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Game Movement Demands of Sub-Elite Rugby Union Referees in Domestic Club Rugby -

Brett A Igoe* **and Declan Browne**

Department of Science and Health, Institute of Technology

***Address for Correspondence:** Brett Igoe, Coaches Office, Barrow Centre, Institute of Technology, Kilkenny Road, Carlow, R93 V960, Ireland, Tel: +353-877-637120; E-mail; brett.igoe@itcarlow.ie

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ABSTRACT

Introduction: A majority of rugby union games are played at the sub-elite level, however the limited number of recent research has taken place within the less participated professional game. There is currently little research into the movement demands of sub-elite rugby union referees for sports scientists and trainers to base specific training programs and use towards the development of referees to a higher level. This study aimed to quantify the movement demands of sub-elite rugby union referees using 10Hz Global Positioning System units by measuring the total distance covered, the relative distance within 10min periods of the game and the speed zones a referee will perform.

Methods: Time-motion analysis was undertaken on ten (n = 10) domestic rugby union referees using 10-Hz GPS devices from 27 games of the All Ireland League Division 1 competition. Total distance (m), relative distance (m·min^{-1}), percentage time spent within various speed zones and directional movement was calculated during 10 minute periods.

Results: The total distance covered was 6501.7 ± 780.2 m, with a relative distance of 75.1 ± 8.6 m·min^{-1} and with no differences observed between halves ($P > 0.05$). A high percentage (79.56%) of the game time was spent in movement speeds of <2.0 m·s^{-1} while Sprinting (>7.01 m.s^{-1}) only occurred 0.03 ± 0.05% of the time. The demands of the game are greater at the start of the game as the first period of the match (0-10 min) shows greater relative distance, distances covered and greater time spent jogging (2.01-4.0 m.s^{-1}), running (4.01-5.5 m.s^{-1}) and high speed running (5.51-7 m.s^{-1}) than other period of the game.

Conclusion: The findings of this study confirm the intermittent natural for sub-elite rugby union referees. Referees will have to maintain a constant relative distance from period 2 to period 8 after a period 1 of greater relative distance and speed. These results will aid trainers and sports scientists in the physical preparations of the sub-elite game and ensure that training should simulate the game demands for referees in rugby union.

Keywords: Rugby union referee; Running demands; Global Positioning System (GPS)

INTRODUCTION

The referee is a vital component of elite and sub-elite competitive field sports who will officiate the game to the required level. The referee in 15 a-side rugby union apply the laws of the game and be the sole judge of fact and law during a match [1], while under the physical pressures of the intermittent nature of the game [2]. Along with the knowledge of the laws, the referee's fitness is critical to their performance [3]. Since the game of rugby union went professional in 1996 and with advancements in research methods and technology, has seen an increase in knowledge into the movement demands of rugby players in the professional game [2,4-9]. However, for a rugby union referee, there has been limited research, using Global Positioning System (GPS), into the movement demands of the referee [10,11].

An un-obstructive view of potential infringements is needed to apply the laws of the game [12] and as the game is becoming faster and more demanding the referee will need to meet these modern demands. The distance a referee is from a potential infringement is a factor in their decision making [13]. It has been reported that soccer referee's accuracy in their decision making reduces in the last 15 minutes due to mental and physical fatigue [12], while reported a moderate drop in penalty accuracy in the last 10 minutes for rugby league referees [14]. However conflicting research suggested that decision making performance was not affected by physical exertion [12,15].

The use of Global Positioning System (GPS) and accelerometer devices provides sports scientists and coaches with an objective and accurate automated system to measure a team's movement demands [16] and with this, has seen an increase in research of rugby using these devices [2,4-9]. GPS units have helped to monitor and track a player's movement during matches and training. GPS units are capable of tracking the performer's movements during team sport performances [17]. GPS units with sampling rates of 10Hz have been proven to be more valid and reliable for team sport than those sampling at lower frequencies [18]. Using the more reliable 10Hz GPS units, this information can give a greater understanding of the demands of the actual sports performance of referees which will aid training and testing and prepare a referee to see the demands of the game. Early referee studies used GPS units with 1Hz sampling frequencies and video analysis which have a poorer validity and inter-unit reliability than GPS units with 10Hz sampling frequencies [19]. Using GPS units with lower sampling frequencies (1Hz and 5Hz) may result in inaccurate results [18]. Using 10Hz GPS which have greater validity and reliability is recommended to gain more accurate results of the demands on rugby union referees.

