

1 **Title:**

2 Legal and illegal ruck cleanouts in South African non-professional youth rugby

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27                   **LEGAL AND ILLEGAL RUCK CLEANOUTS IN SOUTH AFRICAN NON-**  
28   **PROFESSIONAL YOUTH RUGBY**

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36  
37   **Abstract**

38   The ruck area is responsible for the second-highest number of rugby union injuries, therefore it is  
39   necessary to investigate and understand the ruck better for improved player safety. The study  
40   aimed to investigate and compare incidents of legal and illegal ruck cleanouts in non-professional  
41   youth rugby. Using Nacpsort Scout Plus software, 118 South African Rugby Union under 18  
42   Youth Week tournament matches were coded between 2015 and 2019. In total, 35 545 ruck  
43   cleanouts were coded, of which 32 641 (91.8%) were legal and 2 904 (8.2%) were illegal. Of the  
44   2 904 illegal cleanouts, 2 676 (92.2%) were deemed ‘not dangerous’ and 228 (7.8%) were  
45   considered ‘dangerous’. The ‘dangerous’ ruck cleanouts represented 0.6% of the total ruck  
46   cleanouts. Of the most common illegal ruck cleanouts, “not supporting own body weight” were  
47   mostly ‘not dangerous’ (2 498; 99.4%, p=0.01); and all “neck rolls” were considered ‘dangerous’  
48   (147; 100.0%, p=0.02). The findings of the study suggest player behaviour can still be improved,  
49   with regular participation in regular safe and effective technique training drills. The risk of injury  
50   during the ruck can further be influenced positively by coaches, through regular coaching and  
51   training of safe and effective ruck techniques.

52  
53   **Keywords:** Rugby union, player behaviour, injury prevention, performance analysis

## 57 **Introduction**

58 In rugby union (hereafter referred as rugby), the tackle and ruck events are the most  
59 common events of play, with the ruck occurring ~116 times during an 80-minute match.<sup>1</sup> The  
60 second highest proportion of injuries (6 to 17%) at professional level occur during the ruck.<sup>2-5</sup>  
61 During the 2019 injury surveillance report of four youth week tournaments, most injuries occurred  
62 during the tackle (29% for both the tackler and ball carrier) followed by the ruck (25%) for all  
63 youth tournaments combined.<sup>6</sup> The same report found the mechanisms causing the most injuries  
64 in the ruck were being *kicked* (33%), being *cleaned* (22% of injuries), and *cleaning out* (11%).<sup>6</sup>  
65 The high frequency of exposure to rucks and its associated injury risk raises concerns regarding  
66 player safety.

67 A cleanout during a ruck, is when the players contesting in the ruck, make contact, drive  
68 with the legs, and clear the opposition off or away from the ball to either gain or maintain  
69 possession of the ball.<sup>7</sup> To date, only one study has investigated the legality of ruck cleanouts in  
70 rugby.<sup>7</sup> Specifically, this study identified and analysed a total of 22 281 ruck cleanouts during the  
71 2018 Super Rugby competition. Of the 22 281 ruck cleanouts, 2 111 (9%) were deemed illegal  
72 according to the World Rugby (WR) laws of the game, with an average of 16 illegal ruck cleanouts  
73 occurring per match. Of the 2 111 illegal ruck cleanouts, 1 087 (51%) were considered dangerous,  
74 at an average of 10 per match.<sup>7</sup> The physical, mental and emotional fatigue associated with the  
75 ruck can impair players' decision-making abilities,<sup>8-10</sup> and can result in poor techniques.<sup>11</sup> This can  
76 subsequently increase injury risk, because players become more vulnerable to making errors in a  
77 fatigued state.<sup>8,9</sup>

78 The injury risks need to be investigated further and the first step in injury prevention is  
79 surveillance.<sup>12</sup> Injury surveillance research published on the ruck is limited,<sup>7, 13-15</sup> especially at  
80 school level rugby. Having surveillance data on illegal and dangerous ruck cleanouts, could help  
81 BokSmart, the South African Rugby Union (SARU), WR and other international rugby unions  
82 who implement injury prevention initiatives. According to Viljoen & Patricios<sup>16</sup>; Carter<sup>17</sup>; and  
83 Archbold *et al.*<sup>18</sup> data from the current study can provide information to improve their current  
84 programmes, by using this data to improve player, coach and referee behaviour. Coaches need to  
85 monitor all risk factors and must ensure that their players are technically and tactically prepared,  
86 by teaching safe techniques and contact skills during practise. Coaches also have a duty of care

87 and responsibility to teach players to play and adhere to the laws of the game.<sup>19,20</sup> With a focus on  
88 injury prevention, very little research has been done on player behaviour in ruck cleanouts, as most  
89 research has focused on tackles.<sup>11, 21</sup> Therefore, the aim of this study was to investigate technical  
90 execution and player behaviour during ruck cleanouts during the Under 18 Craven Week rugby  
91 tournaments. The study analysed tournaments between 2015 and 2019 to determine whether there  
92 were trends in behaviour of both legal and illegal ruck cleanouts.

