THE BALL ORIENTATIONS USED BY PLACE KICKERS AT THE 2019 RUGBY WORLD CUP AND THEIR ASSOCIATIONS WITH KICK SUCCESS

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The outcomes of place kicks can have a large impact on Rugby Union match results. This study investigated the ball orientations used in place kicking and their potential implications for success. All 416 place kicks from the 2019 Rugby World Cup were grouped into one of three ball orientation categories, and predicted odds of success were calculated for each category using a binomial logistic regression which accounted for situational factors known to affect performance outcome. Kicks taken using a slanted orientation (n = 152) had the greatest odds of success (90.0%) when taken from the mean tournament distance (29.7 m), compared to a near vertical (n = 116) orientation (84.4%), and near horizontal (n = 148) orientation (86.8%). A further investigation into the impact characteristics associated with each ball orientation is required to better understand the relative merits of each.

KEYWORDS: impact, kicking, performance, Rugby Union, technique

INTRODUCTION: Place kicking is a vital skill within Rugby Union. Quarrie and Hopkins (2015) studied 582 international matches, consisting of 6769 kick attempts over the span of nine years, and found that 45% of all points scored came from place kicks. Furthermore, the outcome of 5.7% of matches was decided as a result of a single kick and if the percentage of successful kicks was swapped between teams then the result of the match would have changed 14% of the time. Thus, the importance of successful place kicking and the large impact it can have upon results is evident.

Despite the role place kicking plays in rugby, there is not one technique used by all. Differences between players are evident right from the setup process when the ball is placed on the tee. Different tees are used and the long axis of the ball is orientated differently between kickers. Only one study has measured the ball orientation used by Rugby Union kickers (Bezodis, Atack & Winter, 2018). A range of 2° to 56° was recorded across the group of 14 kickers, with 0° being vertical and a positive value indicating the top of the ball leaning towards the goal posts. Within Rugby League place kicking, a slanted orientation of 30-40° (based on the same convention) was used by the four elite players studied by Ball, Talbert and Taylor (2013). Due to the ellipsoidal shape of the ball in both rugby codes, the use of various ball orientations could potentially influence the impact location as well as the kicker's technique so that they can impact the desired part of the ball. This in turn may have implications for the foot-ball collision, consequent ball flight characteristics, and ultimately the performance outcome.

The effects of differing impact variables have been investigated in detail in both drop punt kicks (Peacock & Ball, 2018) and a stationary ball in Australian Rules Football (Peacock & Ball, 2017). Ball orientation was found to influence ball velocity, elevation angle and spin rate when a mechanical kicking limb enabled systematic exploration of one impact variable. A ball orientation of 43° was found to be optimal for maximum ball velocity as a result of controlling for foot velocity (16.7 m/s) and impact location on the foot in both the medial-lateral and proximal-distal directions (Peacock & Ball, 2017). This would likely have implications on scoring opportunities within a match since a greater ball velocity would result in a greater flight distance, increasing the range at which points could be scored from. However, accuracy is a constraint that was not considered, and it is not known how this would translate to place kicking in rugby. For a Rugby Union place kick to be successful the ball must pass between a set of posts 5.6 m apart and a crossbar 3 m high - hence a level of accuracy, along with sufficient flight distance, is required. The aim of this study was to investigate the different setups used

by international Rugby Union players competing in the 2019 Rugby World Cup, and to quantify the success of place kicks from different ball orientations, after accounting for other situational factors (kick position on the field, time in game the kick was taken, current match score, and outcome of the kicker's previous kick), to inform future research to investigate the mechanics of the foot-ball impact.

