Materials : Rugby Football

Physical Demands of Elite Rugby Union Match-play Using Global Positioning System

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The purpose of this study was to investigate the physical demands of elite rugby union match-play using a Global Positioning System(GPS), and to compare these demands among positional groups with the goal of creating more effective training plans. GPS data were collected from 14 Japan Rugby Top League 2013-2014 season competition games over a single season. Players were categorized into one of four positional groups, Prop/Hooker (Front row forwards; FR), Locks/Flanker/No.8 (2nd and 3rd row forwards; 2&3R), Scrum-half (SH), and Fly-half/Three-quarters/Full-back (Backs; BKs). Total distances covered during match-play by FR, 2&3R, SH, and BKs were 5604.0±252.40m, 5690.2±284.24m, 7001.0±245.79m, 6072.3±852.85m, respectively. Significant differences were observed between positional groups, and then SH covered significantly greater total distances than other positional groups did (SH>FR, BKs; p<0.05, SH>2&3R; p<0.01). Standing & Walking (0-6km/h) distances (ratio for the total distance; %) covered by FR, 2&3R, SH, and BKs were 2209m (39.7%), 2067m (36.5%), 2092m (29.9%), 2581m (43.1%), respectively. Jogging (6-12km/h) distances were 2207m (39.2%), 2028m (35.6%), 2031m (29.0%), 1742m (28.6%). Cruising & Striding (12-18km/h) distances were 967m (17.2%), 1288m (22.6%), 2024m (28.9%), and 1135m (18.6%). High-intensity running (18-20km/h) distances were 104m (1.9%), 163m (2.9%), 425m (6.1%), and 233m (3.8%). Sprinting (20km/h) distances were 117m (2.1%), 142m (2.5%), 430m (6.1%), and 381m (6.0%). Positional differences exist for running based variables. The present data can be used to adapt training to better prepare each position based on the physical demands of the game.

Keywords: GPS, Physical demands, Positional difference, Team sports

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1. Introduction

Physical demands such as distance covered and speed of individual players during football, handball, rugby league (13 players), and rugby union (15 players, hereinafter “rugby”) games were analyzed to create training plans suitable for each sport (Tanisho et al., 2009; Tanaka et al., 2002; Gabbett et al., 2012). In the 1980s, Kawase et al. (1988) conducted research on total distances covered per game utilizing the notational analysis. They reported 4079m covered by Prop, 4788m covered by Hooker, 3432m covered by Flanker, 3356m covered by Number-8, and 3443m covered by Fly-half. In the 2000s, Cunniffe et al. (2009) conducted research utilizing a Global Positioning System (GPS) and reported that the total distances covered per game by Forwards were 6680m and 7227m by Backs. Austin et al. (2011) conducted research utilizing video analysis and reported that the total distances covered by Front Row, Back Row, Inside Back, and Outside Back were 4662±659m, 5262±131m, 6095±213m, and 4774±1017m, respectively.

Meanwhile, a comparison of previous studies on the total distances covered by each positional group revealed differences; therefore, they were insufficient for use as data in the creation of training programs or plans considering the characteristics of rugby. Few studies report physical demands during rugby games, and these studies considered different subject categories (professional, university, etc.), and insufficient numbers of subjects or games, making it difficult to clarify the physical demands of rugby games.

Physical demands during ball games were analyzed by the notational analysis, high-speed transfer analysis system utilizing triangulation, and GPS (Yamanaka et al., 1989; Ohashi et al., 1998; Waldron et al., 2011; McLaren et al., 2015). However, the notational analysis and high-speed transfer analysis are insufficient for the classification and quantification of speed. It is also difficult to calculate data, which requires a significant amount of time and effort, making it difficult to specify exercise load such as distance covered and speed during games (Furukawa et al., 2013). GPS, on the other hand, can accurately and easily record these items. Schutz et al. (2000) reported the differential global positions system (DGPS) to be highly effective and accurate in the measurement of speed. Around 2000, many studies were conducted utilizing GPS during training and games (Twist et al., 2014; Macutkiewicz et al., 2011; Wisbey et al., 2009). In fact, the Japan National Team, which achieved good results in Rugby World Cup 2015, as well as national and club teams around the world have used GPS to evaluate game performance and to manage the intensity and amount of training (GPSPORTS, 2014).