## 93 **Methodology**

### 94 *Sample*

95 One hundred eighteen matches from the SARU Under 18 Craven Week tournaments between 2015  
96 and 2019 (N=118 matches) were analysed by a single coder using Nacsport software (Version:  
97 Scout Plus, Spain: 2008). The video recordings were supplied by SARU's technical department.  
98 All were analysed. Ethical approval was obtained from the Research Ethics Committee: Human  
99 Research, Stellenbosch University (REC-2019-10416).

100

### 101 *Data collection procedure*

102 Prior to coding, a “gold standard” was set by an international referee, using the 2019 World Rugby  
103 Laws of the Game definitions, and by analysing a match in conjunction with the coder. Thereafter,  
104 each ruck cleanout was coded according to the performance indicators (PI's) and operational  
105 definitions (Table 1). The initial PIs were developed based on published peer-reviewed studies in  
106 this field,<sup>7, 22-24</sup> and by consulting an expert panel (N=7). The panel consisted of: (1) a rugby injury  
107 prevention specialist; (2) a rugby coach; (3) a rugby player; (4) a rugby referee; (5) a rugby referee  
108 coach; and (6) two BokSmart representatives. After deciding on the PI's, the panel was consulted  
109 to review the validity and relevance of the proposed PI's and the lucidity of the operational  
110 definitions. The panel agreed that the PI's for the study were appropriate and clear, and no further  
111 changes were required. Prior to coding, a “gold standard” was set by an international referee, using  
112 the 2019 World Rugby Laws of the Game definitions, and by analysing a match in conjunction  
113 with the coders.

114

\*\*\* insert Table 1 here \*\*\*

115 The reliability of the coded ruck cleanouts was tested using Cohen's kappa coefficient ( $\kappa$ )  
116 for intra- and inter-rater reliability. Before data collection for the study started, the primary

117 researcher coded a full match and re-coded the same match 7 days later (intra-rater reliability). An  
118 external coder also coded the same match and recoded the match 7 days later (used for inter-rater  
119 reliability). After the initial coding, the primary researcher, and an external coder re-coded 20  
120 matches that were randomly selected by the statistician for the intra- and inter-rater reliability. The  
121 intra and interrater reliability revealed a “very good agreement” ( $\kappa=0.81-0.99$ ) for both before and  
122 after coding.

123

### 124 *Statistical analysis*

125 All statistical analysis were performed using Statistica software (version 13.3.721.1).  
126 Descriptive data of the PI's were reported as frequencies (number of observations) and  
127 percentages, with a significance level of 5% applied ( $p<0.05$ ). Association between ruck cleanout  
128 outcome (legal, illegal ‘*not dangerous*’ and illegal ‘*dangerous*’) and PIs were determined using  
129 Chi-Squared analyses. Four *a priori* proportions were decided upon as proxies of player behaviour.  
130 Player behaviour was measured by: (1) *legal* ruck cleanouts as a percentage of *all* ruck cleanouts  
131 (i.e., legal, illegal ‘*not dangerous*’ and illegal ‘*dangerous*’ combined); (2) *illegal* ruck cleanouts  
132 as a percentage of *all* ruck cleanouts; (3) *illegal ‘not dangerous’* ruck cleanouts as a percentage of  
133 *all illegal* ruck cleanouts (i.e., illegal ‘*not dangerous*’ and illegal ‘*dangerous*’ combined); and (4)  
134 *illegal ‘dangerous’* ruck cleanouts as a percentage of *all illegal* ruck cleanouts. A Classification  
135 and Regression Tree (CART) model was established with the dependable variable, namely ruck  
136 cleanout outcome, and the independent variables being the PI's. This model classified the best  
137 group of predictors for the ruck cleanout outcome and to establish the cut-off point values for each  
138 of the PIs.

139

### 140 **Results**

141 A total of 35 545 ruck cleanouts were recorded over the five-year period, at an average of 301 ruck  
142 cleanouts per match. Most ruck cleanouts (32 641; 91.8%) were legal, and the proportions of legal,  
143 illegal, illegal ‘*not dangerous*’, and illegal ‘*dangerous*’ ruck cleanouts were similar for all factors  
144 including years, quarters, zonal locations, channels and match outcomes (Table 2). When  
145 comparing the ruck cleanout outcomes per year the results showed a significant ( $p=0.01$ ) decrease  
146 in the number of legal and illegal ‘*dangerous*’ ruck cleanouts, and an increase in illegal ‘*not*  
147 *dangerous*’ cleanouts in 2018 and 2019 compared to the earlier years. The quarters, zonal

148 locations, and channels did not indicate any significance differences when comparing ruck  
149 outcomes.

150 \*\*\* insert Table 2 here \*\*\*

151  
152 Table 2 shows the legal and illegal ruck cleanouts as a percentage of all ruck cleanouts. The  
153 percentages ranged from 89% (5 614 out of 6 306) in 2019 to 94% (5 580 out of 5 959) in 2017.  
154 When observing all illegal ruck cleanouts, regardless of whether ‘*not dangerous*’ or ‘*dangerous*’,  
155 this ranged from 6% (578 out of 8 488) in 2016 to 11% (692 out of 6 306) in 2019. We explored  
156 the impact of illegal ‘*dangerous*’ and illegal ‘*not dangerous*’ percentages further on overall illegal  
157 player behaviour and represented this information as a percentage of all *illegal* ruck cleanouts  
158 (Table 2). The illegal ‘*not dangerous*’ ruck cleanouts, percentage ranged between 89% (504 out of  
159 578) in 2016 and 96% (667 out of 692) in 2019. The illegal ‘*dangerous*’ cleanouts, the percentage  
160 ranged between 4% (25 out of 692) in 2019 and 13% (74 out of 578) in 2016.

