Materials : Rugby Football

Physical Activity of Rugby Players Measured by Global Positioning System

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**Objective: The purpose of this study was to quantify the movement of players in rugby matches.
Methods: Players (n=33) were tracked continuously throughout the 2012-2013 season using Global Positioning System (GPS) software. Player positions were defined as: (1) Backs or Forwards; (2) Front, Second and Back Rows, Inside Backs and Outside Backs.
Result: There was a significant difference in the total distance traveled by backs (6257.4±555.52m) and forwards (5763.3±678.29m, p<0.05) during the matches. Approximately half of this distance (Backs: 47.0% vs Forwards: 45.6%) was in the Standing & Walking speed zone (0-6km/h^{-1}). Forwards covered more distance at Jogging speed than backs did (Backs: 1475.4±283.39m vs Forwards: 1847.8±410.16m, p<0.05). Positive and significant correlation was observed between first and second half distances (r=0.602, p<0.01). Inside backs travelled the farthest (6390.0±520.65m) during matches at the highest average speed (4.4±0.37 km/h^{-1}). Outside backs were distinguished by their attainment of the highest peak speed (31.2±2.19km/h^{-1}). Back rows covered significantly more total distance, relative total distance and maximum speed than front rows did (p<0.05).
Conclusion: The current study has highlighted positional differences in rugby. Results suggested that rugby is an intermittent exercise involving high-intensity (sprinting) and low-intensity work (Standing & Walking). Results also indicated the importance of basic physical fitness as well as the planning of training programs specific to individual positions.**

Keywords: GPS, physical demands, positional differences

1. Introduction

The Rugby World Cup will take place in Japan in 2019, and a wide range of scientific approaches have been employed to improve the competitiveness of individual players in Japan. Specifically, the measurement of individual player movements in the field during actual games has increased because quantitative evaluation of the physiological loads on individual players during games makes it possible to investigate the impact on mental fitness and game performance.

While running, jumping, and throwing are integral parts of the sport, perhaps the most distinctive characteristic of rugby is repeated vigorous body contact when competing for possession of the ball or control of the field. A high level of performance is required throughout the 80 minutes of the match. However, it is not easy to gather information, communicate, make decisions, and respond quickly due to the fluid nature of the situation on the field.

Therefore, it is extremely important to consider efficient ways to develop the physical strength required to produce effective movement.

A number of studies on rugby have been published. Gabbett reported a difference in body composition and physical strength in players by position and performance level. Cunniffe et al. reported that rugby players traveled approximately 6,953m during games, and that Backs traveled farther than Forwards (7,227m vs 6,680m).These findings suggested a significant difference in the type and amount of physical activity required by different positions in rugby, which in turn suggested the need for rational and effective plans to reinforce physical strength based on the characteristics of each position. Based on these consideration, we believe it essential to clarify the physical activities required for effective play during matches to establish more practical training programs.

This study, therefore, was carried out to clarify the physical activity required during games with a focus

on movement patterns specific to rugby, especially running, through an investigation of physical characteristics by position utilizing objective data on exercise intensity.

2. Methods

2.1. Experimental Approach

A global positioning system (GPS) was employed to obtain data on movement patterns and amount of physical activity. This study targeted 19 games with 40-minute halves, including practice matches in pre-season and official matches of Kyushu University Rugby League devision 1 played by F University. Subjects were 33 F University rugby club members (Age: 20.8±1.10 years; Weight: 84.6±15.43kg; Height: 173.8±6.06cm). We analyzed 125 data samples, each of which contained an entire 80-minute game, to evaluate the amount of physical activity during games.

2.2. Processes

Forty-five minutes prior to game time, we fit each player with a special harness on the upper body and affixed a GPS unit (VX225 manufactured by Visuallex Sport International) to the back of the harness. The device is capable of outputting data 4 times per second. We began measurement from 45 minutes before the game, and collected the devices immediately after the game. We downloaded the data from the GPS device with software designed for the purpose (VX VIEW™) for analysis of movement patterns and amount of physical activity.

