] The IRR between any

two tournaments was only considered to be significant if the VRP analysis yielded a p-value of less than 0.05.

A Poisson regression was modelled using STATA 11.1 (StataCorp LP, USA) to determine the probability of injury ~~across the age categories~~at the tournaments (both years were combined and the~~-~~ under-18 Craven Week tournament was used as the reference i.e. denominator). ~~The year of the each tournament was factored into the model (2011 was used as the reference i.e. denominator) even though this was not part of the main analysis.~~

A chi-squared analysis was conducted using GraphPad Prism 5 (version 5.02 for Windows) to determine whether there were any significant linear trends ($p<0.05$) between the proportion of tackle-related injuries occurring in each match quarter for all tournaments across both years.

Results

Injury surveillance was conducted on 1804 players in 2011 and on 1848 players in 2012 (Table 1). Sixty per cent of '*overall*' injuries ~~(Table 2)~~ from 2011 and 2012 (n = ~~263~~ 260 of ~~440~~ 436 injuries) were tackle-related injuries. Sixty-one per cent of 'overall' tackle-related injuries (n = 158 of 260 injuries) were to the tackler and 39% (n = 102 of 260 injuries) were to the ball-carrier. ~~Fifty-nine~~Sixty-one per cent of all 'time-loss' injuries ~~(Table 2)~~ from 2011 and 2012 (n = 104 of ~~176~~ 171 injuries) were associated with the tackle. ~~Sixty~~ Fifty-five per cent of tackle-related 'time-loss' injuries (n = 57 of 104 injuries) were to the tackler and ~~40~~45% (n = 47 of 104 injuries) were to the ball-carrier. Injury rates were calculated for each tournament in both years (Table 2).

(Insert Tables 1 and 2)

~~The '*overall*' tackle related injury rates at the 2011 tournaments were 29.2 injuries per 1000 exposure hours (95%CI: 16.8-41.6) at under-13 Craven Week, 24.7 injuries per 1000 exposure hours (95%CI: 13.9-35.5) at under-16 Grant Khomo Week, 34.4 injuries per 1000 exposure hours (95%CI: 24.6-44.3) at under-18 Academy Week, and 23.8 injuries per 1000 exposure hours (95%CI: 14.5-33.1) at under-18 Craven Week (Figure 1A). The '*overall*' tackle related injury rates at the 2012 tournaments were 50.0 injuries per 1000 exposure hours (95%CI: 33.7-66.3) at under-13 Craven Week, 36.7 injuries per 1000 exposure hours (95%CI: 24.2-49.2) at under-16 Grant Khomo Week, 34.4 injuries per 1000 exposure hours (95%CI: 24.6-44.3) at under-18 Academy Week, and 33.5 injuries per 1000 exposure hours (95%CI: 22.2-44.8) at under-18 Craven Week.~~

~~Analysis of tackle related '*time-loss*' injury rates of the 2011 tournaments showed 11.1 injuries per 1000 exposure hours (95%CI: 3.4-18.8) at under-13 Craven Week, 9.9 injuries per 1000 exposure hours (95%CI: 3.0-16.7) at under-16 Grant Khomo Week, 18.3 injuries per 1000 exposure hours (95%CI: 11.1-25.5) at under-18 Academy Week, and 10.5 injuries per 1000 exposure hours (95%CI: 4.3-16.7) at under-18 Craven Week (Figure 1B). The tackle related '*time-loss*' injury rates of the 2012 tournaments showed 22.2 injuries per 1000 exposure hours (95%CI: 11.3-33.1) at under-13 Craven Week, 13.3 injuries per 1000 exposure hours (95%CI: 5.8-20.9) at under-16 Grant Khomo Week, 11.0 injuries per 1000 exposure hours (95%CI: 5.4-16.6) at under-18 Academy Week, and 8.9 injuries per 1000 exposure hours (95%CI: 3.1-14.7) at under-18 Craven Week.~~