161 When analysing “*Cleaner*” arrival at the ruck for both attacking and defending teams, the  
162 results indicate that “*Cleaner 2*” for the attacking team performed significantly more total  
163 cleanouts ( $p=0.02$ ), legal cleanouts, and illegal cleanouts (both ‘*dangerous*’ and ‘*not dangerous*’)  
164 when compared to the other attacking team “*Cleaner*” roles (Table 3). When looking at the  
165 defending team, “*Cleaner 1*” ( $p=0.01$ ) was responsible for executing significantly more total  
166 cleanouts, legal cleanouts and illegal ‘*not dangerous*’ cleanouts, when compared to the other  
167 defending team “*Cleaners*”. When analysing the ruck cleanout techniques used by both attacking  
168 and defending teams, attacking team’s adopted the “*Protection*” strategy significantly more  
169 ( $p=0.02$ ) during legal ruck cleanouts. However, for illegal ruck cleanouts, both ‘*dangerous*’ and  
170 ‘*not dangerous*’, the “*Clearing and protecting*” strategy was utilised significantly more ( $p=0.04$ )  
171 during match-play. When looking at defending teams, the “*Jackal*” technique was applied  
172 significantly more ( $p \leq 0.01$ ) during legal cleanouts and in illegal ‘*not dangerous*’ cleanouts, when  
173 compared to the other defensive rucking techniques. The “*Early counter ruck*” was responsible for  
174 significantly more ( $p=0.02$ ) illegal, illegal “*not dangerous*”, and illegal ‘*dangerous*’ ruck cleanouts  
175 (Table 3).

176 \*\*\* insert Table 3 here \*\*\*

177

178 Out of the 2 904 illegal ruck cleanouts most of the ‘*not dangerous*’ types were “*not*  
179 *supporting own body weight*” (f=2 498; 99.4%), which was performed significantly more ( $p=0.01$ )  
180 than the other types of illegal ‘*not dangerous*’ cleanouts. The remaining types of illegal ‘*not*  
181 *dangerous*’ infringements were: “*joining the ruck from an offside position*” (f=68; 100.0%); and  
182 “*side entry*” (f=53; 100.0%). For the illegal ‘*dangerous*’ types of ruck cleanouts, the majority were  
183 “*neck roll*” (f=147; 100.0%), which was significantly ( $p=0.02$ ) greater than the other illegal  
184 ‘*dangerous*’ ruck cleanouts. The remaining illegal ‘*dangerous*’ types were: “*contact above the*  
185 *shoulder*” (f=34; 65.4%) and “*shoulder charge*” (f=30; 62.5%).

186  
187 The importance plot showed that the *Cleaner* technique (1.0) and year (0.3) were the best  
188 predictors of outcome using the current CART model. The results in Table 4 predict a 5% increase  
189 in legal ruck cleanout outcomes when the attacking cleaner technique “*Protecting the ball*” and  
190 the defending cleaner techniques, “*Jackals*” or applies “*No pressure*”, were used. However, the  
191 largest reduction (from 92% to 77%) in legal ruck cleanouts, and an increase (7% to 21%) in illegal  
192 ‘*not dangerous*’ ruck cleanouts were evident in 2018 and 2019, and when the attacking cleaner  
193 executed the following techniques: “*Clearing*”, “*Clearing and protecting*”, and “*Protecting and*  
194 *clearing*”, and the defending cleaner executed the following techniques, the “*Early counter ruck*”  
195 and “*Late counter ruck*”.

196 \*\*\* insert Table 4 here \*\*\*

## 197 **Discussion**

198 The major findings were that: 1) the majority of the ruck cleanouts were deemed legal and out of  
199 all the illegal cleanouts the majority were not dangerous, 2) the attacking team was responsible for  
200 more legal ruck cleanouts when compared to the defending team; 3) for the attacking team, of the  
201 illegal “*Clearing and protecting*” techniques, the majority were ‘*not dangerous*’, compared with  
202 the defending teams, where the majority of the illegal “*Jackal*” techniques were also considered  
203 ‘*not dangerous*’; and 4) the majority of the illegal ‘*not dangerous*’ ruck cleanouts were “*not*  
204 *supporting own body weight*” and for illegal ‘*dangerous*’ cleanouts were the “*neck roll*”. To our  
205 knowledge, this is the second study that has focused on legal and illegal (both ‘*dangerous*’ and  
206 ‘*not dangerous*’) cleanouts at the ruck to assess player behaviour during match-play and is the first

207 study on the ruck at youth rugby level. The study by Kraak *et al*<sup>7</sup> investigated the non-sanctioning  
208 of illegal ‘*dangerous*’ and ‘*not dangerous*’ ruck cleanouts in the Super Rugby.

