Original Article

Maximum ball in play demands for sub-elite Rugby Union referees in domestic club rugby

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ABSTRACT

Purpose: Rugby union referee research has reported the game demands for whole game averages and comparisons between each half and 10 minute periods. No study has reported the movement game demands for the maximum ball in play time for referees. The purpose of this study was to quantify the maximum ball in play (Max BiP) demands termed "worst case scenario" (WCS) of sub-elite rugby union referees using 10Hz Global Positioning System (GPS) units. Method: Movement demands of ten (n=10) sub-elite referees across 27 matches, played during the 2017/18 All Ireland League Division 1, was calculated using 10Hz GPS units. The total distance covered (m), relative distance ($m.min^{-1}$), percentage time in 6 velocity zones, were reported across the whole match, 1st half, 2nd half, 10minute periods and the maximum ball in play time using paired sample t-tests. Cohen's d effect sizes was reported. Results: The maximum ball in play time was reported to be 172 ± 71 sec. The relative distance during Max BiP (107.9 ± 22.54 $m.min^{-1}$) was significantly higher ($p < 0.005$) than whole match (75.1 ± 8.6 $m.min^{-1}$) and 1st half (75.4 ± 8.7 $m.min^{-1}$) & 2nd half (74.8 ± 13.1 $m.min^{-1}$). During the Max BiP, referees spend a significantly higher ($p < 0.005$) percentage of time above whole game averages for walking (0.5 - 2.0$m.s^{-1}$), jogging (2.01 - 4.0$m.s^{-1}$), running (4.01 - 5.5$m.s^{-1}$) and lower for high speed running (5.51 - 7.00 $m.s^{-1}$) and sprinting (>7.01$m.s^{-1}$). Conclusion: The results of this study quantifies the Max BiP movement demands for a sub-elite rugby union referee which are higher than those reported in whole game averages, 1st & 2nd halves and some 10min periods. These results provide sports scientists with the worst case scenario demands and can allow for these demands to be replicated in training with those experienced in matches. **Keywords:** Rugby Union Referee; Maximum ball in play; Global Positioning System (GPS), Worst case scenario.

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INTRODUCTION

Studies of rugby union players have shown it to be a team sport with frequent bouts of high & low intensity and work rates (Cahill et al., 2013; Dubois et., 2017; Cunningham et al., 2016). Referees are vital to team sports and should be recognised as performers in sport (Philippe et al., 2009). Knowledge of the match demands required for a referee is a vital component for sports scientists and trainers of rugby union referees. This information is required to help with training design, talent identification, injury prevention by increasing the knowledge of these key people within the game of rugby. Referees will need to be able to match the running demands in order to officiate the laws of the game (Mascarenhas et al., 2005; Blair et al., 2018).