The physical demands of the referees in 15 a-side rugby union has been previously reported with just five studies [10,11,20-22] all using various research methodologies. One of the first studies using Global Positional System (GPS) in sport, reported that referees covered 3739 ± 368 m [20]. However, this study failed to spark a flow of research reporting referee game demands. Using a video review method, Martin et al. [22] reported that a rugby union referee in the English premiership ran 8581 ± 668 m. This difference in metres covered could be explained by the game time of adult rugby been of longer duration, with Ishii et al. [20] study on Japanese high school referees of a 70-minute game while Martin et al. [22] study used a subjective method of time motion analysis based on visual methods. Just two studies, using 1Hz GPS units, reported that sub-elite rugby union referees in the Spanish/Portuguese adult leagues covered a total distance of 6322.2 ± 564.9 m [11]. While professional rugby union referees in Super Rugby covered a total distance of 8030 ± 506m [10]. Rugby league referees have been reported to cover up to a maximum of 8536m using the more reliable 10Hz GPS units [23] which is similar to Martin et al. [22] findings in rugby union. In comparison with the players within the 15 a-side elite rugby union, it is reported that the backs covered greater total distance (6272 ± 1065m *vs.* 5244 ± 866 m) and relative distance (68.8 ± 10.0 *vs.* 60.8 ± 8.4 m.min^{-1}) than forwards [7]. The movement demands reported for the sub-elite referees [11] and the elite players [7] are similar for backs but the sub-elite referees have reported greater movement demands than forwards. This may to as a result of match fatigue of forwards as the game continues as the will have the added demands of contact situations or differences in data collection devices. The relative distance covered by elite rugby union referees has been reported to be 83 ± 5 $m.min^{-1}$ [10]. There was a significant difference (P <0.05) report between 1st half (77.2 ± 6.1 $m.min^{-1}$) and 2nd half (71.9 ± 7.1 $m.min^{-1}$) [11]. When compared with the 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; all p <0.05) there is a decrease in the distance covered as the game continues towards the final whistle. This reduction in game demands may be down to player/referee fatigue however game tactics may have to be considered as Martin et al. [22] reported no difference in distance travelled in English Premiership referees over 10 minutes periods.

With the intermittent nature of rugby [2,24], a referee will need to be prepared for different velocities of the game. A majority of the total distance covered by a rugby union referee will be at low speed with 76 ± 2% of the total distance covered in speeds of <2.0 $m.s^{-1}$and 4.4% >5.1 $m.s^{-1}$ [10]. Similar studies on rugby union referee found that they would spend 71.8% of the total distance in speed zones of <3.33 $m.s^{-1}$with 5.2% >5.58 $m.s^{-1}$sprinting [11].

The directional movement patterns of rugby union referees using GPS technology has not been reported. In subjective studies, it was found that a rugby union referee walked forwards for 29.5 + 7.2%, walked backwards for 9.9 + 3.2% [22] with rugby league referees spending 22 ± 2% jogging backward [25] and soccer referees in backward movement 16.2% of the total game time [26]. Using GPS technology, rugby league referees showed a significantly greater distance in a forward motion [27]. It has been reported that there was a significantly higher energy expenditure during backward movement when compared to forward movement at a velocity of 9 km/ h [28] while backward movement is not reported as a high-intensity activity there is a higher VO_2 reported during backward walking and jogging when compared to forward walking [29].

With the limited objective research available into the movement demands of rugby union referee, there is a need to report accurate information to inform sports scientists and strength and conditioning coaches of the movement demands and knowledge on the physiology of rugby union referees. This study aims to evaluate the physiological and movement demands of sub-elite rugby un ion referees in Ireland.

MATERIALS AND METHODS

Study design

This study used an observational research design and data was collected from 27 (15 a-side rugby union) matches from the All Ireland League Division 1, which is the highest standard of club rugby union in Ireland. Games were played between September 2017 and April 2018. Global position system (GPS) technology was used to assess the movement demands and velocity zones of each referee. Finding the movement demands of sub-elite movement demands during competition matches is essential to inform sports scientists and trainers so best to prepare for the demands of the current game.