209 The proportions of legal and illegal ruck cleanouts can be viewed as a metric for player  
210 behaviour. The majority (91.8%) of all ruck cleanouts over the period studied were legal, which is  
211 a strong indication of positive on-field player behaviour. The percentage of illegal ruck cleanouts  
212 compared to all ruck cleanouts, however, was 8.2%. Albeit largely due to ‘*not dangerous*’ illegal  
213 ruck cleanouts, the current study indicated that player behaviour worsened during the 2018 and  
214 2019 rugby seasons; ‘*dangerous*’ illegal ruck cleanouts on the other hand, improved. Although  
215 one could argue that the results are not direct “metrics” of player behaviour, they were chosen  
216 because they have practical relevance to rugby stakeholders, to whom this study’s results must be  
217 disseminated. The findings of the current study are still concerning from an injury prevention  
218 perspective because 2 676 not dangerous illegal ruck cleanouts pose an unnecessary injury risk to  
219 the players involved in the breakdown contest. Although representing less than 1% of all ruck  
220 cleanouts, 228 illegal cleanouts were deemed ‘*dangerous*’, and any one of these cleanouts could  
221 have led to severe injury. This reasoning is also consistent with BokSmart’s adopted long-term  
222 goal of “#VisionZero” - eliminating all serious injuries from the game.<sup>25</sup> Players are required to  
223 follow the laws of the game as determined by World Rugby, during training and match-play, to  
224 allow players to participate within the spirit of the game and more importantly, to protect them  
225 from injury and unreasonable risk.<sup>26</sup>

226 Securing and retaining possession of the ball is a fundamental component of attack in  
227 rugby, with the main aim to score points and subsequently win matches.<sup>10</sup> Because of the large  
228 increase in the number of rucks and breakdown contests in match-play, it has become an important  
229 facet of play for both attacking and defending teams in the modern game.<sup>27</sup> A study by Mitchell  
230 and Tierney<sup>15</sup> analysed 7,393 collisions in the Rugby Championship and Six Nations competitions  
231 and found determine that 65% of collisions resulted in a ruck in professional rugby. The current  
232 study showed that the predominant techniques used by the attacking cleaners were “*Protecting*”  
233 and “*Clearing and protecting*”. When the first attacking player arrives at the tackle, and the ball  
234 carrier is on the ground, the player must rapidly assess the situation and decide.<sup>23</sup> “*Protecting*” is  
235 when the “*cleaner*” arrives at the tackle and there is no pressure from the defending team. The  
236 player then goes into a strong position over the ball, to prevent oncoming defensive players from  
237 gaining access to the ball. However, this could also cause a high number of players going off their



238 feet or ‘*not supporting own body weight*’ to protect the ball, as found in the current study. The  
239 second most used technique by the attacking team player in the current study, was when the  
240 “*cleaner*” first clears the defending threat from the ruck, and then goes into a strong body position  
241 to protect the ball.

242 The ruck techniques most frequently used by the defending teams, were the “*Jackal*” and  
243 “*Early counter ruck*”. Wheeler *et al*<sup>10</sup> found a similar trend. The 2011 Super Rugby study  
244 demonstrated, respectively, that the “*Jackal*” and “*Early counter ruck*” techniques were used 39%  
245 and 60% of the time by defensive teams, to win turnovers at the ruck. “*Early counter rucks*” were  
246 effective at turning over possession when the ruck contests occurred in the wide attacking channels  
247 (18% of turnovers), whilst the “*Jackal*” technique was effective in the central field areas (13% of  
248 turnovers). Wheeler *et al*<sup>10</sup> 2013, however, also found that the “*Early counter rucks*” led to 17%,  
249 and the “*Jackal*” technique to 7% of infringements. Players are more susceptible to concussive  
250 impacts when they are in a defensive role.<sup>28</sup> It may, therefore, be useful to incorporate a coaching  
251 emphasis on ‘maintaining awareness’ for players, engaging during a ruck from an attacking and  
252 defensive perspective.<sup>28</sup> The amount of time spent training correct contact techniques is however  
253 associated with positive player behaviour that reduces injury risk.<sup>29</sup> According to Hendricks *et al*<sup>29</sup>  
254 verbal instruction and demonstration of correct and safe techniques are the most effective coaching  
255 methods for contact events. Therefore, coaching the ruck should follow the same principle as the  
256 tackle because they are both contact events. The same key factors that are applied to a tackle can  
257 also be applied to the ruck. To make a legal and safe ruck cleanout, players must have correct  
258 timing, momentum coming into the ruck, and a safe and strong body and head position.<sup>30</sup>

259 The current study found that attacking teams engaged in more illegal ruck cleanouts  
260 (87.9%) when compared to the defending teams. A similar pattern was found by Kraak *et al*<sup>7</sup> and  
261 Mitchell and Tierney<sup>15</sup>. Kraak *et al*<sup>7</sup> demonstrated that attacking teams accounted for 90% (1 895  
262 of 2 111) of all illegal ruck cleanouts, at an average of 16 per match. In the latter study the attacking  
263 team contributed to 70% (340 of 486) of all infringements. A typical game situation on attack  
264 could be as follows: after the initial tackle made by the defender, and ball placement by the ball  
265 carrier, the first arriving player on attack must clear the first arriving defender away from the ball  
266 carrier, with the second arriving player on attack having to secure the possession and engage any  
267 additional defenders, as they arrive to contest for the ball or support the first defender.<sup>23</sup> Possible