There are a small number of studies that quantified the movement demands of rugby union referees using Global Positioning Systems (GPS) technology (Blair et al., 2018; Suarez-Arrones et al., 2013). Similar to other invasion team sports, the intermittent nature of rugby union (Cahill et al., 2013) has no definitive endpoint for each passage of play, and the whistle of the referee will dictate the end of each passage of play. Like players, a referee will need to be exposed to the demands of these continuous passages of play so they can officiate the laws of the game. To the author's knowledge, there have been no studies reporting the running demands of the continuous ball in play time for referees. The average longest ball in ball time reported for professional rugby teams is 152sec (02:32min) -161sec (02:41min) with significantly higher relative distance (117 $m.min^{-1}$) (Reardon et al., 2017) when compared to those previously reported for whole game average, (68 $m.min^{-1}$) (Cahill et al., 2013). The referee will need to consistently match the movement demands throughout the whole game as Super rugby referees are reported to cover distances of 8,030 ± 506 m, and with no differences ($P > .05$; $d = .37$) observed between 1st and 2nd halves (Blair et al., 2018). While domestic Spanish/Portuguese club referees covered 6,322.2 ± 564.9 m with a significant difference ($p < 0.05$) in the total relative distance covered between the 1st and 2nd halves (77.2 ± 6.1d vs. 71.9 ± 7.1 $m.min^{-1}$). Super rugby referees showed no differences in relative distance across each 10min time periods with a match average of 83 ± 5 $m{\cdot}min^{-1}$ (Blair et al., 2018) but there was a significant differences (moderate ES) reported in the distance covered, between 21-30 min v 41-50 min ($P = .004$; $d = 1.16$), and 31-40 v 41-50 min ($P = .022$; $d = .97$) (Blair et al., 2018). It is reported that in the first 10 minutes of a match, a rugby referee will experience higher intensities compared with other 10 minute periods (Emmonds, et al. 2015; Suarez-Arrones et al., 2013). Spanish/Portuguese referees may be affected by fatigue or the game slows downs as there is a significant difference ($p < 0.05$) for the distance covered between the first 10 minutes (876.3 ± 163 m) compared with 50–60 minutes (679.8 ± 117.6 m), 60–70 minutes (713.03 ± 122.3 m), and 70–80 minutes (694.2 ± 125.7 m) (Suarez-Arrones et al., 2013). Elite referees do not experience such declines in their movement demands (Blair 2018). This maybe as a result of better physical preparation for the higher standard of referee or as a result of the impact of substitutions. Using whole match and 1st & 2nd half averages may not report the various running demands and running demands of a rugby union (Jones et al., 2015; Lacombe et al., 2017). Soccer referees have lower error count in their decision making, when adjudicating incidents from a distance of 11 to 15 m (Mallo et al., 2012). Due to the nature of rugby union, a referee will need to be in closer proximity to the ball to officiate the laws of the game. Professional rugby players have reported running 319m at a maximum velocity (MaxVel) (6.8 $m{\cdot}s^{-1}$) during the single longest bout of play (Reardon et al., 2017). While a referee may not have to match this MaxVel, they will have to keep up with the ball and attain a sufficient distance from the ball to rule on the laws of the game, as high relative distance before a decision may increase the likeliness of decision-making errors (Elsworthy et al., 2014).

A rugby union referee will spend most of the game (76.6 ± 1.8%) at low-intensity speed (< 2 $m{\cdot}s^{-1}$) combined with periods of higher speed, with significant and large effects reported for the time spent at different movement velocities. Higher speed running requirements (> 5.1 $m\cdot s^{-1}$) were reported to be significantly higher during the first 10 minutes of a match (Blair et al., 2018). However, limitations of this study are acknowledged as it uses the less reliable 1Hz GPS units. Units with a higher frequency sampling rate have reported having greater validity for distance measurements (Waldron et al., 2011; Jennings et al., 2010), while the 10Hz GPS is more valid and reliable to date for team sport simulated running, (Kelly et al., 2014).

This study aimed to use GPS to quantify the demands on a referee for the single most extended passage of play termed the "worst case scenario" (Reardon et al., 2015). A referee will need to be prepared physically for that worst case scenario they may face at any given time of a game. However, as rugby is an intermittent sport, by just measuring whole match averages or half match averages this will not depicted the absolute running intensities within the whole game or halves. Knowledge of these demands can shape the design of future training by preparing referees for the most demanding scenario of the game.

MATERIAL AND METHODS

Participants
10 Irish Rugby Football Union referees (age 38 ± 7.5 years; stature 177.6 ± 6.1 cm; body mass 83.3 ± 8.7 kg), refereeing in the All Ireland League Division 1 participated in this study. All referee appointments were made by the Irish Rugby Football Union (I.R.F.U.) referee department. All referees were given detailed information on the procedures and permission to undertake the research was granted by the I.R.F.U. Head of Referees. The study protocol was conducted following the ethical standards and the guidelines of the Ethical Committee of the Institute of Technology, Carlow which approved this study protocol.

Measures
During a total of 27 Irish Rugby Football Union domestic All Ireland League Division 1 matches, in the 2017/2018 season, the referee wore a portable 10Hz GPS device (MinimaxX S4; Catapult Sports, Australia: 88x50x19 mm in size, 67 g in weight) which include triaxial accelerometers sampling at 100 Hz. 10 Hz GPS devices are reported to be valid and reliable (Jennings et al., 2010) and it has been reported that 10 Hz GPS devices are two to three times more accurate than 5 Hz devices (Varley et al., 2012) Each Referee wore the GPS unit in the manufacture's vest, with the unit placed on the upper thoracic spine between the scapulae with the antenna facing out to allow for optimal satellite reception.