2.3. Measurement

Evaluation of the amount of physical activity during games was based on total distance and relative total distance (total distance per minute), which were calculated from running time, maximum speed, and average speed. We applied a partially revised the scale by Cunniffe et al. to set the intensity for each exercise. Each speed zone is shown below.
(a) Standing and walking (0-6km/h^{-1})
(b) Jogging (6-12km/h^{-1})
(c) Cruising and striding (12-18 km/h^{-1})
(d) High-intensity running (18-20km/h^{-1})
(e) Sprinting (>20 km/h^{-1})

Subjects were classified into groups for comparative analysis of tracking data.
(a) Forwards (n=19) or Backs (n=14)
(b) Front Row (n=8, PR=6, HO=2), Second Row (n=5, LO=5), Back Row (n=6, FL=3, No.8=3), Inside Backs (n=7, SH=1, SO=1, CTB=5) or Outside Backs (n=7, WTB=4, FB=3)

To facilitate comparison, we classified matches played between the 16th and 22nd weeks as Pre-season games (n=4), the 30th week as Summer games (n=4), and the 33rd and 43rd weeks as Official games (n=11).

2.4. Statistical Analysis

Statistical analysis was performed using SPSS statistics 18. To examine the difference in mean values between Forwards and Backs, t-test was conducted for each item to be analyzed in total distance, relative total distance (total distance per minute), maximum speed, average speed, and speed zone. In order to compare distance traveled between the 1st and 2nd halves, we calculated the Pearson product-moment correlation coefficient. Furthermore, we conducted one-way analysis of variance to analyze the differences in exercise intensity and amount of activity by positional group, and then conducted a multiple comparison utilizing Tukey's test. Level of significance was set at less than 5%.

3. Results

3.1. Distance Traveled and Speed Zones

The average total distance for Backs was 6257.4±555.52m, which exceeded Forwards (5763.3±678.29m) by a significant amount. Average relative total distance (total distance per minute) for Backs was 72.4±6.22m/min^{-1} and 66.4±7.48m/min^{-1} for Forwards. Maximum and average speeds during games revealed that Backs played faster than Forwards (maximum speed: BKs:30.0±2.51km/h^{-1} vs FWs:25.3±2.69 km/h^{-1}; average speed: Ks:4.3±0.38 km/h^{-1} vs FWs:4.0±0.44 km/h^{-1}). Comparison between the two groups revealed a significant difference in total distance, relative total distance (total distance per minute), maximum speed, and average speed between Backs and Forwards.

We calculated the Pearson product-moment correlation coefficient to examine the correlation

between the distance traveled in the 1st and 2nd halves. Results revealed a positive correlation (r=0.602, p<0.01), and players who recorded longer distances traveled in the 1st half also recorded greater distances in the 2nd half. However, comparison of relative total distance (total distance per minute) between 1st and 2nd halves revealed that the 2nd half was significantly shorter than the 1st half (p<0.05).

Next, we compared tracking data by positional group. Inside Backs (6390.0±520.65m) traveled the greatest average distance, followed by Outside Backs (6178.4±571.78m), Back Rows (6053.5±654.48m), Front Rows (5571.5±616.46m); and Second Rows traveled the least distance (5505.2±599.07m). Inside Backs (73.6±6.08m/min^{-1}) also traveled the greatest relative total distance (total distance per minute). Meanwhile, Outside Backs (31.2±2.19km/h^{-1}) showed the highest maximum speed followed by Inside Backs (28.6±2.31km/h^{-1}), Back Rows (27.1±1.69 km/h^{-1}), Second Rows (25.0±1.72 km/h^{-1}), and Front Rows maximum speed was the lowest (23.5±2.30 km/h^{-1}). Inside Backs (4.4±0.37 km/h^{-1}) showed the highest average speed and Second Rows showed the lowest (3.8±0.41 km/h^{-1}).