The Poisson regression model revealed no significant differences in *'overall'* and *'time-loss'* tackle-related injury rate ~~across the age categories~~at the different tournaments when both

years were combined. However, there was a higher probability of *'overall'* tackle-related injury at the under-13 Craven Week when compared to the under-18 Craven Week (IRR: 1.38; 95%CI: 0.96-1.99, p=0.08). Tackle-related *'time-loss'* injury also had a higher probability of occurring at the under-13 Craven Week when compared to the under-18 Craven Week (IRR: ~~1.72~~1.79; 95%CI: ~~0.95~~0.99-~~3.12~~3.23, p=~~0.07~~0.05). ~~There was a significantly higher chance of incurring an *'overall'* tackle-related injury in 2012 when compared to 2011 (IRR: 1.31; 95%CI: 1.03-1.67, p<0.05).~~

There were no significant differences when *'overall'* and *'time-loss'* tackle-related IRRs were calculated for the 2011 tournaments. However, there was a significantly greater tackle-related '*time-loss*' injury rate at the 2012 under-13 Craven Week tournament when compared to the 2012 under-18 Academy Week (IRR: 4.43; 95%CI: 2.13-9.21, p<0.05) and under-18 Craven Week (IRR: 3.52; 95%CI: 1.54-8.00, p<0.05). This is consistent with the result from the Poisson regression (see above).

(Insert Figures 1A and 1B)

The largest proportion of '*overall*' tackle-related injuries were joint/ligament/tendon '*type*' injuries (29%, n = 76 of 260 injuries), bruise/contusions (2~~1~~%), muscle injuries (15%), concussions (~~11~~10%), and lacerations (10%) when all tournaments in 2011 and 2012 were combined. The greatest proportion of tackle-related '*time-loss*' injuries were joint/ligament/tendon injuries (~~32~~34%, n = 35 of 104 injuries), concussions (~~27~~25%), ~~muscle injuries (12%), and~~ broken bone/fractures (~~12~~13%), and muscle injuries (12%). ~~The under-13 Craven Week tournament had the greatest proportion of broken bone/factures and muscle-related injuries for both '*overall*' (12% and 23% respectively) and '*time-loss*' injuries (28% and 22% respectively) when 2011 and 2012 were combined.~~

When observing anatomical injury locations, 40% of '*overall*' tackle-related injuries (n = 63 of 158 injuries) to the tackler across all four tournaments in both years, were head/neck injuries. Upper torso injuries (24%) were the next most frequent in tacklers followed by lower limb (17%) and upper limb (16%) injuries. The majority of tackle-related 'time-loss' injuries to tacklers across all four tournaments in both years, were head/neck (~~45~~44%; n = 25 of 57 injuries) followed by upper torso (~~26~~30%), lower limb (~~19~~18%) and upper limb (~~10~~9%) injuries.

In contrast, the majority of ball-carrier '*overall*' tackle-related injuries were lower limb (44%; n = 45 of 102 injuries) followed by head/neck (~~26~~25%) and upper torso (22%) injuries. The highest proportion of tackle-related *'time-loss'* injuries to ball-carriers were lower limb (~~41~~40%; n = 19 of 47 injuries) followed by upper torso (~~29~~28%) and head/neck (~~26~~23%) injuries.

When 2011 and 2012 *'overall'* tackle-related injuries were combined, the proportion of injuries increased significantly with each quarter of the match (chi-squared linear trend: p<0.05). Approximately 35% (n = 91 of 260 injuries) of *'overall'* tackle-related injuries across all tournaments in 2011 and 2012 occurred during the final quarter of the match. Twenty-four per cent of *'overall'* tackle-related injuries occurred in the third quarter followed by the second (23%) and first (17%) quarters (1% were unknown). Significantly more tackle-related *'time-loss'* injuries occurred in the final quarter of matches when both years were combined (p<0.05). Thirty ~~three~~ seven per cent (n = 38 of 104 injuries) of tackle-related *'time-loss'* injuries across all tournaments in both years occurred during the final quarter of the match followed by the second ~~(24%)~~, third ~~(22%)~~ and first ~~(18%)~~ quarters (all 20%, 3% were unknown).