Clarifying physical demands during rugby games is significant because the data can be used in the creation of training plans to improve competitiveness. In order to clarify the physical demands of rugby, which have been difficult to evaluate or compare using previous studies, it is necessary to target sufficient subjects and games.

This study, therefore, was conducted to clarify distances covered and speed per rugby game by positional group. Data of elite rugby players in games during a single season were collected. Clarification of the physical demands on elite rugby players makes it possible to set a standard. This standard could assist in estimating physical demands in other categories and be used in the creation of training programs. In this study, we utilized GPS to calculate data.

2. Methods

2.1. Subjects & Subject Games

Subjects of this study were the 14 games played by the Top League in the 2013-2014 season of the Japan Rugby Top League and 15 starters of each game (14 games × 15 players = 210 samples). We excluded players who found the GPS vest uncomfortable and players with a history of asthma or other respiratory conditions from the subjects of this study. We used only data of plays who played the entire period of the relevant games (80 minutes).

The total number of samples was 177, among which the number of samples that played the entire period of the relevant game was 71. A breakdown of the 71 samples Front row is as follows: 3; 2nd row, 13; 3rd row (Back-row), 6; Scrum-half, 7; Fly-half, 5; Three-quarters, 28; and Full-back, 9.

The 2014 Japanese rugby national team was 9th in the world ranking; therefore, players belonging to the Top League in Japan can be considered elite rugby players (World Rugby, 2014).

2.2. Classification by Position

Previous studies reported that the characteristics of plays in rugby games differ by position; therefore, it is necessary to examine these by positional group (Ishii et al., 2002). This study classified positions into four groups based on performance characteristics. Among Forwards, we designated two categories, FR (Front row) and 2&3R (2nd row and 3rd row). Among Backs, we designated two categories, SH (Scrum-half) and BKs (Fly-half, Three-quarters, and Full-back). The FR is required to play a particular role in the scrum. The 2nd &3rd row are classified as 2&3R, which have a high work-load during games. The Scrum-half (SH) is required to actively move around the field to pass the ball out of the ruck. Fly-half, Three-quarters and Full-back were classified as BKs, which are required to move at high speed. The physical characteristics of these four categories are shown in **Table 1**.

2.3. Wearing GPS

The GPS employed was SPI Pro XII (GPSPORT, Australia) due to its having the highest accuracy of sampling and use for analysis in a wide variety of sports, including rugby (SPSPORTS, 2014). The sampling accuracy of the GPS used in this study was 15 Hz.

We employed the GPS vest recommended by the manufacturer and positioned the GPS device on the upper part of the middle of left and right shoulder blades of the subjects. This GPS does not limit the movement of players during games.

Table 1 Subject characteristics

Position	n	Age (years)	Height (cm)	Weight (kg)
FR	3	27.0 ± 2.0	179.0 ± 6.0	104.5 ± 10.5
2&3R	19	28.1 ± 3.1	184.3 ± 5.9	99.1 ± 5.4
SH	7	26.0 ± 2.0	160.0 ± 8.0	61.5 ± 6.5
BKs	42	28.0 ± 2.7	176.2 ± 4.7	88.0 ± 7.5

Data are mean ± SD.

2.4. Analysis Items

GPS is capable of analyzing a wide range of items. This study focused on total distance covered to analyze physical demands during games. The total distance covered in this study was determined to be the distance covered between kick-off to no-side, including the distance covered while the ball is in and out of play. The rationale for including distance covered while the ball is out of play is the importance of players taking their positions for the next play (Furukawa et al., 2013). In this study, we also calculated distance covered by time zone and speed zone to clarify total distance covered in greater detail. Details of each analysis item are explained below.

(1) Distance Covered by Time Zone

Previous studies analyzed entire games or divided games into 1st and 2nd halves. In this study, we analyzed each game as a total unit as well as divided into 1st and 2nd halves to clarify physical demands in greater detail. Furthermore, we divided the 1st half into Quarter-1 (Q-1) and Quarter-2 (Q-2), and the 2nd half into Quarter-3 (Q-3) and Quarter-4 (Q-4). Data obtained in this study, therefore, were calculated as total, 1st half, 2nd half, Q-1, Q-2, Q-3, and Q-4.