Tukey's test after one-way analysis of variance revealed a significant difference in total distance traveled by Forwards between Summer and Official games (p<0.05). However, Backs showed no change by each period. Among Forwards, Front Rows and Second Rows traveled significantly shorter total distances during games than other positional groups did (p<0.05). Back Rows showed a significant difference; however, there was no correlation between Inside and Outside Backs.

3.2. Exercise Intensity and Play Time

According to the average of exercise intensity during games acquired by separating speed zones, approximately 50% of the distance (BKs:47.0% vs FWs:45.6%) was in the Standing & Walking speed zone (0-6km/h^{-1}). In addition, 7.6% of the distance traveled by Backs was in the Sprinting speed zone (>20kmk/h^{-1}) compared with 2.8% for Forwards. Comparison of exercise intensity among groups in the Standing & Walking (0-6km/h^{-1}), Cruising & Striding (12-18km/h^{-1}), High-intensity running (18-20km/h^{-1}), and Sprinting (>20km/h^{-1}) speed zones revealed that Backs traveled farther than Forwards. Distance spent in the Jogging (6-12km/h^{-1}) speed zone

by Forwards was significantly greater than Backs (BKs:1475.4±283.39m vs FWs:1847.8±410.16m).

Next, we calculated average of exercise intensity by positional group. Results revealed that Outside Backs traveled the greatest distance (3051.6±303.99m) in the Standing & Walking speed zone (0-6km/h^{-1}), followed by Inside Backs (2819.7±240.84m), Back Rows (2735.9±178.11m), Second Rows (2599.0±319.59m); and Front Rows traveled the least distance (2568.6±385.04m). In regard to distance traveled in the Jogging speed zone (6-12km/h^{-1}), Front Rows traveled the greatest distance (2062.5±420.37m); and Outside Backs traveled the least (1390.7±259.54m). In regard to the Cruising & Striding (12-18km/h^{-1}) and High-intensity running (18-20km/h^{-1}) speed zones, Inside Backs traveled the greatest distance among all positional groups (Cruising & Striding: 1264.6±273.33m, High-intensity running: 280.2±64.01m). In regard to the distance traveled in the Sprinting speed zone (>20km/h^{-1}), Outside Backs traveled the greatest distance (518.6±162.12m) followed by Inside Backs (430.0±128.37m), Back Rows (292.0±116.10m), Second Rows (90.6±48.19m); and Front Rows traveled the least (56.8±48.99m).

Statistical analysis revealed that Outside Backs traveled the greatest distance in the Standing & Walking (0-6km/h^{-1}) and Sprinting (>20km/h^{-1}) speed zones, and Front Rows traveled the farther in the Jogging speed zone (6-12km/h^{-1}) than other positional groups.

4. Discussion

The average total distance traveled by Backs was 6257.4±555.52m, which exceeded Forwards (5763.3±678.29m) by a significant amount. This matched rugby union results acquired by Cahill et al. (Backs:6545m, Forwards:5850m). However, they differed significantly from rugby league results reported by Mclellan et al. (Backs:5573±1128m, Forwards:4982±1185m). Although these findings suggested that Backs traveled farther than Forwards, it is difficult to estimate the total distance traveled by players during games; and the total distance traveled by players is significantly influenced by game conditions, including performance level, body composition, exercise intensity levels, and environment.