Procedure
The GPS unit was turned on 30 minutes before the referees warm up to the kick off of the match. The GPS unit was positioned within an undergarment, worn beneath their standard refereeing uniform. Total distance (m), and relative distance covered ($m.min^{-1}$), during match play per half and in 10-minute periods were examined. The movement demands were categorised into six velocity classifications according to prior criteria. These were standing (< 0.5 $m.s^{-1}$), walking (0.51 - 2.0$m.s^{-1}$), jogging (2.01 - 4.0 $m.s^{-1}$), running (4.01 - 5.5 $m.s^{-1}$), high speed running (5.51 - 7.0 $m.s^{-1}$; HSR) and sprinting (> 7.01 $m.s^{-1}$). Despite no gold standard set for velocity zones, the zones above have been used by varies referee research and allowed comparison with the limited literature (Brightmore et al., 2016; O'Hara et al., 2013).

All referees in this study completed the whole game. All data from the GPS unit was downloaded after each match using propriety analysis software (Catapult Sprint Version 5.1.1, Melbourne, Australia) and the output file was exported to Excel CSV (Microsoft, Redmond, USA) for analysis. The single longest bout in each game was identified using GPS analysis software (Catapult Sprint Version 5.1.1, Melbourne, Australia). The operational definition for the longest ball in ball duration was from the time the ball entered play (when the ball was kicked at restarts, throw-in at the lineouts, and on the “set” call at scrums) until it went dead or until play was stopped by the referee.

For the 27 matches analysed, mean match duration was 01:26:32 min (1st half = 00:42:57 min; 2nd half = 00:43:34 min). Match play commenced between 14:00 h and 20:00 h with data collected at six grounds throughout the AIL.

Analysis

Once the data collection period was completed, the excel files were transferred to SPSS (version 23.0.0.0.3 IBM Corporation, Armonk, New York) for statistical analysis with statistical significance set at $P < 0.05$. Data are presented as mean ± standard deviations. Preliminary analyses was conducted to check for normality with Kolmogorov-Smirnov test performed on the data set to check data distribution with $P < 0.05$ indicating normality.

Paired samples t-tests were used to assess differences between the maximum ball in play time and whole match, 1st half & 2nd half, 10 min period means for relative distance and the six velocity zones. Statistical significance was set at $P < 0.05$ and Cohen's d effect size (ES) was reported. The magnitude of the effect size was classified as; trivial < 0.2, small 0.21 - 0.6, moderate 0.61 - 1.2, large 1.21 - 1.99, and very large > 2.0.

RESULTS

The maximum ball in play (maxBiP) ranged from 91-313 sec with a mean of 172 ± 71 sec. The total distance covered in maxBiP was 308.4 ± 148.1 m with a range of 125-644m (Table 1). The highest percentage of time (48.25 ± 9.89min) was spent walking (0.51 - 2.0m.s^{-1}). The max velocity mean was presented as 5.3 ± 0.89 m/sec during the maxBiP period. There was a significant difference with a large effect size reported between the relative distance covered during maxBiP 107.9 ± 22.54 (m.min^{-1}) and whole match 75.1 ± 8.6 ($P < 0.05$; $d = 1.92$), 1st half 75.4 ± 8.7 ($P < 0.05$; $d = 1.90$) and 2nd half 74.8 ± 13.1 ($P < 0.05$; $d = 1.79$) (Table 2). The percentage of time spent in higher velocity bands is significantly greater ($P<0.05$) for walking (0.51 - 2.0m.s^{-1}), jogging (2.01 - 4.0 m.s^{-1}) and running (4.01 - 5.5 m.s^{-1}) in comparison to the whole game, 1st half and 2nd half averages in presented in Table 2.