In actual games, play does not end in 80 minutes because of water breaks, injury time, and time used for activities other than actual play. Similarly, the 1st and 2nd halves usually last longer than 40 minutes, and each quarter usually lasts longer than 20 minutes. Therefore, we divided each quarter considering water breaks, injury time and time used for activities other than actual play rather than simply using the value of 20 minutes after the start of the 1st and 2nd halves. For example, when injury time was two minutes between 30 and 32 minutes after the 1st half started and the total time of the game was 42 minutes, the period from 0 minute to 20 minutes in the 1st half was considered Q-1, and the period from 20 to 42 minutes in the 1st half was considered Q-2. Q-2 running time was 22 minutes; however, it included the 2-minute injury time and the play time was equal to Q-1. This is the manner in which we adjusted the division of each quarter.

Employing this method of adjusting time, we used the running time including injury time, etc. (e.g. 22 minutes for the above-mentioned Q-2) to calculate values per minute.

(2) Moving Distance by Speed Zone

Based on the report on speed during games by Cunniffe et al. (2009), we divided speed into five zones and calculated the distance covered in each zone. The five speed zones were set as follows:

1. Speed Zone 1 (SZ-1): Standing & Walking (0-6km・h^{-1}),
2. Speed Zone 2 (SZ-2): Jogging (6-12km・h^{-1}),
3. Speed Zone 3 (SZ-3): Cruising & Striding (12-18km・h^{-1}),
4. Speed Zone 4 (SZ-4): High-intensity running (18-20km・h^{-1}), and
5. Speed Zone 5 (SZ-5): Sprinting (20km・h^{-1}<).

We also combined SZ-4 and SZ-5 and calculated the data as high intensity running (HIR). HIR is an important indicator for assessment of the percentage of high intensity physical movement (Otsuka, 2013).

The results of the distance covered by speed zone were calculated by absolute values of distance covered in each zone, and relative values of the percentage of distance covered in each zone against the total distance covered.

2.5. Statistical Analysis

The distances covered by positional group and time zone were indicated as mean value and standard deviation. In order to compare the distances covered by positional groups and time zones, we applied the analysis of variance (ANOVA), including interactions for cases whose uniformity of dispersion were confirmed by Bartlett's test, and applied the Kruskal-Wallis test for cases whose uniformity of dispersion was not confirmed. When the differences between each factor were observed, we conducted parametric or non-parametric multiple comparisons that were suitable for each case.

3. Results

The purpose of this study was to clarify the physical demands by positional group during rugby games for use in creating training plans to improve performance. The details of distance covered by time zone and speed zone are shown in **Tables 2 and 3**, respectively. The number of samples of each position varied, and this prevented confirmation of the uniformity of dispersion; therefore, we conducted Kruskal-Wallis test for one factor for physical demands by positional group and time zone, and the overview of the interactions between two and among three factors were shown without statistical analysis. The total distances covered by positional group, including the distances covered by time zone, and distances covered by speed zone are shown in **Figures 1 and 2**, respectively.

3.1. Total Distances Covered

According to our comparison of the total distances covered among positions, SH revealed the highest at 7001.0±245.79m, followed by BKs and 2&3R. FR revealed the lowest at 5604.0±252.40m. A significant difference in the number of subjects by position was observed, and the Bartlett test showed no conformity of dispersion. Kruskal-Wallis test showed a significant difference among positions ($p<0.01$); therefore, we conducted Steel-Dwass multiple comparison, which revealed that SH was significantly higher compared with other positions (SH>FR, BKs; $p<0.05$, SH>2&3R; $p<0.01$).

3.2. Distance Covered by Time Zone

The distances covered by time zone were as follows: 153.9m for Q-1, 1475.8m for Q-2, 1472.2m for Q-3, and 1605.0m for Q-4. Bartlett's test did not confirm conformity of dispersion for each factor of quarters; therefore, we conducted Kruskal-Wallis test. As a result, there was a significant difference among time zones ($p<0.01$). The results of Steel-Dwass multiple comparison revealed that Q-4 was significantly higher than Q-2 and Q-3 (Q-4>Q-2>q-3; $p<0.01$).