Average relative total distance (total distance per

Table 1 Distance Traveled and Exercise Intensity

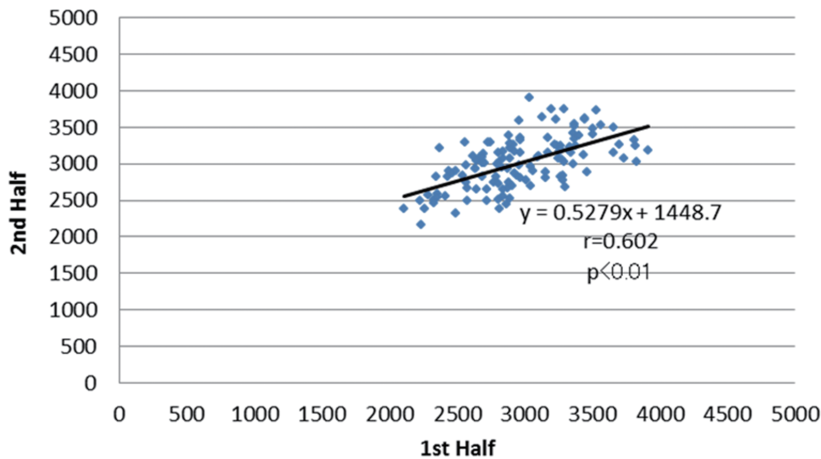|	BKs	FWs
Total Distance (m)	6257.4±555.52*	5763.3±678.29
Relative total distance (m/min^{-1})	72.4±6.22*	66.4±7.48
Maximum Speed (km/h^{-1})	30.0±2.51*	25.3±2.69
Average Speed (km/h^{-1})	4.3±0.38*	4.0±0.44
Distance (m) within speed zone		
Standing & Walking: 0-6 km/h^{-1}	2942.2±297.51*	2648.5±320.71
Jogging: 6-12 km/h^{-1}	1475.4±283.39*	1847.8±410.16
Cruising & Striding: 12-18 km/h^{-1}	1120.1±272.24*	997.3±307.84
High-intensity running: 18-20 km/h^{-1}	245.8±70.85*	144.8±99.00
Sprinting: >20km/h^{-1}	472.5±152.82*	164.5±155.80

* $p < 0.05$

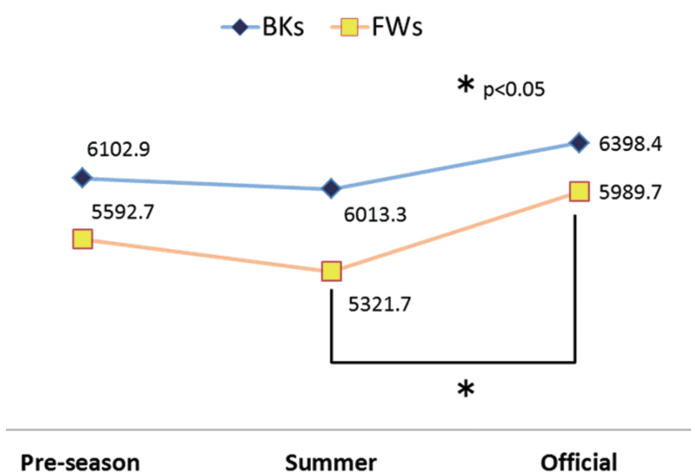**Figure 1** Distance Traveled in the 1st and 2nd Halves

Figure 2 Comparison of BKs and FWs by Season

Figure 3 Comparison of Exercise Intensity in Backs and Forwards

minute) traveled by Backs was 72.4±6.22m/min^{-1}, and that traveled by Forwards was 66.4±7.48m/min^{-1}. This showed similarities with the report by Cahill et al. (BKs: 71.1m/min^{-1},FWs: 64.6m/min^{-1}), and the report by Cunniffe et al. (BKs: 71.9 m/min^{-1},FWs: 66.7m/min^{-1}). A major role of Forwards is to obtain the ball

in set plays and breakdowns, and they are involved in more contact than Backs (Eaton et al.). Gabbett et al. reported that among Forwards, frequency of contact per minute by Front Rows was 1.09, significantly more than Outside Backs at 0.38. Backs are characterized by broader positioning in both