268 reasons for the high infringement rate by attacking teams are the following: (a) The ball carrier  
269 does not dominate the collision and does not present the ball effectively to his teammates.<sup>24</sup>  
270 Therefore, the first arriving player on attack uses an illegal technique to try and retain possession.  
271 (b) The support players on attack react poorly to the tackle situation and arrive late at the ruck.<sup>7</sup>  
272 (c) Poor decision-making and assessment of the situation by the players involved in the contest.  
273 (d) Poor ruck cleaning techniques used in the latter stages of the match due to fatigue.<sup>31</sup> (e) The  
274 defending team might already be infringing, and the attacking team then also uses illegal  
275 techniques to try and retain possession.<sup>7</sup> Studies by Wheeler *et al*<sup>32</sup> and Kraak and Welman<sup>23</sup>  
276 identified that players must execute specific actions and techniques to retain (attacking team) or  
277 turnover (defending team) possession of the ball at the ruck.

278 “*Not supporting own body weight*” was the type of ‘*not dangerous*’ illegal ruck cleanouts  
279 that occurred the most in the current study. This finding agrees with Kraak *et al*<sup>7</sup>, who also found  
280 that “*not supporting own body weight*” occurred the most out of all illegal ‘*not dangerous*’ ruck  
281 cleanouts during the 2018 Super Rugby tournament. However, this pattern was not evident during  
282 the 2019 Rugby World Cup.<sup>15</sup> In this study “*head and shoulders below hips*” was the infringement  
283 that occurred most.

284 A possible reason why players might *not* support their body weight properly can be two-  
285 fold: 1) The first attacking cleaner arrives late, and the defending team might already have  
286 protection over the ball. Therefore, the cleaner decides to perform an illegal action to try and get  
287 to the ball and regain possession. 2) The first arriving player might execute an illegal action and  
288 be off their feet, and therefore, the second arriving player tries to clear the player off the ball  
289 illegally. To clear the player, the cleaner then uses the ‘*neck roll*’, or grabs onto the head or neck,  
290 and twists or forces it to the side of the ruck,<sup>33</sup> which is considered the most ‘*dangerous*’ ruck  
291 cleanout. “*Not supporting own body weight*” and “*neck rolls*” can lead to major injuries at all  
292 levels, but especially because of the size and height of the players that participate in the Craven  
293 Week tournament.<sup>34</sup>

294

### 295 ***Limitations and future research directions***

296 The available camera angles, at times, caused a limitation in the sense that it was difficult to see  
297 all players’ actions during a ruck. Another limitation was that the current study only analysed one  
298 youth week competition, and therefore, the findings of the study cannot be generalised across all

299 youth rugby levels. Future studies should investigate the ruck cleanouts in other elite competitions  
300 and at community level rugby, and should also include other potential factors, such as log position  
301 and nationality of teams.

302

### 303 **Conclusion**

304 The study found that 91.8% of ruck cleanouts were legal cleanouts, which reflect positive player  
305 behaviour, and 92.1% of illegal ruck cleanouts were '*not dangerous*'. Although contributing to  
306 less than 1% of all cleanouts recorded, the illegal '*dangerous*' ruck cleanouts remain a concern for  
307 stakeholders from an injury prevention perspective. This equates to approximately 2 dangerous  
308 ruck cleanouts per match, every '*dangerous*' illegal act is an opportunity for catastrophic injury.  
309 Because of the evolving nature of the game, the number of ruck cleanouts in rugby matches are  
310 unlikely to decrease. Therefore, the focus must be placed on how cleanouts are taught and then  
311 carried out. To aid injury prevention efforts, future studies should explore why players perform  
312 illegal ruck cleanouts in contravention with the laws of the game. Additional educational and  
313 operational interventions need to be targeted at coaches, referees, and players to improve these  
314 shortcomings. If players are not playing within the laws, and coaches are not implementing the  
315 prevention strategies, the effectiveness of injury prevention programmes will be limited. The data  
316 from the current study reinforces the importance of coaching correct techniques, correcting player  
317 behaviour and continued strict action against illegal '*not dangerous*' and illegal '*dangerous*'  
318 cleanouts during training and matches. Because of limited research on investigating the legal,  
319 illegal '*not dangerous*' and illegal '*dangerous*' cleanouts during match-play, and to assist in  
320 lowering injury incidence, it is important to expand the area of research so that the game is  
321 continually made safer for all involved.

322

### 323 ***Practical applications***

324 Albeit that less than 1% of cleanouts were deemed to be dangerous, there are methods to improve  
325 the illegal activities of player behaviours. These includes participating in regular and effective  
326 technique training drills, changing on-field player behaviours and improved decision-making on  
327 match days. The risk of injury can be influenced positively by coaches, through regular coaching  
328 and training of only safe and effective ruck techniques with their players. The on-field referee on  
329 match days can also reduce the risk of injury, by dealing appropriately with the players who go off

330 their feet, who perform “*neck rolls*”, who fly into the ruck leading with the shoulder, and who  
331 make contact above the shoulder line. A special focus must be applied to those events with the  
332 potential to cause serious life-threatening or debilitating injuries, such as “*neck rolls*” and  
333 ‘*shoulder charges*’.