3.3. Distance Covered by Speed Zone

The rates of distances covered by speed zone against total distances covered were 39.9% (SZ-1), 31.0% (SZ-2), 20.6% (SZ-3), 3.7% (SZ-4), and 4.9% (SZ-5). Results showed differences in distances covered among speed zones; therefore, we conducted comparisons among positional groups for each speed zone. This study did not include statistical analysis for comparisons among positional groups for each speed zone, but provided an overview. In SZ-1, SH revealed the lowest value, followed by 2&3R and FR; and BKs showed the highest value. In SZ-2, Forwards

Table 2 Distance covered by positional group in each time zone

Position		Total	1st Half			2nd Half		
				Quarter-1	Quarter-2		Quarter-3	Quarter-4
FR	(n=3)	5604.0 ±252.40 (5261.7~5863.1)	2821.5 ±236.06	1442.5 ±69.66	1379.0 ±197.86	2782.5 ±44.42	1361.9 ±83.26	1420.6 ±42.32
2&3R	(n=19)	5690.2 ±284.24 (4928.2~6240.5)	2854.3 ±242.45	1474.2 ±106.88	1380.1 ±159.44	2835.9 ±143.76	1335.0 ±90.46	1501.0 ±150.61
SH	(n=7)	7001.0 ±245.79 (6657.4~7507.8)	3461.1 ±264.92	1752.7 ±76.52	1708.4 ±249.83	3539.9 ±166.01	1684.9 ±86.26	1855.0 ±181.86
BKs	(n=42)	6072.3 ±852.85 (4387~9643.6)	2921.7 ±399.73	1486.0 ±208.16	1435.7 ±238.68	3150.6 ±630.70	1507.1 ±277.42	1643.4 ±414.20
Total	(n=71)	6041.8 ±770.05 (4387~9643.6)	2952.6 ±385.87	1507.3 ±190.12	1445.3 ±237.73	3089.2 ±535.75	1472.5 ±243.88	1616.7 ±349.47