Relative distance and percentage time spent in each velocity zone during maxBiP and in each 0-10min period and the extra periods are presented in table 3. During maxBiP a referee will spend a lower percentage standing (>0.5m.s^{-1}) with significant differences ($p<0.05$) and very large effect size ($d<2.0$) across all 10 minute periods. Significant differences ($p<0.05$) with very large effect size ($d>2.0$) were found in the percentage of time walking (0.51 - 2.0m.s^{-1}), and with a large effect size ($d>1.2$) for Jogging (2.01 - 4.0m.s^{-1}) across all 10 minute periods. There was a significant difference ($p<0.05$) with a moderate effect size ($d>1.2$) between maxBip and percentage time spent running (4.01 - 5.5m.s^{-1}) for all 10 minute periods except the first 10 minutes of each half. There was no significant difference ($p>0.2$); with a moderate effect size ($d <0.37$) reported when comparing High Speed Running (5.51 - 7.0 m.s^{-1}) in each period and maxBiP. while no referee spent time sprinting (>7. 01m.s-1) in any maxBiP period.

Table 1. Movement demands for Rugby Union referees during Maximum Ball in Play time during match play

	Referee (mean ± SD)
Duration (sec)	172 ± 71
Total Distance (m)	308.4 ± 148.1
Relative Distance (m.min^{-1})	107.9 ± 22.54
MaxVel (m.s^{-1})	5.3 ± 0.89
Standing (< 0.5 m.s^{-1})	17.69 ± 9.12
Walking (0.51 - 2.0m.s^{-1})	48.25 ± 9.89
Jogging (2.01 - 4.0 m.s^{-1})	21.19 ± 6.93
Running (4.01 - 5.5 m.s^{-1})	11.13 ± 6.28
High Speed Running (5.51 - 7.0 m.s^{-1})	3.63 ± 2.20
Sprinting (> 7.01 m.s^{-1}).	0.00 ± 0.00

DISCUSSION

This study aimed to report the movement demands of rugby union referees during the maximum ball in play time. During the maxBiP time, a referee travelled a mean distance of 308.4 ± 148.1m during a mean time of 172 ± 71 sec. The maximum distance covered was 644m, while the maximum time was 313 sec. The mean maxBiP time reported for professional rugby players was 161sec for a front 5 player and a mean distance of 319m for an outside back. (Reardon et al., 2017). This is the first time that the maxBiP is reported for sub-elite rugby union, which may help in player match preparation. Despite the different standards of the game, a referee will have to maintain similar continuous physical movement demands to match the game for these maximum ball in play time. Maximum ball in play times for elite rugby league (NRL) matches were 318.3 ± 65.4 seconds and for National Youth Competition (u20s) was 288.9 ± 57.5 seconds (Gabbet et al., 2012). This may be to do with the 6 tackle law and a reduced contest for the ball in the tackle area when compared to rugby union. These findings show that a referee needs to be prepared for the maximum ball in play time, but as sports scientists may not know how long that is as there is no fixed time for the maximum Ball in Play time for rugby union. While rugby has clearly defined start for ball in play time, the end of the ball in play is very much down to the ability of the player's to score, keep the ball in play and play within the laws of the game. This non-defined end time makes it difficult for the training of referees and players to meet the demands of the game. Further studies need to be done to compare the different levels of the game and to give sports scientists an indication of what the demands are.

This is the first time that the maximum ball in play time is reported for sub-elite referees. Similar to findings reported for professional rugby union players (Reardon et al., 2017), a majority of a referee's percentage of movement (87.13% ± 7.66) is carried out in low intensity (<4.0 m.s^{-1}). The intensity during the maximum ball in play time is higher (107.9 ± 23.28 m.min^{-1}) than the whole match average (75.1 ± 8.6 m.min^{-1}). These intensities are similar to those reported for front 5 players (109 m.min^{-1}) in European Cup standard professional rugby but less than those reported for outside backs (124 m.min^{-1}) (Reardon et al., 2017). This reported relative distance is lower than maxBiP periods >90sec reported by Pollard et al., (2018) (141.9 m.min-1 for forwards and 155.5m.min-1 for backs). This may be due to the standard of players and their ability to keeping the ball alive for longer at a higher intensity. It should also be noted that Pollard et al., (2018) used the "worst case scenario", the plays with the highest intensity not the maximum ball in play time as