Participants

10 (n = 10) Irish Rugby Football Union male 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 and were from taken from the IRFU National panel. 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 in accordance with the ethical standards and the guidelines of the Ethical Committee of the Institute of Technology, Carlow which approved this study protocol.

Data collection procedures

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 normal refereeing uniform. Total distance (m), and relative distance covered ($m.min^{-1}$), during match play per half and in 10-minute periods was examined. The movement was 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 $m.s^{-1}$) 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 [23,27]. All referees in this study completed the whole game.

Statistical analyses

Post-match, the raw data were downloaded from the GPS units using a USB device and GPS manufacturers download hardware in the charging box, to the manufacturer's software (Catapult Sprint 5.1) on a laptop (Dell). Field time was applied to each referee's raw file by inserting 1st half and 2nd half period. Excel (Microsoft, California, USA) reports for each match were created using the velocity band. Once appropriately formatted, data were exported for analysis in Microsoft Excel 2015 (Microsoft Corporation, USA) for the purpose of data management. 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. Data are presented as mean ± standard deviations.

Preliminary analyses were conducted to check for normality with Kolmogorov-Smirnov tests performed on the data set to check data distribution with P < 0.05 indicating normality. A paired samples t-test was used to assess differences between first and second half movements and speed zones. A one-way ANOVA with Bonferroni post-hoc procedure was used to analyse the differences in velocity and movement direction classifications. Statistical significance was set at P < 0.05 and Cohen's d Effect Size (ES) was reported using a modification to the effect size scale of Cohen. 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 mean total distance covered in match play (Table 1) was 6501.7 ± 780.2 m (range: 5243-8507m). No significant differences (P = .848, d = 0.061) were found between mean distance covered in the first (3235.1 ± 359.6 m) and second (3266.7 ± 629.7m) half periods. Based on the mean match duration (86.32 ± 3.06 min), the relative distance covered for the total game was 75.1 ± 8.6 $m.min^{-1}$with no significant difference (P = 0.876, d= 0.05) found between the first (75.4 ± 8.7 $m.min^{-1}$) and second (74.8 ± 13.1 $m.min^{-1}$) half periods. There were no significant differences found in each of the six velocity bands (Table 1) between the first half and second half. There was a significant difference (p < 0.001) between all six velocity bands.

In analysis of the periods of 10 mins (Table 2), it was identified that there was a significant difference and large effect size in relative distance covered between period 1 (0-10mins) and period 2 (10-20 mins) ($P > 0.001$, d = 1.20), and significant differences with moderate ES when compared to period 3 (20-30 mins) ($P = 0.005$, d = 1.12), period 4 (30-40 mins) ($P = 0.002$, d = 1.16), period 5 (40-50 mins) ($P = 0.016$, d = 0.653), period 6 (50-60 mins) ($P = 0.002$, d = 0.99) and, period 8 (70-80 mins) ($P = 0.030$, d = 0.788).

The greatest percentage of time (79.56%) for a rugby union referee is spent in <2.0m/sec^{-1}, standing (43.53 ± 3.79 %) and walking (36.03 ± 1.61 %) with no significant difference between halves ($P > 0.05$) presented in table 1. Referees are spending < 0.05 % of their time on the field sprinting (> 7.01m.s^{-1}) with 0.17% (± 0.28%) of total distance covered in a game and with no significant difference ($P < 0.05$) between halves (Table 3). Most of the percentage distance covered (36.72 ± 4.80 %) is walking (0.5-2.0 m.s^{-1}) and high speed running (5.51-7m.s^{-1}) 1.70 ± 0.79 %. Time spent in jogging (2.01-4.0m.s^{-1}), running (4.01-5.5m.s^{-1}), and, high speed running (5.51-7m.s^{-1}) was greater in period 1 (Table 4 and Table 5). Results found that a rugby union referee covered a distance of 530.2 ± 185.3m on periods of "extra" time, over the 40 min and 80 min.

DISCUSSION

To the author's knowledge, this is the first study evaluating the distance and velocity of referees using the more reliable 10Hz GPS units. GPS technology has provided a reliable method to evaluate the demands of the game of rugby union. These studies have been in the area of professional competitions with little research in the area of match officials. This study aimed to evaluate the movement demands of sub-elite rugby union referees in Ireland using 10Hz GPS units. Other previous studies, using GPS technology, have reported the referee demands during the professional Super Rugby competition [10], and domestic Spanish/Portuguese rugby [11] using the less reliable 1Hz GPS units.