METHODS: Data were collected visually from televised footage of the 2019 Rugby World Cup. The type of tee used and ball orientation were observed for each kicker, at each kick. These were qualitatively categorised by a single observer as either high or low (for tee type), and ball orientation was defined as either upright, slanted or flat depending on whether it visually appeared to be closest to 0°, 45° or 90°, respectively.
Distances and angles to the goal posts (kick angle was 0° if the kick was straight in front of the goal posts and increased as the kick position moved towards either the left or right touchline) were collected from www.goalkickers.co.za for all kicks, where they had been manually plotted and calculated (to the nearest integer) based on the television footage. Mean distance and angle were calculated for the kicks taken in each category of ball orientation. A one-way ANOVA was used to identify any significant ($p < 0.05$) main effects of kick distance and angle, and pairwise comparisons were made with Fisher's LSD.
The following variables were also recorded for each kick based on the procedures of Pocock, Bezodis, Davids and North (2018): time in game the kick was taken (categorised into 10-minute intervals, where kicks taken after 40 minutes but during the first half were included in the 31-40 interval, and kicks taken after 80 minutes were included in the 71-80 interval), the current score (categorised into score margin intervals relative to the current kicker's team: winning by 8+, 4-7, 1-3; scores tied; or losing by 1-3, 4-7, 8+), kick type (conversion or penalty), outcome (success or miss), and the outcome of the kicker's previous kick.
Binomial logistic regression analysis was performed to estimate the probability of kick success based on the recorded variables (SPSS Statistics version 26, IBM, USA). A logistic regression was used for comparisons between the orientation categories as it accounts for the interacting constraints that can influence kick outcome. Categorised time of kick and score margin, kick distance, kick angle, success of previous kick and ball orientation category were therefore all used in the regression model as independent variables. One unit was regarded as 1 m and 1° for kick distance and kick angle, respectively. Predicted odds of success were calculated from the output of the regression model at each independently increasing metre and degree, for each of the three ball orientations. Distance and angle thresholds were then identified (for each category of ball orientation) as the first values where predicted percentage of success dropped below the mean success percentage for the tournament (Pocock et al., 2018).

RESULTS: A total of 416 place kicks were taken by 51 different kickers; 314 were successful, giving a success percentage of 75.5%. Of the 416 kicks, 116 (27.9%) were setup with an upright ball orientation, 152 (36.5%) with a slanted orientation, and 148 (35.6%) with a flat orientation. Each kicker used a consistent ball orientation for all of their kicks throughout the tournament. Raw success rate varied between the categories of kicks (Table 1); the slanted category was most successful at 78.9%.

Table 1: Success percentages and mean distances and angles for all kicks taken in each category (mean ± SD).

Ball Orientation Category	Success (%)	Distance (m)	Angle (°)
Upright	73.3	28.0 ± 12.1	31 ± 15
Slanted	78.9	29.8 ± 11.4	31 ± 16
Flat	73.6	31.0 ± 11.3*	29 ± 16
All	75.5	29.7 ± 11.6	30 ± 16

* significantly ($p < 0.05$) different from the upright ball orientation category.

Kicks in the flat category were taken from the greatest mean distance to the posts (31.0 ± 11.3 m), whilst the upright (31 ± 15°) and slanted kicks (31 ± 16°; Table 1) were taken from the

largest mean kick angle. There was no significant main effect of ball orientation category on kick distance ($p = 0.12$) or angle ($p = 0.59$), although pairwise comparisons revealed flat kicks were taken from significantly further away than upright kicks. Over the course of the tournament, six kicks were attempted from more than 50 m and all used ball orientations classified into the flat category.

In comparison to a model with no independent variables, the binary logistic regression was statistically significant in predicting the outcome of kicks at goal ($\chi^2 = 93.1$, $df = 19$, $p < 0.001$). The model correctly predicted 79.1% of cases; 37.3% of misses were classified correctly, whilst 92.7% of successful kicks were classified correctly. Kick distance ($p < 0.001$) and kick angle ($p < 0.05$) were the only two independent variables statistically significant in predicting kick outcome. When setting the upright ball orientation as the reference category, the slanted category had an odds ratio (OR) for success of 1.7 (95% CI 0.9 – 3.2) and the OR for the flat orientation was 1.2 (95% CI 0.6 – 2.3).

From the tournament mean distance (29.7 m) and an angle of 0° (i.e. directly in front of the goal posts), the model indicated that a place kick had an expected success of 84.4%, 90.0% or 86.8% when taken using an upright ball orientation, slanted orientation and flat orientation, respectively. Using the mean tournament success percentage of 75.5% as a threshold, distance thresholds were identified (using kick angle = 0°) from the results of the logistic regression for the upright ball orientation (35 m), slanted orientation (40 m) and flat orientation (37 m; Figure 1). The angle thresholds (when keeping distance constant at the tournament average of 29.7 m) were 27° (upright orientation), 52° (slanted orientation), and 37° (flat orientation).