Table 2 Distance Traveled and Exercise Intensity by Positional Group

	Player Position				
	Front Rows	**Second Rows**	**Back Rows**	**Inside Backs**	**Outside Backs**
Total Distance (m)	5571.5±616.46#☆	5505.2±599.07#☆	6053.5±654.48*+	6390.0±520.65*+	6178.4±571.78*+
Relative total distance (m/min^{-1})	64.1±6.68#☆	63.9±6.80#☆	69.6±7.45*+	73.6±6.08*+	71.6±6.17*+
Maximum Speed (km/h^{-1})	23.5±2.30#☆	25.0±1.72#☆	27.1±1.69*+	28.6±2.31*+	31.2±2.19*+#☆
Average Speed (km/h^{-1})	3.9±0.40#☆	3.8±0.41☆	4.2±0.44*	4.4±0.37*+	4.3±0.37*+
Distance (m) within speed zone					
Standing & Walking: 0-6 km/h^{-1}	2568.6±385.04☆	2599.0±319.59	2735.9±178.11	2819.7±240.84*	3051.6±303.99*+#☆
Jogging: 6-12 km/h^{-1}	2062.5±420.37+#☆	1737.9±332.05*	1682.2±353.78*	1596.2±279.58*	1390.7±259.54*+#
Cruising & Striding: 12-18 km/h^{-1}	906.5±346.46#☆	952.4±264.10☆	1121.4±257.67*	1264.6±273.33*+	994.6±198.95☆
High-intensity running: 18-20 km/h^{-1}	74.2±52.29#☆	124.9±63.47#☆	224.7±89.38*+☆	280.2±64.01*+#	219.3±65.78*+☆
Sprinting: >20km/h^{-1}	56.8±48.99#☆	90.6±48.19#☆	292.0±116.10*+☆	430.0±128.37*+#	518.6±162.12*+#☆

Compare with

Significant difference	*	Front Rows
(p<0.05)	+	Second Rows
	#	Back Rows
	☆	Inside Backs

wings on the ground, and more changes of direction in kicking and chasing than Forwards. This study did not analyze the number of set plays, breakdowns, contacts, or change of direction, which made it difficult to compare among positions. However, as has been shown in a number of previous studies, the current study suggested that difference in roles by position exerted an influence on distance traveled.

A positive correlation was observed in distance traveled between the 1st and 2nd halves in subject games (r=0.602, p<0.01). However, relative total distance (total distance per minute) in the 2nd half was significantly shorter than that seen in the 1st half (p<0.05). Given the results for distance traveled in this study, it is difficult to explain correlation with performance. However, GPS tracking data is thought to be useful as an index for the measurement of amount of physical activity and exercise intensity in running. We believe that linking data obtained from game analysis contributes to the clarification of physical activity required for players.

Comparison of tracking data by positional group revealed that Inside Backs had the greatest average of total distance (6390.0±520.65m), followed by Outside Backs (6178.4±571.78m), Back Rows (6053.5±654.48m), Front Rows (5571.5±616.46m); and Second Rows was the least (5505.2±599.07m). Scrum-Half, Stand-Off, and Center, which are in the same positional group with Inside Backs, significantly influenced the results for Inside Backs. The Scrum-Half usually plays around the ball with the role of connecting Backs and Forwards. They require not only agility and passing skills to deliver accurate passes, but also the ability to make quick decisions and to have the physical endurance necessary to get

to the crowd. The Stand-Off receives the ball from the crowd first, and must decide to run, pass, kick, or contact according to the situation. Therefore, the Stand-Off is required to have accurate skills, the ability to make quick decisions and to position quickly based on the anticipated need to prepare to be a base for attacking. The Stand-Off is also required to be able to run to control the chase line during kicking games. The Center is positioned outside the Stand-Off, and is responsible for breaking through opponents in attacking. They are required to be fast runners and strong. These positions included among Inside Backs are required to have skill, the ability to make decisions, and high physical fitness to continue providing accurate plays throughout the 80 minutes of the game. Front Rows traveled relatively short distances (5571.5±616.46m) followed by Second Rows (5505.2±599.07m). Gabbet et al. reported many contacts in rugby games, with Front Rows (42) and Second Rows (45) having significantly more contacts than Outside Backs (28). This suggested that Forwards spent more time and energy in getting the ball through set plays and breakdowns, and that Backs received and advanced the ball to lead to goal scoring; and the difference in the movements of these two positions may have influenced the difference in total distance between the two positions.