The mean total distance covered by a rugby union during a game of 6501.7 ± 780.2 m was substantially lower than the 8,030 ± 560 m reported in Super Rugby [10] but is similar to the 6322.2 ±

Table 1: Movement demands of sub-elite rugby union referees - Total Distance (m), Total Relative Distance (m.min-1), Velocity zones (% of time).

	1st Half (mean ± SD)	z2nd Half (mean ± SD)	Whole Match (mean ± SD)	First v second half
Total Distance (m)	3235.1 ± 359.6	3266.7 ± 629.7	6501.7 ± 780.2	P = .848 d = 0.061
Total Relative Distance (m.min^{-1})	75.4 ± 8.7	74.8 ± 13.1	75.1 ± 8.6	P = .876 d = 0.054
Standing 0-0.5m.s^{-1} (% Time)	43.24 ± 5.4	43.82 ± 3.9	43.53 ± 3.79*	P = .645 d = 0.123
Walking 0.5-2.0m.s^{-1} (% Time)	35.85 ± 2.8	36.20 ± 2.1	36.03 ± 1.61*	P = .704 d = 0.141
Jogging 2.01-4.0m.s^{-1} (% Time)	13.43 ± 2.4	13.11 ± 1.8	13.37 ± 1.69*	P = .602 d = 0.151
Running 4.01-5.5m.s^{-1} (% Time)	5.61 ± 2.1	5.29 ± 1.3	5.45 ± 1.55*	P = .415 d = 0.183
High Speed Running 5.51-7m.s^{-1}(% Time)	1.82 ± 0.93	1.57 ± 0.94	1.70 ± 0.79*	P = .274 d = 0.267
Sprinting > 7.01m.s^{-1}(% Time)	0.05 ± 0.09	0.01± 0.02	0.03 ± 0.05*	P = .092 d = 0.613

*Significantly different to all velocity zones ($p < 0.001$).

Table 2: Movement demands of rugby union referees per 10 minute match periods and % time spent at each movement velocity zone.

	Periods of Time									
	1st Half					2nd half				
	0-10 min	10-20 mins	20-30 mins	30-40 mins	40+ mins	40-50 mins	50-60 mins	60-70 mins	70-80 mins	80+ mins
Total Distance (m)	882.5 ± 173.2	716.1 ± 96.3*	724.2 ± 102.2	681.2 ± 172.5	230.5 ± 116.3	765.7 ± 190.9	730.6 ± 130.4	728.2 ± 139.2	741.8 ± 178.3	299.7 ± 185.3
Relative Distance (m.min^{-1})	88.6 ± 17.4	71.7 ± 9.5*	72.5 ±10.1*	68.3 ±17.4*	77.0 ± 24.6	76.6 ± 19.2	73.2 ±13.2*	73.1 ± 14.5	74.5 ± 18.4	83.3 ± 25.8
Standing 0-0.5m.s^{-1} (% Time)	37.7 ± 9.6	44.7 ± 6.1*	44.4 ± 5.6*	46.9 ± 9.5*	40.2 ± 15.6	44.5 ± 7.6*	43.2 ± 6.8*	44.6 ± 8.8*	44.4 ± 8.0*	39.2 ± 14.2
Walking 0.5-2.0m.s^{-1} (% Time)	36.6 ± 4.9	36.0 ± 4.2	35.9 ± 3.6	34.2 ± 5.06	38.1 ± 10.3	34.7 ± 4.3	36.7 ± 4.79	36.0 ± 5.3	36.5 ± 4.8	38.2 ± 2.1
Jogging 2.01-4.0m.s^{-1} (% Time)	15.4 ± 3.6	12.9 ± 2.8*	12.9 ± 2.3*	12.0 ±4.10*	14.80 ± 6.3	13.0 ± 2.9*	13.9 ± 3.6	13.0 ± 3.3	12.2 ± 2.6*	14.9 ± 7.2
Running 4.01-5.5m.s^{-1} (% Time)	7.5 ± 3.6	4.7 ± 2.2*	5.2 ± 2.2*	5.23 ±2.94*	5.6 ± 4.5	5.8 ± 2.8*	4.8 ± 1.7*	5.1 ± 2.0*	5.4 ± 2.1*	6.0 ± 3.2
High Speed Running 5.51-7m.s^{-1} (% Time)	2.6 ± 1.7	1.6 ± 1.1*	1.6 ± 1.1*	1.59 ±1.16*	1.36 ± 2.4*	1.9 ± 1.3	1.4 ± 1.2*	1.3 ± 0.9*	1.6 ± 1.2*	1.7 ± 1.9
Sprinting > 7.01m.s^{-1} (% Time)	0.0 ± 0.0	0.06 ± 0.17	0.07 ± 0.2	0.08 ± 0.3	0.0 ± 0.0	0.01 ± 0.04	0.0 ± 0.0	0.0 ± 0.0	0.02 ± 0.09	0.0 ± 0.02