Table 2. Relative distance and percentage time spend in velocity zone for Rugby Union referees during Maximum Ball in Play time during match play, comparison with Max BiP

	Max BiP (mean ± SD)	**Whole Match (mean ± SD)**	**1st half (mean ± SD)**	**2nd half (mean ± SD)**
Relative Distance ($m.min^{-1}$)	107.9 ± 22.54	*75.1 ± 8.6 P<0.005; d=1.9	*75.4 ± 8.7 P<0.005; d=1.9	*74.8 ± 13.1 P<0.005; d=1.8
Standing (< 0.5 $m.s^{-1}$)	17.64 ± 9.64	*43.53 ± 3.79 P<0.005; d=3.8	43.23 ± 5.4 P<0.005; d=3.5	*43.86 ± 3.9 P<0.005; d=3.8
Walking (0.51 - 2.0$m.s^{-1}$)	48.29 ± 9.57	*36.03 ± 1.61 P<0.005; d=1.78	*35.85 ± 2.8 P<0.005; d=1.76	*36.20 ± 2.1 P<0.005; d=1.74
Jogging (2.01 - 4.0 $m.s^{-1}$)	21.17 ± 6.71	*13.37 ± 1.69 P<0.005; d=1.64	*13.43 ± 2.4 P<0.005; d=1.53	*13.11 ± 1.8 P<0.005; d=1.64
Running (4.01 - 5.5 $m.s^{-1}$)	10.47 ± 6.46	*5.45 ± 1.55 P=0.003; d=1.06	*5.61 ± 2.1 P=0.002; d=1.01	*5.29 ± 1.3 P=0.004; d=1.11
High Speed Running (5.51 - 7.0 $m.s^{-1}$)	1.88 ± 2.34	1.70 ± 0.79 P>0.5; d=0.10	1.82 ± 0.93 P>0.5; d=0.03	1.57 ± 0.94 P>0.5; d=0.17
Sprinting (> 7.01 $m.s^{-1}$).	0.00 ± 0.00	0.03 ± 0.05 P>0.5; d=0.0	0.05 ± 0.09 P>0.5; d=0.0	0.01± 0.02 P>0.5; d=0.0

**significant difference P<0.005 when compared to MaxBiP*

Table 3. Movement demands for Rugby Union referees during Maximum Ball in Play time during match play