334         Effective execution of contact techniques depends on players’ physical conditioning, skill  
335 level, and tactical awareness.<sup>4,11,35</sup> Coaches can improve player technique by designing technical  
336 training sessions that both assess and develop the technical skill level of the players.<sup>24</sup> This can be  
337 done by using a simple two-on-two contact drill, as proposed by den Hollander *et al.*<sup>36</sup> Using the  
338 technical assessments of this drill, senior level players scored higher in contact technique  
339 proficiency than academy players. The authors also highlighted that players need to develop proper  
340 ruck technique to progress safely through the levels of competition, that better technique leads to  
341 better player and team performance, and that it also lowers injury risk.<sup>36</sup> This cultivates a better  
342 attitude towards injury prevention and management, which coaches must encourage and  
343 implement.<sup>37</sup> However, these attitudes are also dependent on how compliant the players are with  
344 these interventions.<sup>38</sup>

345         Senior professional players with elite training and more competitive international games  
346 are stronger in all neck strength measures than players at any other age or level of competition.<sup>39</sup>  
347 Because of access to higher quality coaching, the players will be more experienced and have a  
348 better understanding of injury mechanisms.<sup>30</sup> Training schedules must be customized and adapted  
349 to suit the specific team’s level of play, age, skill level, experience, and the different positions.<sup>11</sup>

350         Subsequently, a call for the development of a contact-skill programme was made.<sup>28</sup> The  
351 results of the current study provide evidence to contribute to the design of such a programme and  
352 highlights the need for specific techniques that need to be emphasised during training.  
353 Furthermore, the contact technique elements associated with success in the current study are useful  
354 to consider for other levels of play. Ruck sessions should include the initial tackle, fight for  
355 dominance, correct ball placement, and safe and effective clearing techniques in the same drills.  
356 By including all these events, players will develop decision-making skills during practise, which  
357 can be transferred better into match situations.<sup>7</sup> Performance analysis could also be beneficial and  
358 should, where possible, be included in training sessions and matches. Players should be able to  
359 have access to these videos and after every training session or match, do self-reflection on their  
360 individual and team’s performance. Self-reflection is an effective way for players to recognise

361 their mistakes, to identify poor behaviour and illegal actions, and to reflect on what an ideal  
362 situation should look like. Looking at the team's performance, will help each player realise how  
363 the team can progress, by improving performance and player safety at the same time. According  
364 to Hendricks *et al*<sup>28</sup> more work is required to improve the understanding of the relationships  
365 between technique, fatigue, tactics and performance, and coaches must consider these factors when  
366 designing and developing contact-technique training sessions.

367

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469 Tables

470 Table 1: *Performance indicators (PI) and operational definitions*

<b>Performance indicators</b>	<b>Operational definitions</b>
Ruck.	The ruck is defined as a phase of play where one or more players from each team, are on their feet and in physical contact close around the ball, which is on the ground.
Ruck cleanout.	A cleanout during a ruck is when the players contesting in the ruck make contact, drive with the legs, and clear the opposition off or away from the ball in an attempt to either turnover or maintain possession.
Ruck cleanout outcome.	Legal: according to the 2020 WR law book. Illegal: according to the 2020 WR law book.
Illegal ruck cleanout outcomes.	Not dangerous: action was not deemed dangerous their no risk of injury of (a) himself, (b) own players, and (c) opposition players.



	Dangerous cleanout: action was deemed dangerous if the action of the player could lead to possible injury of (a) himself, (b) own players, and (c) opposition players.
Score outcome	Based on points difference between winning and losing teams: Based on whether the attacking team was winning, losing, or drawing at the time of the ruck event, based on the score.
Match-time period.	Quarter 1: 0 to 17.5 minutes Quarter 2: 17.5 to 35 minutes Quarter 3: 35 to 52.5 minutes Quarter 4: 52.5 to 70 minutes
Zonal locations.	Zone A: Attacking area between opposition 22m area and try line. Zone B: Attacking area between opposition 22m area and halfway line. Zone C: Defending area between own 22m area and the halfway line. Zone D: Defending area between own 22m area and try line.
Channels.	Channel 1: From left touchline to left 15m line. Channel 2: In between the two 15m lines. Channel 3: From right 15m line to right touchline line.
Attacking team.	The team in possession of the ball.
Defending team.	The team not in possession of the ball.
Number of players involved in the cleanout: Attack/Defence.	Number of attacking/defending players that are actively involved in the ruck contest and cleanout: Ball carrier (Player 1 (Attack): player carrying the ball Tackler (Player 2 (Defence): tackler Cleaner 1 (Player 3 (Attack or defence): first cleaner Cleaner 2 (Player 4 (Attack or defence)): second cleaner Cleaner <sup>33</sup> (Player <sup>35</sup> ) (Attack or defence)): third or more cleaners.
Types of illegal and dangerous ruck cleanouts.	<i>Neck roll</i> : A cleaner must not grasp an opposition player around the neck area to cleanout. <i>Not supporting own body weight</i> : A player cleaning out a ruck must be on his feet. <i>Joining the ruck while in an offside position</i> : A player cleaning at the ruck may not do so while in an offside position. Non-participants at the breakdown must be behind the hindmost foot of the last player in their side of the ruck. <i>Shoulder charge</i> : A player must not charge into a ruck. Charging includes any contact made without use of the arms, or without grasping a player. <i>Side entry</i> : A cleaner must join alongside, but not in front of, the hindmost player. <i>Not grasping on teammate when cleaning</i> : A player joining a ruck must bind onto a teammate or an opponent, using the whole arm. The bind must either precede, or be simultaneous with, contact with any other part of the body of the player joining the ruck.