*Significantly different to Period 1 ($p < 0.05$).

564.9 m reported in another sub-elite league [11]. Those mentioned above, demonstrates the lower distance demands of a referee in sub-elite rugby. Referees in this study covered similar distances to English professional players [2] (6545 ± 1055 m backs & 5850 ± 1101 m forwards) and greater distances than university forwards [24] (4683 ± 1377 m) and higher than the backs in the same study (5889 ± 719 m). Similar to other studies, in rugby union [10] there were no significant differences between the total distance covered in each half, but differing to soccer where it is reported that distance covered decreases in the 2nd half [13]. This finding shows that a referee will need to maintain a similar distance covered throughout the 80mins game duration. The lack of research using more reliable GPS units and other research studies using subjective methods [22], makes it difficult to compare these studies with further research needed into other sub-elite and professional competitions. There was no significant difference in relative distance between the first half and second half. However period 1 (0-10min) reported the highest relative distance (88.6 ± 17.4 m.min^{-1}) and significant difference in comparison to period 2, period 3, period 4 and, period 6. This shows that the game intensity is highest in period 1 and reduces as the game continues. The drop in intensity rises again as the match enters the last 20 mins. It may be from the impact of substitutions on the game

Table 3: Differences and Effect Sizes in mean relative distance for each 10 minute period across a match for the sub-elite rugby union referees.

	Periods of Time									
	1st Half					2nd half				
	0-10 min	10-20 mins	20-30 mins	30-40 mins	40+ mins	40-50 mins	50-60 mins	60-70 mins	70-80 mins	80+ mins
0-10min										
10-20mins	*P* < 0.005 d=1.20									
20-30mins	p = 0.0049 d = 1.13	p = 0.823 d = 0.082								
30-40mins	p = 0.002 d = 1.17	p = 0.484 d = 0.244	p = 0.331 d = 0.298							
40+mins	p = 0.093 d = 0.55	p = 0.398 d = 0.282	p = .480 d = 0.237	p = 0.113 d =0.408						
40-50mins	p = 0.016 d = 0.654	p = 0.291 d = 0.322	p = 0.398 d = 0.266	p = 0.147 d = 0.453	p = .962 d = 0.017					
50-60mins	p = 0.001 d = 0.99	p = 0.645 d = 0.134	p = 0.834 d = 0.063	p = 0.320 d = 0.322	p = 0.616 d = 0.188	p = 0.256 d = 0.203				
60-70mins	P=0.015, d=0.965	p = 0.719 d = 0.115	p = 0.891 d = 0.041	p = 0.410 d = 0.303	p = 0.625 d = 0.190	p = 0.472 d = 0.203	p = 0.974 d = 0.009			
70-80mins	p = 0.03 d = 0.788	p = 0.499 d = 0.188	p = 0.687 d = 0.131	p = 0.355 d = 0.345	p = 0.774 d = 0.115	p = 0.631 d = 0.113	p = 0.763 d = 0.076	p = 0.739 d = 0.081		
80+mins	p = 0.48 d = 0.238	p = 0.127 d = 0.597	p = 0.118 d = 0.552	p = 0.063 d = 0.684	p = 0.504 d = 0.252	p = 0.314 d = 0.296	p = 0.081 d = 0.492	p = 0.103 d = 0.488	p = 0.238 d = 0.396	