	Max BiP (mean ± SD)	0-10min	10-20mins	20-30mins	30-40mins	40+mins	40-50mins	50-60mins	60-70mins	70-80mins	80+mins
Relative Distance ($m.min^{-1}$)	107.9 ± 22.54	*88.6 ± 17.4 P=0.003; d=0.95	*71.7 ± 9.5 P<0.005; d=2.09	*72.5 ±10.1 P<0.005; d=2.02	*68.3 ±17.4 P<0.005; d=1.97	*77.0 ± 24.6 P<0.005; d=1.31	*76.6 ± 19.2 P=0.001; d=1.49	*73.2 ± 13.2 P<0.005; d=1.88	*73.1 ± 14.5 P=0.001; d=1.83	*74.5 ± 18.4 P=0.001; d=1.62	83.3 ± 25.8 P=0.012; d=1.01
Standing (< $0.5m.s^{-1}$)	17.64 ± 9.64	*37.72 ± 9.6 P<0.005; d=2.08	*44.65 ± 6.1 P<0.005; d=3.34	*44.39 ± 5.6 P<0.005; d=3.39	*46.90 ± 9.5 P<0.005; d=3.05	*40.15 ± 15.6 P<0.005; d=1.73	*44.48 ± 7.6 P<0.005; d=3.09	*43.16 ± 6.8 P<0.005; d=3.05	*44.63 ± 8.8 P<0.005; d=2.92	*44.39 ± 8.0 P<0.005; d=3.01	*39.17 ± 14.2 P<0.005; d=1.77
Walking ($0.51-2.0m.s^{-1}$)	48.29 ± 9.57	*36.75 ± 4.9 P=0.001; d=1.52	*36.00 ± 4.23 P<0.005; d=1.66	*35.91 ± 3.56 P<0.005; d=1.71	*34.17 ± 5.06 P<0.005; d=1.84	38.09 ± 10.28 P=0.021; d=1.03	*34.73 ± 4.28 P<0.005; d=1.83	*36.72 ± 4.79 P=0.001; d=1.53	*36.01 ± 5.32 P<0.005; d=1.59	*36.49 ± 4.77 P<0.005; d=1.56	38.19 ± 2.09 P=0.006; d=1.46
Jogging ($2.01-4.0m.s^{-1}$)	21.17 ± 6.71	*15.43 ± 3.60 P=0.003; d=1.06	*12.93 ± 2.80 P<0.005; d=1.60	*12.87 ± 2.30 P<0.005; d=1.65	*12.03 ± 4.10 P<0.005; d=1.64	14.80 ± 6.30 P=0.007; d=0.98	*13.02 ± 2.88 P<0.005; d=1.58	*13.86 ± 3.64 P<0.005; d=1.35	*13.01 ± 3.33 P=0.001; d=1.54	*12.16 ± 2.57 P<0.005; d=1.77	*14.88 ± 7.21 P=0.004; d=0.90
Running ($4.01-5.5m.s^{-1}$)	10.47 ± 6.46	*7.46 ± 3.61 P=0.021; d=0.57	*4.72 ± 2.24 P=0.001; d=1.19	*5.15 ± 2.20 P=0.001; d=1.10	*5.23 ± 2.94 P=0.005; d=1.04	*5.59 ± 4.53 P=0.004; d=0.87	*5.80 ± 2.78 P=0.010; d=0.94	*4.82 ± 1.67 P=0.002; d=1.19	*5.11 ± 2.00 P=0.005; d=1.12	*5.35 ± 2.14 P=0.003; d=1.06	*6.04 ± 3.21 P=0.017; d=0.87
High Speed Running ($5.51-7.0m.s^{-1}$)	1.88 ± 2.34	2.63 ± 1.67 P=0.31; d=0.37	1.64 ± 1.07 P=0.69; d=0.13	1.62 ± 1.07 P=0.59; d=0.14	1.59 ± 1.16 P=0.65; d=0.16	1.36 ± 2.36 P=0.50; d=0.22	1.96 ± 1.26 P=0.89; d=0.04	1.44 ± 1.24 P=0.39; d=0.23	1.25 ± 0.97 P=0.28; d=0.35	1.58 ± 1.21 P=0.61; d=0.16	1.71 ± 1.96 P=0.79; d=0.08
Sprinting (> $7.01m.s^{-1}$)	0.00 ± 0.00	0.00 ± 0.00 P=0.33; d<0.2	0.06 ± 0.17 P=0.25; d<0.2	0.07 ± 0.18 P=0.11; d<0.2	0.08 ± 0.26 P=0.19; d<0.2	0.00 ± 0.00 P>0.05; d<0.2	0.01 ± 0.04 P=0.33; d<0.2	0.00 ± 0.00 P>0.05; d<0.2	0.00 ± 0.00 P>0.05; d<0.2	0.02 ± 0.09 P>0.05; d<0.2	0.00 ± 0.02 P=0.25; d<0.2

**significant difference P<0.005 when compared to MaxBiP*

Reardon et al., (2017) defined the “worst case scenario” as “the single longest period of continuous ball-in-play time from a game”, it may not in some cases be the play with the highest intensity.