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Discussion

This study is unique in that it reports exclusively on the nature and rates of tackle-related injuries in ~~elite~~ high-level South African youth rugby union players at a week-long tournament, and it will add to the current literature on tackle injury epidemiology, which is well documented in senior rugby union cohorts.[9,10,~~14~~15]

The high proportion of tackle-related injuries observed in this study ~~(Table 2)~~ is consistent with previous rugby union research.[8-10] The higher proportion of both '*overall*' and '*time-loss*' injuries occurring to the tackler during this study is consistent with some studies conducted in youth rugby union,[~~13~~14,~~20~~21,~~21~~ 22] however this finding is also in contrast to other studies which found ball-carriers to be at greater risk.[~~12~~13,~~22~~ 23,24] ~~A summary of the evidence suggests that both the tackler and the ball-carrier are proportionally at similar risk of injury during a tackle event.~~ Therefore, based on these data, evidence is equivocal as to whether the tackler or ball-carrier is at greatest risk during the tackle situation.

The rate of *'overall'* tackle-related injuries at the Youth Week tournaments ranged from 23.8 injuries per 1000 exposure hours (95%CI: 14.5-33.1) at the 2011 under-18 Craven Week tournament to 50.0 injuries per 1000 exposure hours (95%CI: 33.7-66.3) at the 2012 under-13 Craven Week tournament (Table 2). These injury rates are similar to those observed in English Premiership rugby union (33.9 injuries per 1000 exposure hours (30.3-37.9))[8] and at the Rugby World Cup (tackling 20.2 injuries per 1000 exposure hours (95%CI: 13.9-26.5)[12] and being tackled 18.7 injuries per 1000 exposure hours (95%CI: 12.6-24.7)). However they are much higher than those rates seen in English community-level rugby union (8.4 injuries per 1000 exposure hours (96%CI: 7.8-9.0)).[11] This may be due to the higher intensity and level of competition associated with high-level youth and professional senior rugby union in

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comparison to sub-elite levels of play. It is noteworthy that the English community-level rugby study took place over three seasons in comparison to the compressed tournament structure observed at the SARU Youth Week tournaments and at the Rugby World Cup.

This study showed ~~a~~ that there were significantly ~~decrease~~ more ~~in~~ *'time-loss'* tackle-related injuries ~~between~~ at the 2012 under-13 Craven Week ~~and~~ in comparison to the two under-18 tournaments (Academy Week and Craven Week) ~~tournaments~~ in 2012. ~~This decrease in injury rates with increasing age is in contrast to previous research.[3,13,14]~~ There were no significant differences in the probability of *'overall'* and *'time-loss'* tackle-related injury between the ~~age categories~~tournaments when both years were combined. ~~However, there was a significantly greater probability of an *'overall'* tackle-related injury occurring in 2012 when compared to 2011, although this was not a part of the main analysis.~~ On-going injury surveillance is necessary before these injury trends may be interpreted with confidence.

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The type of tackle-related injuries did not differ greatly between the ~~age categories~~tournaments. ~~However, there were a higher proportion of skeletal and muscular tackle-related injuries at the under-13 Craven Week tournament. This may perhaps be attributed to the fact that the adolescent skeletal system takes time to adapt to the rapid increase in muscular strength experienced during puberty[20] and, as such, not all adolescents are able to tolerate frequent contact situations, potentially placing them at a greater risk. This is an important consideration as these types of contact injuries may affect growth and development.~~

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~~The prevalence of concussion injuries at these tournaments, consistent with previous research in rugby union,[13,21] remains an area of concern and highlights the need for danger~~

~~and symptom awareness amongst coaching staff, parents and players[3] as many concussion injuries go unreported.[23] In certain instances, symptoms may only manifest at a later stage.~~

The majority of injuries to the tackler were to the head/neck region while ball-carriers most frequently suffered a lower limb injury. Similar results have been found in senior cohorts,[9,~~14~~ 15] although the current study's findings remain to be confirmed in other youth cohorts. These findings are not unexpected as the nature of the tackle situation in rugby union means that the upper extremity of the tackler and lower extremity of the ball-carrier are usually the first points of contact.[~~24~~25]

The finding that the frequency of tackle-related injuries increased as playing time progressed within the match is consistent with previous findings in rugby union.[1,~~20~~ 21] This was significant for both *'overall'* and *'time-loss'* tackle-related injuries and may be attributed to the effect of fatigue which has been found to play a role in reducing tackle technique proficiency in professional rugby league.[~~25 26~~] This may expose players to a greater risk of injury in the tackle situation as playing time in the match progresses. Therefore, each coach should make use of their entire squad and ensure that players are substituted and rotated in relation to their levels of fatigue. This is important at the Youth Week tournaments as matches are played on consecutive days and players have less time to recover. Coaches should also condition their players to tackle correctly under fatigued conditions. It is important to train, progress and reinforce tackle safety elements under fatigued and game-like conditions, where decision-making becomes important. By coaching and training these safety elements while fatigued, players will be more likely to execute a safer and more effective tackle under highly pressurised situations in dynamic environments.