Table 4: Differences and Effect Sizes in % of time for each 10 minute period across a match for the sub-elite rugby union referees for walking 0.5-2.0 m.s^{-1} and jogging 2.01-4.0 m.s^{-1}

	Periods of Time									
	1st Half					2nd half				
	0-10 min	10-20 mins	20-30 mins	30-40 mins	40+ mins	40-50 mins	50-60 mins	60-70 mins	70-80 mins	80+ mins
0-10min		P = 0.013 d = 0.774	P = 0.006 d = 0.849	P = 0.004 d = 0.881	P = 0.641 d = 0.130	P = 0.022 d = 0.740	P = 0.161 d = 0.435	P = 0.075 d = 0.698	P = 0.005 d = 1.047	P = 0.781 d = 0.097
10-20mins	P = 0.616, d=0.166		P = 0.930 d = 0.026	P = 0.466 d = 0.256	P = 0.221 d = 0.377	P = 0.937 d = 0.030	P = 0.435 d = 0.284	P = 0.938 d = 0.024	P = 0.338 d = 0.288	P = 0.356 d = 0.355
20-30mins	p = 0.530 d = 0.198	P = 0.935 d = 0.230		P = 0.347 d = 0.251	P = 0.172 d = 0.402	P = 0.853 d = 0.058	P = 0.281 d = 0.325	P = 0.863 d = 0.049	P = 0.279 d = 0.290	P = 0.242 d = 0.375
30-40mins	p = 0.109 d = 0.518	p = 0.146 d = 0.390	p = 0.277 d = 0.396		P = 0.061 d = 0.516	P = 0.322 d = 0.279	P = 0.104 d = 0.470	P = 0.436 d = 0.261	P = 0.912 d = 0.037	P = 0.156 d = 0.485
40+mins	p = 0.613 d = 0.166	p = 0.475 d = 0.266	p = .441 d = 0.284	p = 0.119 d =0.483		P = 0.332 d = 0.358	P = 0.594 d = 0.177	P = 0.286 d = 0.350	P = 0.103 d = 0.544	P = 0.960 d = 0.017
40-50mins	p = 0.236 d = 0.415	p = 0.470 d = 0.278	p = 0.353 d = 0.276	p = 0.759 d = 0.113	p = .259 d = 0.418		P = 0.226 d = 0.254	P = 0.993 d = 0.004	P = 0.361 d = 0.316	P = 0.300 d = 0.338
50-60mins	p = 0.985 d = 0.006	p = 0.659 d = 0.161	p = 0.479 d = 0.194	p = 0.164 d = 0.518	p = 0.579 d = 0.170	p = 0.287 d = 0.414		P = 0.490 d = 0.242	P = 0.139 d = 0.539	P = 0.528 d = 0.178
60-70mins	P=0.624 d=0.146	p = 0.995 d = 0.002	p = 0.958 d = 0.022	p = 0.185 d = 0.353	p = 0.381 d = 0.254	p = 0.515 d = 0.250	p = 0.694 d = 0.141		P = 0.322 d = 0.285	P = 0.306 d = 0.332
70-80mins	p = 0.897 d = 0.054	p = 0.765 d = 0.110	p = 0.745 d = 0.139	p = 0.194 d = 0.471	p = 0.558 d = 0.199	p = 0.292 d = 0.366	p = 0.894 d = 0.048	p = 0.732 d = 0.096		P = 0.162 d = 0.502
80+mins	p = 0.515 d = 0.205	p = 0.441 d = 0.323	p = 0.355 d = 0.347	p = 0.185 d = 0.569	p = 0.975 d = 0.106	p = 0.218 d = 0.495	p = 0.546 d = 0.210	p = 0.399 d = 0.305	p = 0.534 d = 0.244	

Note: No shading indicates walking 0.5-2.0 m.s^{-1} Grey indicates jogging 2.01-4.0 m.s^{-1} Bold text indicates a significant difference / *d* = Cohen's *d* effect size.