Comparison of the maximum speed by positional group revealed that Outside Backs traveled fastest (31.2±2.19km/h^{-1}), followed by Inside Backs (28.6±2.31km/h^{-1}), Back Rows (27.1±1.69 km/h^{-1}), Second Rows (25.0±1.72 km/h^{-1}); and Front Rows traveled slowest (23.5±2.30 km/h^{-1}). Gabbett reported that the majority of sprinting is 20m or less (67.5%). Among sprinting performed by Front Rows, 46.3%

was between 6 and 10m. Among sprinting performed by Outside Backs, 33.7% was 21m or less. These results suggested that different positions in rugby require different running patterns, making it important for players to improve their basic physical strength and acquire strength specific to each position through positional sprinting training.

Comparison of total distance among Pre-season (Week 16-22), Summer games (Week 30), and Official games (Week 33-43) revealed a significant difference in total distance traveled by Forwards between Summer and Official games ($p<0.05$). Although Backs did not show significant difference by each period, distance traveled by Backs in Official games was farther than it was in other period. These findings suggested that players ran faster and that the ball moved more in Official games compared to other period However, there is a difference in game intervals according to period (Pre-season: 1 game/week; Summer game: 1 game/3 days; Official games: 1 game/week), which may also influence player condition.

Separating speed zones and calculating average of exercise intensity during games, approximately 50% of Backs and Forwards (BKs: 47.0% vs FWs: 45.6%) played in the Standing & Walking speed zone. Breakdown of exercise intensity in subject games was Jogging (BKs: 23.6% vs FWs: 31.8%), Cruising & Striding (BKs: 17.9% vs FWs: 17.2%), High-intensity running (BKs: 3.9% vs FWs: 2.5%), Sprinting (BKs: 7.6% vs FWs: 2.8%). This study clarified peculiarity in the sprinting of Forwards and Backs during games. According to a study by Cunniffe et al. targeting players belonging to rugby unions, 37% of the running speed in subject games was 0-6km/h^{-1}, 27% was 6-12km/h^{-1}, 10% was 12-14km/h^{-1}, 14% was 14-18km/h^{-1}, 5% was 18-20km/h^{-1}, and 6% was >20km/h^{-1}. Duthie et al. reported in the results of Super 12 game analysis that Backs were engaged in sprinting an average of 24±7 per person during games, which exceeded Forwards significantly

(13±6). In addition, they also reported that continual sprinting time in Backs was 3.1±1.6 seconds, which significantly exceeded that in Forwards (2.5±1.6 seconds) ($p<0.01$). Previous studies also suggested that sprinting in rugby differed by position, and thus clarifying the starting point of sprinting will lead to an understanding of more detailed running movements required by players.

We compared exercise intensity by positional group utilizing the average against distance traveled. As a result, Outside Backs traveled the greatest distance and Front Rows traveled the least in the Standing & Walking speed zone. Front Rows traveled the greatest distance and Outside Backs traveled the least in the Jogging speed zone. In the Cruising & Striding and High-intensity Running Speed Zones, Inside Backs traveled farther than other positional groups. Outside Backs traveled the greatest distance in the Sprinting speed zone, and Front Rows traveled the least.

In regard to movement patterns specific to rugby in both attack and defence, especially running movement, Backs repeated high-intensity (Sprinting) and low-intensity work (Standing & Walking). This suggested that Backs had sufficient time for recovery during games. Forwards repeated medium-intensity (Jogging) and high-intensity work such as scrum, kick-off, and line-out that were not reflected to tracking data, which suggested that Forwards were required to perform intermittent physical exercise with shorter recovery time compared with Backs.

5. Conclusions

The results of this study are as follows:
(1) The average total distance for Backs was 6257.4±555.52m and 5763.3±678.29m for Forwards ($p<0.05$).
(2) Average relative total distance (total distance per minute) for Backs was 72.4±6.22m/min^{-1} and 66.4±7.48m/min^{-1} for Forwards ($p<0.05$).
(3) Maximum speed during games for Backs was

Table 3 Comparison by Speed Zone

	Cunniffe (2009)	BKs	FWs
Standing & Walking: 0-6 km/h^{-1}	37.0	47.0	45.6
Jogging: 6-12 km/h^{-1}	27.0	23.6	31.8
Cruising & Striding: 12-18 km/h^{-1}	24.0	17.9	17.2
High-intensity running: 18-20 km/h^{-1}	5.0	3.9	2.5
Sprinting: >20km/h^{-1}	6.0	7.6	2.8

30.0±2.51km/h^{-1} and 25.3±2.69 km/h^{-1} for Forwards (p<0.05).