Multiple risk factors play a role in causing an injury during a tackle event. For example, technique has been found to be an associated risk factor in previous tackle-related injury

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epidemiology research.[13,14,24,25] This may, in part, explain the higher rates of tackle-related injuries observed in the youngest playing group (under-13 Craven Week). Older, more experienced players have been found to execute a greater proportion of effective tackles, and also miss fewer tackles and incur fewer tackle-breaks.[14,15,26,27] It has also been found that players may only learn proper tackle technique at an older age.[27,28]

These findings emphasise the need for coaches to teach correct contact technique from an early age.[27,28] Correct technique is not only necessary to prevent injury but it also increases the likelihood of a successful performance outcome.[5] Further research into which optimal movement patterns are required during tackle training is essential to help reduce injury rates.[28,29]

In addition to technique, it has also been suggested that the increased proportion of injuries associated with the tackle may be due to its open and unpredictable nature in comparison to more structured and controlled situations such as the scrum, maul or lineout.[1,29,30] This may warrant research that involves explaining the role of complex, rapidly changing sport ~~systems~~[30] systems[31] in tackle-related injury events. Using video analysis in future studies may be one method with which to achieve this.

The injury rates associated with the tackle may, however, be attenuated by adopting and implementing a multidisciplinary approach.[21,22] The following points are examples that could be incorporated into an injury prevention plan; (1) education and coaching of safe and effective tackle techniques e.g. body height and position, head position, and falling technique,[20,21,22,23,24,25] (2) prompting players to become aware of their immediate surroundings,[29,30] (3) coaching tackle technique in both a fatigued and non-fatigued state,[25,26] and (4) stricter officiating.[10,22,23]

Data from this study should ~~not~~ be generalised with caution as the injury surveillance was conducted on a select cohort of ~~elite~~ high-level youth rugby players at specific week-long tournaments in South Africa. Comparison of injury rates between youth and senior cohorts, and tournament and league formats should also be made with caution. There are physical growth and developmental differences between the age-group levels, and previous team sport injury epidemiological research has shown that injury rates at tournaments may be inflated in comparison to injury rates during a league season.[~~31~~ 32] This may be due to the higher intensity of play involved with a knock-out competition, fatigue-related factors due to matches being played on consecutive days, or over-reporting of injuries due to the presence of numerous medical personnel. Injury intervention strategies and injury management protocols should be sensitive to these differences.[2,~~14~~15,~~22~~ 23]

A limitation of this study is the short duration and competitive nature of the tournaments. This may result in teams 'hiding' injuries from the tournament doctor to keep that player available for the duration of the week. Players may also have been less likely to report injuries on the final day of the tournament as they might have preferred to see their own physician once they had returned home.[7]

Continued injury surveillance is required in youth rugby union cohorts so that patterns can be identified and better interpreted. A reduced injury risk and a subsequent decrease in injury rates in rugby union should hopefully result in an enhanced player experience, prolonged participation, and increased player numbers.

Conclusion

This study provides insight into the nature and rates of tackle-related injuries occurring amongst youth rugby union players in South Africa. ~~The finding that t~~Tackle-related injury rate~~s decreased~~ was highest at the 2012 under-13 Craven Week tournament~~with increasing age is in contrast to previous literature~~. On-going injury surveillance is required to determine if this finding is repeated in future tournaments. Tackle-related injury type did not differ across the tournaments for both *'overall'* and *'time-loss'* injuries. ~~Skeletal and muscular injuries were more prominent in the youngest playing group and the long-term impact of these might need further exploration.~~ Fatigue appears to play a role in the increasing tackle-related injury rates as match time progresses. Further research is required to determine the precise effect of fatigue on tackle technique proficiency and its relation to injury. ~~One can only create an effective injury prevention strategy once the~~ This evidence, along with information detailing the precise risk factors and aetiology of tackle event injuries, may help guide the formation of effective injury prevention strategies.~~have been properly determined.~~

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Acknowledgments

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Contributors

NB was granted access to analyse the data, was involved in conceptualising the manuscript, conducted statistical analyses and wrote the initial drafts of the manuscript. NB, JB and SH collected and entered the data. All authors (ML, WV, JB, CR and SH) were involved in conceptualising and editing drafts of the paper, in the order that they appear on the author list.