Table 3 Distance covered by positional group in each speed zone

Position	Quarter	Speed Zone SZ-1	SZ-2	SZ-3	SZ-4	SZ-5	HIR [SZ-4 & SZ-5]
FR	(n=3)	2209.0 ±231.63 (39.7%)	2207.1 ±398.79 (39.2%)	967.2 ±166.39 (17.2%)	103.7 ±10.14 (1.9%)	116.8 ±14.45 (2.1%)	220.5 ±7.39 (3.9%)
	Q-1	479.5 ±63.27	580.8 ±119.57	272.9 ±19.81	54.1 ±11.74	55.2 ±4.22	109.3 ±14.58
	Q-2	574.8 ±38.90	573.9 ±185.46	203.6 ±59.94	14.7 ±2.74	12.0 ±5.16	26.7 ±7.85
	Q-3	537.1 ±80.41	532.8 ±75.13	267.0 ±68.66	13.6 ±7.76	11.5 ±9.87	25.0 ±17.39
	Q-4	617.7 ±51.81	519.6 ±87.98	223.7 ±54.36	21.3 ±6.88	38.2 ±11.64	59.5 ±14.55
2&3R	(n=19)	2067.0 ±202.37 (36.5%)	2028.2 ±237.44 (35.6%)	1288.1 ±187.75 (22.6%)	162.9 ±45.21 (2.9%)	142.1 ±44.55 (2.5%)	304.9 ±68.18 (5.4%)
	Q-1	464.0 ±67.58	543.8 ±87.98	375.5 ±71.87	47.2 ±18.56	41.8 ±29.12	89.0 ±33.16
	Q-2	534.3 ±66.62	489.3 ±100.17	283.8 ±52.92	39.9 ±17.40	32.7 ±23.48	72.6 ±34.01
	Q-3	482.8 ±68.00	476.0 ±76.64	304.1 ±65.35	40.6 ±22.45	31.5 ±22.18	72.1 ±37.01
	Q-4	585.8 ±84.98	519.2 ±80.68	324.7 ±77.11	35.2 ±14.83	36.1 ±14.78	71.3 ±23.02
SH	(n=7)	2091.7 ±89.46 (29.9%)	2031.1 ±165.73 (29.0%)	2023.8 ±163.57 (28.9%)	424.7 ±88.05 (6.1%)	429.7 ±128.76 (6.1%)	854.4 ±199.51 (12.2%)
	Q-1	467.4 ±45.60	519.9 ±56.46	535.8 ±55.64	120.7 ±34.30	108.8 ±46.37	229.5 ±71.87
	Q-2	563.0 ±49.31	489.4 ±77.48	485.2 ±138.57	87.6 ±41.28	83.2 ±29.44	170.8 ±67.80
	Q-3	499.6 ±39.17	485.1 ±41.33	500.1 ±56.54	105.0 ±29.54	95.1 ±51.27	200.1 ±76.02
	Q-4	561.7 ±96.54	536.7 ±114.31	502.6 ±116.33	111.5 ±37.52	142.5 ±49.87	254.0 ±82.85
BKs	(n=42)	2581.3 ±259.82 (43.1%)	1741.9 ±407.42 (28.6%)	1135.3 ±305.56 (18.6%)	232.5 ±89.50 (3.8%)	381.2 ±300.21 (6.0%)	613.7 ±369.50 (9.7%)
	Q-1	597.6 ±75.91	434.6 ±92.23	300.7 ±98.65	61.4 ±30.99	91.6 ±56.33	153.1 ±75.21
	Q-2	638.5 ±97.34	412.8 ±104.26	263.1 ±89.91	49.9 ±25.08	71.4 ±48.96	121.3 ±66.34
	Q-3	638.9 ±79.19	427.3 ±179.41	279.2 ±103.03	61.7 ±27.86	100.0 ±69.76	161.7 ±90.10
	Q-4	706.3 ±88.63	467.1 ±160.54	292.3 ±106.28	59.5 ±40.83	118.1 ±225.51	177.7 ±259.74
Total	(n=71)	2379.7 ±337.01 (39.9%)	1866.7 ±382.71 (31.0%)	1256.7 ±372.83 (20.6%)	227.4 ±108.03 (3.7%)	310.8 ±262.72 (4.9%)	538.2 ±343.50 (8.6%)
Position × Speed Zone		Summary of the result of multiple comparison					Multiple comparison
		SH < 2&3R < FR < BKs	SH = BKs < 2&3R < FR	FR = BKs < 2&3R < SH	FR < 2&3R < BKs < SH	FR = 2&3R < SH = BKs	FR = 2&3R < BKs < SH
	Q-1	544.0 ±95.78	478.4 ±104.45	342.7 ±112.59	63.2 ±34.38	78.4 ±53.78	141.6 ±76.05
	Q-2	600.5 ±96.37	447.6 ±114.85	288.0 ±109.92	49.4 ±28.99	59.7 ±45.59	109.1 ±66.90
	Q-3	579.1 ±103.28	450.5 ±148.03	307.1 ±110.18	58.3 ±32.76	77.5 ±65.99	135.7 ±90.34
	Q-4	656.1 ±106.60	490.1 ±139.26	318.8 ±117.77	56.5 ±40.77	95.2 ±178.88	151.7 ±210.38
Speed Zone × Quarter		Summary of the result of multiple comparison					Multiple comparison
		Q-1 < Q-3 < Q-2 < Q-4	Q-2 = Q-3 < Q-1= Q-4	Q-2 < Q-3 = Q-4 < Q-1	Q-2 < Q-3 = Q-4 < Q-1	Q-2 < Q-1 = Q-3 < Q-4	Q-2 < Q3 = Q-1 = Q-4