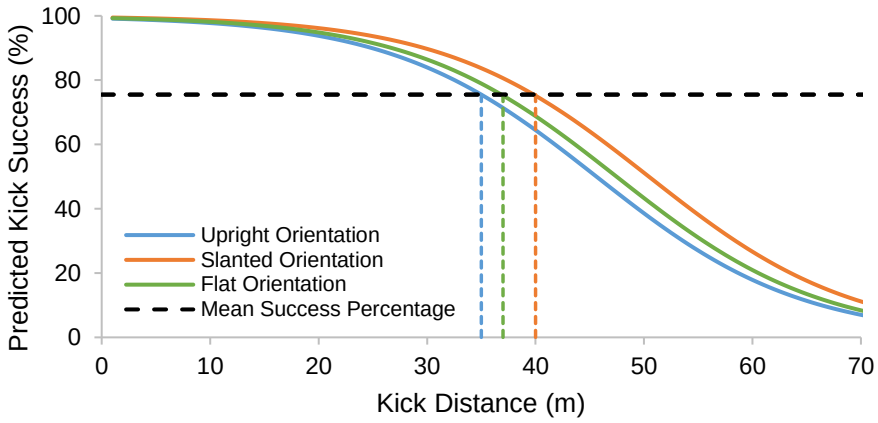

Figure 1: Predicted percentages of kick success at each independent metre for each of the three ball orientation categories. Threshold distances are calculated from the results of the logistic regression as the distance at which success dropped below the mean tournament success percentage.

DISCUSSION: This study investigated the use of different place kicking ball orientations at the 2019 Rugby World Cup and the association these had with success. The logistic regression revealed that kicks taken with a slanted ball orientation had the greatest odds of success (90.0% for a kick taken from 29.7 m and 0°), when controlling for all other variables, compared with the upright (84.4%) and flat (86.8%) orientation categories (Figure 1). The sigmoidal curve indicating predicted success, at progressively increasing distances, is shifted furthest to the right for the slanted orientation and therefore this setup has the greatest chance of success at any given distance. A similar pattern was observed when investigating kick angle due to the ORs of the ball orientation categories. An OR of 1.7 was calculated from the logistic regression for the slanted category and an OR of 1.2 for the flat orientation category (relative to the upright orientation as the reference category). This means that when all other factors remain constant, the increase in odds of success is greater for the slanted category of kicks than the flat category, in relation to the upright ball orientation category. Therefore, when accounting for the effects of other potentially influential factors, at the 2019 Rugby World Cup, the use of a slanted ball orientation led to the highest rate of predicted success, whilst the upright orientation led to

the poorest predicted kick success. No statistical analyses were performed on the simple success percentages between the three orientation categories, as they should not be directly compared due to that fact that they do not account for other interacting constraints. These include those input into the logistic regression as independent variables, as has previously been shown in all matches at the previous (2015) Rugby World Cup (Pocock et al., 2018).

Kicks categorised as using a flat ball orientation were attempted from the greatest mean distance (31.0 m) and contained the only kicks taken from greater than 50 m (n = 6), with the furthest attempted kick being 57 m. When systematically examining ball orientation using a mechanical kicking limb and an Australian Football ball, previous research has shown that ball velocity is greater when impacted on the point (ball orientation of 65° = ball velocity of 24 m/s) compared to the centre (ball orientation of -25° = ball velocity of 20 m/s). However, the greatest ball velocity (24.4 m/s) was achieved when using an orientation of 43° (Peacock & Ball, 2017). Flight elevation angle must also be considered because Peacock and Ball (2017) also found that the elevation of ball flight reduced as ball orientation angle increased. Since ball flight parameters combine to determine whether a given kick is successful, further work is needed to quantify the overall success (i.e. incorporating distance and accuracy; Atack et al., 2019) of a kick when the effects of ball orientation are explored.

Although ball orientations were visually categorised into one of three categories, the current results revealed the existence of different ball orientation preferences between kickers at the very highest level of competition. Also, the logistic regression model incorrectly classified 20.9% of cases which indicates there are parameters not in the model that influence kick outcome. Since these results were obtained from television footage, it is not possible to quantify the mechanical differences between the different orientations used, but these results provide justification for more detailed experimental analyses of the foot-ball interaction in Rugby Union place kicking from a range of different ball orientations. This could enable an understanding of whether one orientation is simply preferable to the others for all performance considerations (i.e. distance and accuracy) irrespective of the technique of the kicker striking the ball, or whether a range of factors interact to influence and inform the selection of a preferred ball orientation for a given kicker.

CONCLUSION: This study identified the use of different ball setups by players competing at the highest level of international rugby and that success rates varied between categories of kicks where different ball orientations were employed. At the 2019 Rugby World Cup, the use of a slanted ball orientation (~45°) was associated with the highest odds of success when accounting for the influence of important situational constraints. Detailed biomechanical analyses of the foot-ball impact are required to better understand the relative merits of each of the different ball orientations and to inform coaching practice by identifying whether certain orientations might be preferable for a given kicker based on their place kicking technique.

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