Competing interests

The authors have no conflict of interest to declare.

Ethics approval

UCT Human Ethics Committee

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Data sharing statement

Owing to the sensitive nature of the information and appropriate medical ethics, access to a more detailed aspect of the available dataset will be reviewed upon request and on a discretionary basis. Sharing of only depersonalised and non-relatable data will be

considered, once permission has been received from WV or CR (can be contacted through the corresponding author).

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Table 1. Tournament details, 2011 vs. 2012.

	Under-13 Craven Week		Under-16 Grant Khomo Week		Under-18 Academy Week		Under-18 Craven Week	
Year	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**
Teams	18	18	18	20	26	26	20	20
Matches	36	36	27	30	39	39	30	29
Match time (minutes)	40	40	60	60	70	70	70	70
Tournament structure	M, M, R, M, M		M,M,R,M		M,M,R,M		TM, TM, TM, TM, R, M	
Exposure time (hours)	720	720	810	900	1365	1365	1050	1015

M – match day, R – rest day, TM – tournament match day

~~**Table 2. Proportion of *'overall'* and *'time-loss'* tackle-related injury events occurring in the four South African Rugby Union (SARU) Youth Week tournaments, 2011 vs. 2012.**~~

	~~Under-13 Craven Week~~		~~Under-16 Grant Khomo Week~~		~~Under-18 Academy Week~~		~~Under-18 Craven Week~~	
~~Year~~	~~2011~~	~~2012~~	~~2011~~	~~2012~~	~~2011~~	~~2012~~	~~2011~~	~~2012~~
~~Overall tackle injury %~~	~~68~~	~~58~~	~~54~~	~~59~~	~~68~~	~~65~~	~~48~~	~~56~~
~~*Tackler*~~	~~29~~	~~39~~	~~19~~	~~38~~	~~48~~	~~37~~	~~31~~	~~39~~
~~*Ball-carrier*~~	~~39~~	~~19~~	~~35~~	~~21~~	~~20~~	~~28~~	~~17~~	~~17~~
~~TL tackle injury %~~	~~73~~	~~80~~	~~50~~	~~52~~	~~74~~	~~65~~	~~37~~	~~47~~
~~*Tackler*~~	~~27~~	~~45~~	~~6~~	~~48~~	~~50~~	~~39~~	~~20~~	~~31~~
~~*Ball-carrier*~~	~~46~~	~~35~~	~~44~~	~~4~~	~~24~~	~~26~~	~~17~~	~~16~~

~~TL – time-loss~~

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Table 2. *'Overall'* and *'time-loss'* tackle-related injury rates occurring in the four South African Rugby Union (SARU) Youth Week tournaments, 2011 vs. 2012.

	Under-13 Craven Week		Under-16 Grant Khomo Week		Under-18 Academy Week		Under-18 Craven Week	
Year	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**
Overall tackle injuries (n)	21	36	20	33	47	44	25	34
Overall injury rate	29.2	50.0	24.7	36.7	34.4	32.2	23.8	33.5
95% CI	16.8 - 41.6	33.7 - 66.3	13.9 - 35.5	24.2 - 49.2	24.6 - 44.3	22.7 - 41.8	14.5 - 33.1	22.2 - 44.8
TL tackle injuries (n)	9	16	8	13	25	13	11	9
TL injury rate	12.5	22.2	9.9	14.4	18.3	9.5	10.5	8.9
95% CI	4.3 - 20.7	11.3 - 33.1	3.0 - 16.7	6.6 - 22.3	11.1 - 25.5	4.3 - 14.7	4.3 - 16.7	3.1 - 14.7

Injury rate per 1000 exposure hours; 95% CI – 95% confidence intervals; TL – time-loss

Figure legend:

Fig.1. (a) A comparison of injury rate (± 95%CIs) of 'overall' tackle-related injuries (including 'time-loss' injuries) at each South African Rugby Union (SARU) tournament in 2011 (white bars) and 2012 (shaded bars), and (b) a comparison of injury rate (± 95%CIs) of tackle-related 'time-loss' injuries between each South African Rugby Union (SARU) tournament in 2011 (white bars) and 2012 (shaded bars). (CW13 – under-13 Craven Week; GK16 – under-16 Grant Khomo Week; AW18 – under-18 Academy Week; CW18 – under-18 Craven Week)

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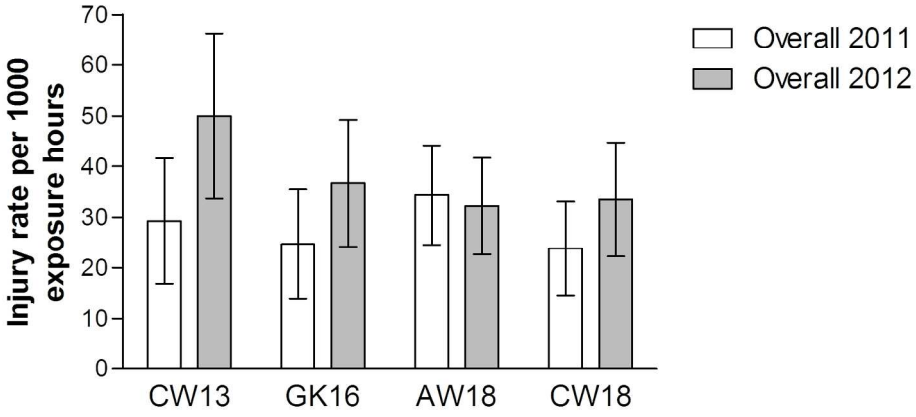

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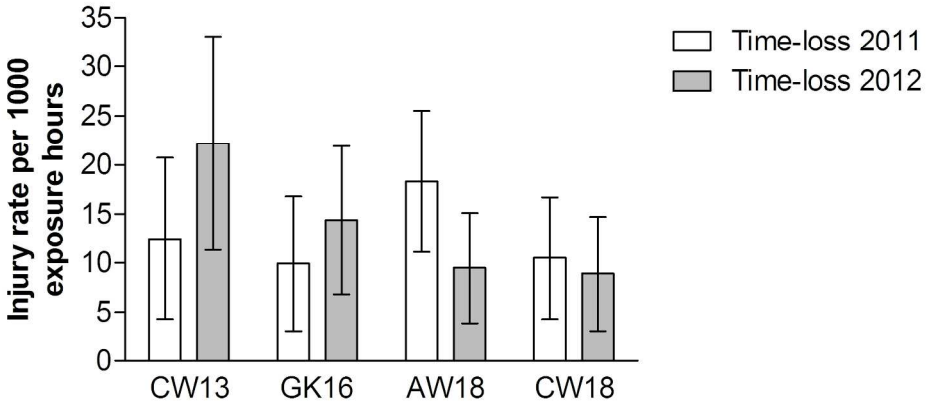

Fig.1. (b) A comparison of injury rate (± 95%CIs) of tackle-related 'time-loss' injuries between each South African Rugby Union (SARU) tournament in 2011 (white bars) and 2012 (shaded bars). (CW13 – under-13 Craven Week; GK16 – under-16 Grant Khomo Week; AW18 – under-18 Academy Week; CW18 – under-18 Craven Week)
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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4-5
Methods			
Study design	4	Present key elements of study design early in the paper	5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6, 9
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	5-6
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7
Bias	9	Describe any efforts to address potential sources of bias	N/A
Study size	10	Explain how the study size was arrived at	N/A
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-9
		(*b*) Describe any methods used to examine subgroups and interactions	N/A
		(*c*) Explain how missing data were addressed	N/A
		(*d*) If applicable, explain how loss to follow-up was addressed	N/A
		(*e*) Describe any sensitivity analyses	N/A
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	5, 9
		(b) Indicate number of participants with missing data for each variable of interest	N/A
		(c) Summarise follow-up time (eg, average and total amount)	N/A
Outcome data	15*	Report numbers of outcome events or summary measures over time	9
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9-12
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	12-14
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	17

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.