This study reports that no referee reached sprinting velocity (>7.01 $m.s^{-1}$) during the maximum ball in play time. Reardon et al., (2017) reported that only outside backs player reached >7.01 m.s-1 and had a mean of 6.84 $m.s^{-1}$. As there is no gold standard for what velocity bands to use for GPS velocity, defining sprinting at >7.01 $m.s^{-1}$ may be too high when using velocity bands during research into sub-elite sport. Prospective studies should look at using the percentage of max velocity for each referee. The referee will spend 13.07 ± 7.32% of time during a maximum ball in play >4.0m.sec, which is higher than the 7.17 ± 2.5% mean for the whole game. It is reported that law errors are greater if the referee decision is made during high relative running (Elsworthy et al., 2011). Rugby league referees penalty decision-making accuracy decreases in the final 10 minutes of a game (Emmonds et al., 2015), indicating that referee fatigue plays a factor in a referees performance. It is reported that a soccer referee has a lower error rate when judging incidents from a distance of 11 to 15 m, and errors increase when referees were more distant from the infringements (Mallo et al., 2012). The tackle area is one of the most complex areas to officiate in team sports, so the referee will need to get close to the ball to officiate the laws around the tackle and breakdown, while also maintaining offside lines. This study did not look at the decision making aspects during these maximum ball in play times but is an aspect worth investigating during the maximum ball in play time.

Understanding the specific movement demands of domestic rugby union referee is useful for trainers and sports scientists to determine whether the referee is adequately prepared for the game in which they will officiate. During the maximum ball in play time, a referee spent a significant greater time jogging (2.01-4.0$m.s^{-1}$) and running (4.01-5.5 $m.s^{-1}$) when compared with whole match, 1st and 2nd half averages (Table 2) and when compared to 10 minute periods (Table 3). This confirms the reported intermittent nature of refereeing of rugby union (Blair et al., 2017) with a majority of time spent in low intensity walking (48.29 ± 9.57%) and jogging (21.17 ± 6.71%) with bouts of higher velocity running (10.47 ± 6.46%). As the game intensity increases so do the movement demands on the referee. This increase in intensity by the players will result in an increase in the referee’s velocity, so that they are at an adequate distance from play to officiate the laws of the game. While some players may be afforded an opportunity to reduce their running speeds and gain a recovery opportunity due to their positioning and repositioning, due to the laws of the game a referee has to stay with the velocity of the game consistently. The referee will have to adjudicate on upwards of 200 contested breakdown/tackle situations a match, once every 30 seconds (Nazarudin et al., 2015). While there are no known studies are looking at fatigue and decision making of rugby union referees, it is reported that fatigue affects decision making for soccer referees (Mallo et al., 2012) and AFL referees (Elsworthy et al., 2011). This study did not look at the multi-directional nature of these velocities presented and movement in forward, lateral and backwards movement during the maximum ball in play time needs investigation. While it is essential for trainers to know what the velocity is during the maximum ball in play time it is unknown if these movements are multi-directional as such further research is needed into the directional movement at these velocities during the maximum ball in play time.

PRACTICAL APPLICATION

Findings of this study may be used to facilitate the physical preparation and training programs of a sub-elite rugby union referee. Sports scientists and conditioning coaches should incorporate movement demands of maximum ball in play time within conditioning sessions to best prepare the referee for theses match moments. Game simulation drills in multi-directional low speeds (<4.0 $m.s^{-1}$) with intermittent bouts of higher speeds

(>4.0 m.s-1) for durations of >120sec should be designed to assist with game preparation and to aid injuring prevention. This will provide a greater transfer to real match performance for a rugby union sub-elite referee.

CONCLUSION

This study is the first to report the maximum ball in play for a referee in sub-elite rugby. It is not possible to compare this study to other games of a similar standard. The study confirms the intermittent nature of the game of rugby union. The referee will need to keep up with the velocity demands of the game in order to officiate the laws of the game. The nature of rugby union refereeing requires the referee to be close to the breakdown situations while removing themselves to allow room for play to continue and look at administer the laws for the attack and defence. Trainers and sports scientists need to prepare the referee to meet these maximum ball in play times, incorporating low and high-intensity efforts and speeds. This study should be used as a guide to train sub-elite referees. Further research needs to concentrate on the directional movements and accelerations and decelerations during these periods of higher intensities and the referee's ability to administrate the laws of the game during these periods. This would further enhance the knowledge of the trainers and sports scientists to prepare the referee for the demands of the game better.

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No conflict of interest is reported by authors.

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