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Table 5: Differences and Effect Sizes in % of time for each 10 minute period across a match for the sub-elite rugby union referees for running 4.01-5.5 $m.s^{-1}$ and High Speed Running 5.51-7.0 $m.s^{-1}$

	Periods of Time									
	1st Half					2nd half				
	0-10min	10-20 mins	20-30 mins	30-40 mins	40+ mins	40-50 mins	50-60 mins	60-70 mins	70-80 mins	80+ mins
0-10min		P = 0.025 d = 0.703	P = 0.022 d = 0.723	P = 0.009 d = 0.726	P = 0.022 d = 0.621	P = 0.178 d = 0.452	P = 0.025 d = 0.809	P = 0.001 d = 1.016	P = 0.050 d = 0.719	P = 0.175 d = 0.504
10-20mins	P = 0.0003 d=0.909		P = 0.943 d = 0.024	P = 0.859 d = 0.054	P = 0.644 d = 0.154	P = 0.448 d = 0.272	P = 0.592 d = 0.172	P = 0.184 d = 0.387	P = 0.864 d = 0.053	P = 0.906 d = 0.043
20-30mins	p = 0.024 d = 0.769	P = 0.489 d = 0.193		P = 0.925 d = 0.025	P = 0.618 d = 0.140	P = 0.178 d = 0.294	P = 0.512 d = 0.150	P = 0.145 d = 0.363	P = 0.900 d = 0.030	P = 0.860 d = 0.060
30-40mins	p = 0.026 d = 0.675	p = 0.477 d = 0.194	p = 0.912 d = 0.030		P = 0.665 d = 0.122	P = 0.320 d = 0.308	P = 0.654 d = 0.121	P = 0.314 d = 0.320	P = 0.986 d = 0.005	P = 0.818 d = 0.077
40+mins	p = 0.068 d = 0.452	p = 0.418 d = 0.245	p = .671 d = 0.125	p = 0.712 d =0.096		P = 0.366 d = 0.317	P = 0.886 d = 0.043	P = 0.859 d = 0.062	P = 0.736 d = 0.118	P = 0.634 d = 0.162
40-50mins	p = 0.037 d = 0.513	p = 0.072 d = 0.427	p = 0.390 d = 0.258	p = 0.303 d = 0.198	p = .829 d = 0.053		P = 0.062 d = 0.415	P = 0.022 d = 0.637	P = 0.156 d = 0.307	P = 0.662 d = 0.151
50-60mins	p = 0.010 d = 0.936	p = 0.856 d = 0.050	p = 0.618 d = 0.169	p = 0.613 d = 0.171	p = 0.548 d = 0.227	p = 0.144 d = 0.426		P = 0.555 d = 0.177	P = 0.532 d = 0.113	P = 0.535 d = 0.164
60-70mins	P=0.028 d=0.800	p = 0.570 d = 0.186	p = 0.959 d = 0.016	p = 0.865 d = 0.045	p = 0.696 d = 0.137	p = 0.344 d = 0.282	p = 0.620 d = 0.160		P = 0.157 d = 0.305	P = 0.347 d = 0.301
70-80mins	p = 0.048 d = 0.706	p = 0.374 d = 0.289	p = 0.743 d = 0.093	p = 0.890 d = 0.048	p = 0.844 d = 0.068	p = 0.570 d = 0.179	p = 0.222 d = 0.277	p = 0.764 d = 0.115		P = 0.757 d = 0.080
80+mins	p = 0.214 d = 0.411	p = 0.161 d = 0.478	p = 0.290 d = 0.325	p = 0.199 d = 0.265	p = 0.718 d = 0.114	p = 0.793 d = 0.082	p = 0.203 d = 0.479	p = 0.273 d = 0.348	p = 0.484 d = 0.253	

Note: No shading indicates running 4.01-5.5 $m.s^{-1}$ Grey indicates High Speed Running 5.51-7.0 $m.s^{-1}$