	<i>Cleaning a player not involved in the ruck:</i> A cleaner must not take-out opposition players who are not part of the ruck. <i>Contact above shoulder of opposition player:</i> A cleaner must not make contact with an opponent above the line of the shoulders.
Cleaner technique at the ruck (Attacking team).	<i>Clearing:</i> Attackers are actively driving opponents off the ball. <i>Protecting the ball:</i> Attackers are positioned over the ball to prevent opponents' access. <i>Clearing and protecting:</i> Attackers actively clear the ruck first, before protecting the ball. <i>Protecting and clearing:</i> Attackers actively protect the ball first, before clearing the ruck.
Cleaner technique at the ruck (Defending team).	<i>Early counter ruck:</i> Defenders compete for the ball without the use of their hands before attackers had secured possession. <i>Jackal:</i> A defender competes for the ball using his hands after a tackle was made but before a ruck is formed. <i>No pressure:</i> Defenders are not actively attempting to regain possession. <i>Late counter ruck:</i> Defenders compete for the ball without the use of their hands after attackers had secured possession of the ball.

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474 Table 2. *The number of ruck cleanouts presented as both frequency (n) and percentage (%) for legal and*  
475 *illegal (including “dangerous” and “not dangerous”) ruck cleanouts and various*  
476 *performance indicators.*

<b>PI's</b>	<b>Legal n (%)</b>	<b>Illegal n (%)</b>	<b>Illegal ‘not dangerous’ n (%)</b>	<b>Illegal ‘dangerous’ n (%)</b>
	<b>32 641 (91.8)</b>	<b>2 904 (8.2)</b>	<b>2 676 (92.2)</b>	<b>228 (7.9)</b>
<i>Year</i>				
2015	7216 (93.3)	521 (6.7)	463 (88.9)	58 (11.1)
2016	7910 (93.2)	578 (6.8)	504 (87.2)	74 (12.8)
2017	5580 (93.6)	379 (6.4)	342 (90.2)	37 (9.8)
2018	6321 (89.6)	734 (10.4)	700 (95.4)	34 (4.6)
2019	5614 (89.0)	692 (11.0)	667 (96.4)	25 (3.6)
<i>Match outcome</i>				
Win	4272 (91.8)	382 (8.2)	372 (97.4)	10 (2.6)

Draw	1422 (93.1)	106 (6.9)	101 (95.3)	5 (4.7)
Loss	4324 (92.0)	377 (8.0)	367 (97.4)	10 (2.7)
<b>Quarter</b>				
Quarter 1	8536 (91.4)	798 (8.6)	741 (92.9)	57 (7.1)
Quarter 2	8076 (91.9)	708 (8.1)	651 (92.0)	57 (8.1)
Quarter 3	7847 (91.7)	708 (8.3)	645 (91.1)	63 (8.9)
Quarter 4	8182 (92.2)	690 (7.8)	639 (92.6)	51 (7.4)
<b>Zonal location</b>				
Zone A	8525 (91.4)	803 (8.6)	744 (92.7)	59 (7.4)
Zone B	12579 (91.5)	1105 (8.5)	1063 (91.2)	102 (8.8)
Zone C	9289 (91.6)	790 (8.4)	688 (92.2)	58 (7.8)
Zone D	2248 (92.3)	187 (7.7)	178 (95.2)	9 (4.8)
<b>Channel</b>				
Channel 1	5894 (92.2)	502 (7.9)	456 (90.8)	46 (9.2)
Channel 2	10332 (91.8)	928 (8.2)	853 (91.9)	75 (8.1)
Channel 3	16415 (91.8)	1474 (8.2)	1367 (92.7)	107 (7.3)

477 Table 3. The number of coded legal and illegal ruck cleanouts, presented as both frequency (n) and  
478 percentage (%) illegal 'dangerous' and illegal 'not dangerous' ruck cleanouts, and various  
479 other performance indicators.