(4) Average speed during games for Backs was 4.3±0.38 km/h^{-1} and 4.0±0.44 km/h^{-1} for Forwards (p<0.05).

(5) A positive correlation (r=0.602, p<0.01) was observed between the 1st and 2nd halves.

(6) Inside Backs (6390.0±520.65m) traveled the greatest average distance, followed by Outside Backs (6178.4±571.78m), Back Rows (6053.5±654.48m), Front Rows (5571.5±616.46m); and Second Rows traveled the least distance (5505.2±599.07m).

(7) Inside Backs (73.6±6.08m/min^{-1}) also traveled the greatest relative total distance (total distance per minute).

(8) Outside Backs (31.2±2.19km/h^{-1}) showed the highest maximum speed followed by Inside Backs (28.6±2.31km/h^{-1}), Back Rows (27.1±1.69 km/h^{-1}), Second Rows (25.0±1.72 km/h^{-1}); and Front Rows maximum speed was the lowest (23.5±2.30 km/h^{-1}).

(9) Inside Backs (4.4±0.37 km/h^{-1}) showed the highest average speed.

(10) A significant difference in total distance traveled by Forwards between Summer and Official games was observed (p<0.05).

(11) Front Rows and Second Rows traveled significantly shorter total distance during games than other positional groups did (p<0.05).

(12) Approximately 50% of the distance (BKs:47.0% vs FWs:45.6%) was in the Standing & Walking (0-6km/h^{-1}) speed zone.

(13) A total of 7.6% of the distance was in the Sprinting (>20kmk/h^{-1}) speed zone for Backs compared with 2.8% for Forwards.

(14) Distance spent in the Jogging (6-12km/h^{-1}) speed zone by Forwards was greater than Backs (BKs:1475.4±283.39m vs FWs:1847.8±410.16m, p<0.05).

(15) Outside Backs traveled the greatest distance (3051.6±303.99m) in the Standing & Walking (0-6km/h^{-1}) speed zone and Front Rows traveled the least distance (2568.6±385.04m).

(16) Front Rows traveled the greatest distance (2062.5±420.37m) in the Jogging (6-12km/h^{-1}) speed zone and Outside Backs traveled the least (1390.7±259.54m).

(17) In the Cruising & Striding (12-18km/h^{-1}) and High-intensity running (18-20km/h^{-1}) speed zones, Inside Backs traveled the greatest distance among all positional groups (Cruising & Striding: 1264.6±273.33m, High-intensity running: 280.2±64.01m).

(18) In the Sprinting (>20km/h^{-1}) speed zone, Outside Backs traveled the greatest distance (518.6±162.12m) and Front Rows traveled the least (56.8±48.99m, p<0.05).

The above results suggested that movement patterns and exercise intensity differ by position. While Backs repeated high-intensity (Sprinting) and low-intensity work (Standing & Walking), and had sufficient time for recovery during games, Forwards repeated medium-intensity (Jogging) and high-intensity work such as scrum, kick-off, and line-out that were not reflected to tracking data, which suggested that Forwards were required to perform intermittent physical exercise with a shorter recovery time compared with Backs. These findings suggested that rugby is characterized by the mixture of aerobic and anaerobic power that includes intermittent high-intensity power exertion. Therefore, it is important for rugby coaches to create training programs that take into account basic physical exercise ability, differences in running movement that can be obtained by GPS, and skills and techniques required for different positions. GPS is useful for the analysis of Sprinting ability and movement patterns by position. Doing so will contribute to the improvement of performance. Results also indicated the importance clarifying contact during games, which is one of the characteristics of rugby in future.

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