or, there could be a pacing strategy by players. It is worth noting that there are no referee substitutions and they must be physically prepared to meet the demands of up to 16 new players entering the field of play and the demands that may have to the intensity of the game. The average relative distance was 75.1 ± 8.64 $m.min^{-1}$ which is below that reported for professional, backs (68.8 ± 10.0 $m.min^{-1}$) and forwards (60.8 ± 8.4 $m.min^{-1}$) [7]. These differences may be as a result of the referee needs to be constantly in movement around the ball area, whereas support players spend time repositioning away from the ball. The relative distance covered by elite rugby union referees has been reported to be 83 ± 5 $m.min^{-1}$ [10]. This difference may be as a result of the standard of the elite and sub-elite game. There appears to be higher relative distances reported in referee studies than those reported in player studies. With the nature of rugby union, not all the players on the field are involved on the ball all the time, while a referee will need to be position themselves close to the ball to referee the laws of the game. It is unknown if the difference in the relative distance reported between halves is down to referee fatigue or player fatigue. When analysed in 10min periods, it is reported that a greater distance is covered in the first 10minutes [10, 11]. It is unclear from this research if the referee may only have the physical ability to match the game demands for the first 10min period and may not be able to match the game demands for the rest of the game. Further research may need to gather data on players within the same game to see if the movement demands of the players are consistent to the movement demands of the referee during match play and do the demands of the players match the demands of the referee for each 10min period.

This study confirms the intermitted nature of rugby union for referees in a velocity zone of walking (0.5 - 2.0 $m.s^{-1}$) 36.03 ± 1.61 % of the match and a majority of the time (79.56 %) spent in <2.0 $m.s^{-1}$, interspersed with bouts of higher speeds with 19.79 ± 4.34 % of the total distance covered in speed zone 4.01-5.5$m.s^{-1}$. The finding of this low speed is similar to other referee studies [10] even with the different level of competition. There is a significant amount of time spent in higher speed zones in the 0-10min period Jogging (2.01-4.0 $m.s^{-1}$) and Running (4.01-5.5 $m.s^{-1}$) than other periods of the match.

The referees in this study, reached sprinting velocity speeds (>7.01 $m.s^{-1}$) 0.03 ± 0.05 % of the time of a whole match. It is unknown what the maximum speed was for each referee, and it may be that the referee does not reach maximum speed or that the velocity bands used in this study may have defined sprinting at too high a speed. The velocities bands used may have to be redefined for sub-elite performers and using bands used for professional/elite performers should be reconsidered. However, due to positioning on the pitch, sub-elite soccer referees were found not to need to reach their max speed to referee effectively [30]. The multi-directional, short distance sprints and lateral and backward movement of the game may not allow reaching max speed, and an ability to referee from a distance from the ball area may not require for the referee to reach their max speed. For future research, it would be beneficial to use individual velocity bands for each referee and to evaluate the percentage of their max speed they perform at within a match and follow the recommendations for reporting demands for players [31].

This is the first study looking at the movement demands for a rugby union referee in a sub-elite competition using 10Hz GPS units. A small percentage of referees perform in the professional game, however a vast majority of referees are involved in sub-elite competitions. This study addresses the knowledge gap that exists in this area. All future referee research needs to use equipment that has high validity and reliability, to give the most accurate findings. The small sample size of this study was a limiting factor, and all future studies should have larger sample sizes. Further investigation is needed using larger data sizes to gain further knowledge about the movement demands of the referee. As some of these referees in this study would referee throughout the different levels of the game, a greater knowledge of the demands of these different standards would benefit the preparation of the referee.

CONCLUSION

Practical applications

The referee for rugby union needs to be trained to meet the demands of the game. This research confirms the intermitted nature of the game they officiate with little high velocity and activity at low velocity. Referee trainers need to prepare them for the performance of this type of activity within the game. As rugby does not have a set period of ball in play time, the referee will have to be meet the demands as they occur. There is no way in telling how long a bout of play is for or the demands within each bout. Further research into rugby union referees will continue to guide trainers in preparing for a game with no definite ball in play time as well as further player physical development and even rule changes. There will be a need to continue researching this ever-changing part of the game.

To prepare sub-elite rugby union referees, sports scientists and conditioning coaches should consider programmes which incorporate low velocity multi-directional with higher velocity movements (>5.51 $m.s^{-1}$) As there are no fixed referee substitutions (only in some injury circumstances), a referee needs to perform for a duration over >80 mins and maintain running demands throughout the whole game. A weekly training plan should incorporate low and high-intensity aerobic sessions and repeated high-intensity running that would include mimicking the multi-directional game movements. With the information from this research, sports scientists should look to design sub-elite game simulations as part of a referees training program. This type of training will best prepare the sub-elite referee for the demands currently placed on them some they can apply the laws during physical activity. More regular and consistent research is needed into the performances of referees as to future proof the performances of these vital performers for the game of rugby union.

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