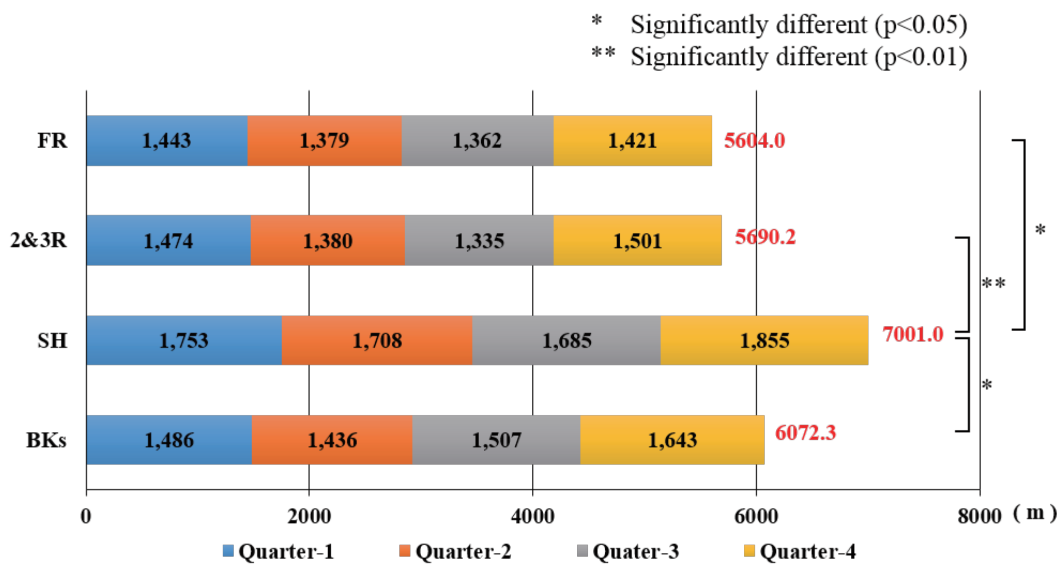

Figure1 Distance covered by positional group in each time zone

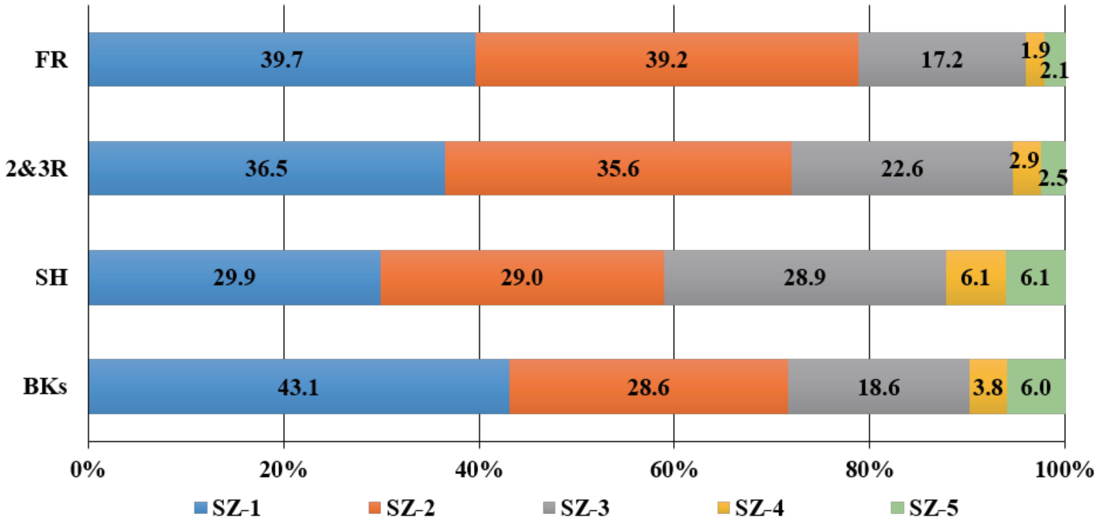

Figure2 Percent distance covered by positional group in each speed zone

showed higher values compared with Backs. In SZ-3, FR and BKs revealed equivalent values, and 2&3R revealed the highest value, followed by SH. In SZ-4, FR revealed the lowest value followed by 2&3R and BKs; and SH revealed the highest value. In SZ-5, BKs revealed higher value than FR, which was contrary to SZ-2 results. As for the HIR, equivalent values were observed among FR, and SH showed the highest HIR followed by BKs.

Next, we compared the distances covered among time zones for each speed zone. We did not conduct statistical analysis for the comparison, but provided an overview. In SZ-1, Q-1 showed the lowest value, followed by Q-3 and Q-2; and Q-4 revealed the highest value. In SZ-2, Q-1 and Q-4 revealed higher values than Q-2 and Q-3 did. In SZ-3, Q-3 and Q-4 revealed higher values than Q-2 did; and Q-1 revealed the highest value. The SZ-4 revealed similar results as SZ-3. In SZ-5, Q-1 and Q-3 revealed higher values than Q-2 did; and Q-4 revealed the highest value. As for HIR, Q-2 revealed the lowest value; and Q-3, Q-1 and Q-4 revealed equivalent values.