Performance indicators	Legal n(%) <b>32 641 (91.8)</b>	Illegal n(%) <b>2 904 (8.2)</b>	Illegal "not dangerous" n(%) <b>2 676 (92.1)</b>	Illegal "dangerous" n (%) <b>228 (7.9)</b>
<b>Attacking team</b>				
<b>Frequency</b>	2 3305 (90.1)	2 552 (9.9)	2 366 (92.7)	186 (7.3)
<b>Cleaner arrival number</b>				
Cleaner 1	4654 (87.0)	694 (13.0)	673 (97.0)	21 (3.0)
Cleaner 2	<b>7644 (86.1) *</b>	<b>1236 (13.9) *</b>	<b>1128 (91.3)*</b>	<b>108 (8.7)*</b>
Cleaner 3	6748 (93.2)	494 (6.8)	457 (92.5)	37 (7.5)
Cleaner 4	3146 (96.6)	110 (3.4)	93 (84.6)	17 (15.5)
Cleaner 5	912 (98.6)	13 (1.4)	10 (76.9)	3 (23.1)
Cleaner 6	201 (97.6)	5 (2.4)	5 (100.0)	0 (0)
<b>Cleaner technique</b>				
Protecting	<b>17131 (96.4) *</b>	640 (3.6)	629 (98.3)	11 (1.7)
Clearing and protecting	5753 (78.2)	<b>1603 (21.8) *</b>	<b>1445 (90.1) *</b>	<b>158 (9.9) *</b>

Clearing	415 (57.5)	307 (42.5)	290 (94.5)	17 (5.5)
Protecting and clearing	6 (75.0)	2 (25.0)	2 (100.0)	0 (0)
<b>Defending team</b>				
<b>Frequency</b>	9336 (96.4)	352 (3.6)	310 (88.1)	42 (11.9)
<b>Cleaner arrival number</b>				
Cleaner 1	<b>5364 (96.9) *</b>	171 (3.1)	<b>167 (97.7) *</b>	4 (2.3)
Cleaner 2	1925 (96.1)	78 (3.9)	59 (75.6)	19 (24.4)
Cleaner 3	1020 (95.4)	49 (4.6)	45 (91.8)	4 (8.2)
Cleaner 4	639 (95.2)	32 (4.8)	25 (78.1)	7 (21.9)
Cleaner 5	287 (94.1)	18 (5.9)	12 (66.7)	6 (33.3)
Cleaner 6	101 (96.2)	4 (3.8)	2 (50.0)	2 (50.0)
<b>Cleaner technique</b>				
Jackal	<b>5311 (97.3) *</b>	<b>147 (2.7) *</b>	<b>143 (97.3) *</b>	4 (2.7)
Early counter ruck	3522 (95.7)	<b>158 (4.3) *</b>	<b>125 (79.1) *</b>	<b>33 (20.9) *</b>
No pressure	355 (92.2)	30 (7.8)	30 (100.0)	-
Late counter ruck	148 (89.7)	17 (10.3)	12 (70.6)	5 (29.4)

480 *Note: \* = statistically significant ( $p \leq 0.05$ )*

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483 Table 4. *The number of illegal ruck cleanout types presented both as frequency (n) and percentage (%) for*

484 *illegal 'dangerous' and illegal 'not dangerous' ruck cleanouts.*

Types of illegal cleanouts	Illegal 'not dangerous'	Illegal 'dangerous'
	n (% of type of illegal cleanout) n = 2 676 (92.1%)	n (% of type of illegal cleanout) n = 228 (7.9%)
Not supporting own body weight	<b>2498 (99.4) *</b>	15 (0.6)
Joining the ruck from an offside position	68 (100)	0
Shoulder charge	18 (37.5)	30 (62.5)
Contact above the shoulder	18 (34.6)	34 (65.4)
Side entry	53 (100)	0
Cleaning a player not involved in ruck	2 (100)	0
Not grasping	19 (90.5)	2 (9.5)
Neck roll	0	<b>147 (100.0) *</b>

485 Note: \* = statistically significant ( $p \leq 0.05$ ) when comparing individual illegal 'not dangerous' and illegal  
 486 'dangerous' ruck cleanouts to the other types of illegal cleanout techniques

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495 Table 5. Classification and Regression Tree (CART) of all ruck cleanouts, with ruck cleanouts outcome as  
 496 the dependent variable (legal 92%; illegal 'not dangerous' 7%; illegal 'dangerous' 1%).

Binary trees	Terminal nodes	Predictive values for ruck cleanout outcome
Tree Level 1	<i>Attacking cleaner technique:</i> protecting the ball.	Legal: increased by 5% (97%).
	<i>Defending cleaner technique:</i> jackal and no pressure.	Illegal (not dangerous): reduced by 5% (2%).
		Illegal (dangerous): reduced by 1% (0%).
Tree Level 2	<i>Attacking cleaner technique:</i> clearing and protecting	Legal: reduced by 6% (86%).
	and protecting and clearing.	Illegal (not dangerous): increased by 5% (12%).
	<i>Defending cleaner technique:</i> early counter ruck, late	Illegal (dangerous): increased by 1% (2%).
	counter ruck.	
	<i>Year:</i> 2015, 2016 and 2017.	
Tree Level 3	<i>Attacking cleaner technique:</i> clearing, clearing and	Legal: reduced by 15% (77%).
	protecting and protecting and clearing.	Illegal (not dangerous): increased by 13% (21%).
		Illegal (dangerous): no change.

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*Defending cleaner technique:* early counter ruck, late  
counter ruck.

*Year:* 2018 and 2019.

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