4. Discussion

4.1. Physical Demands by Positional Group

In order to clarify the physical demands by positional group, we focused on the total distances covered per game. According to **Table 2**, which shows total distances covered by positional group, FR revealed 5604.0±252.40m, 2&3R revealed 5690.2±284.24m, SH revealed 7001.0±245.79m, and BKs revealed 6072.3±852.85m. SH revealed significantly longer distances covered than other positions did. Compared with BKs, SH moved approximately 1000m longer and showed markedly different physical demands. The reason for this is that the SH position always moves around the ruck when passing the ball out of the ruck during games. BKs showed significantly shorter total distances covered than SH did; however, BKs did not show a significant difference with Forwards. Therefore, it is necessary to examine the distance covered by speed zone to clarify the speed of total distance covered by BKs. We also analyzed the performance of Forwards and found no significant difference between the FR and 2&3R. However, because the insufficient number of subjects influenced the result, we hypothesized that total distances covered by 2&3R would be longer than those covered by FR in actual games. Mean values of the total distances covered revealed no significant difference. However, maximum values listed in **Table 2** show that the total distances covered by 2&3R were greater than those covered by FR, which suggested that physical demands differed among Forwards. Recently, coaches tend to change FR during games for physical and statistical reasons, and they do not usually play the entire game. Therefore, we were unable to examine a sufficient number of FR in this study. Because of this, total distances covered revealed no significant difference. It is also possible that FR physical demands are similar to 2&3R because the FR is also frequently involved in the breakdown in recent games and required to perform a high amount of movement. These results suggested the need for further research, including the issue of the number of subjects.

Next, we focused on the distance covered by speed zone to clarify the speed at which total distance was covered. The percent distance in SZ-1 and SZ-2 at low speed, which was jogging or lower (12 km/h or lower), covered by FR was 78.9%, 2&3R was 72.1%, SH was 58.9% and BKs was 71.7%. SH showed a clearly different tendency from other positions, and the ratio of low speed was low while positions other than SH moved at low speed over more than 70% of the total distances of a game. FR in particular moved nearly 80% of the total distances at low speed. BKs were 43% in SZ-1, which was the highest among all positions. HIR, an indicator of high speed, (the total of SZ-4 and SZ-5, 18 km/h or greater) was 3.9% (FR), 5.4% (2&3R), 12.2% (SH), and 9.7% (BKs), which revealed higher values for Backs than Forwards.

The results of the total distances covered and distances by speed zone clarified the physical demands by positional group. This showed that SH performs under high exercise load during games and requires specific training. Although BKs HIR was approximately 10%, which is higher than that of Forwards, the percent distance at the speed of jogging or lower in SZ-1 and SZ-2 was 70% or greater, which was similar to Forwards. The ratio in SZ-1 was highest (43%) among all positional groups, which suggested that BKs repeated high-intensity movement with intervals of low-intensity movement. Since BKs must perform at high speed due to the characteristics of the positions, they require the ability to maintain and repeat high-intensity movement. FR and 2&3R revealed low total distances covered and HIR; and the percent distances covered at the speed of jogging or lower was 70% or greater. This showed that FR and 2&3R had lower exercise load compared with other positional groups. However, these results seemed to have been influenced by the frequency of contact due to positional characteristics, characteristics such as tackling and support around the ruck. Before their speed increased, they often had contact with other positions, which prevented them from entering the speed zones that were classified into HIR; and the percent distances covered at the speed of jogging or lower became larger in SZ-1 and SZ-2. This study did not include indicators of contact or frequency of increased or decreased speed in the analysis items for GPS. It is necessary to conduct further research on physical demands considering the frequency of contact and increased and decreased speed.

We compared the total distances analyzed in the previous studies and in this study by positional group. Kawase et al. (1988) reported 4079m covered by Prop, 4788m covered by Hooker, 3432m covered by Flanker, 3356m covered by Number-8, and 3443m covered by Stand-off. Austin et al. (2011) reported that the total distances covered by Front Row, Back Row, Inside Back, and Outside Back were 4662±659m, 5262±131m, 6095±213m, and 4774±1017m, respectively. Compared with the results of previous studies, our study revealed higher values for all positional groups. While Cunniffe et al. (2009) reported that total distances covered per game were 6680m by Forwards and 7227m by Backs, all positional groups in this study had lower values. However, the subjects of the study conducted by Cunniffe et al. (2009) were limited to one for both Forwards and Backs, and subject games were one, meaning that results may have been influenced by the physical fitness of the subjects and the flow of the subject game. The comparison of maximum values, not mean values, of this study with the values reported by Cunniffe et al. (2009) showed Backs to have higher values than those reported by Cuuniffe et al. These comparisons showed that the total distance covered per rugby game has been increasing for each position recently.

Results for physical demands by positional group during games showed that each position has specificity, making it necessary to consider training programs suitable for each position. We considered the total distances covered as amount of exercise, and distances by speed zone as exercise intensity (Otsuka, 2013). When designing training programs, we applied the overload principle. In order to set the load to reflect the physical demands by positional group in training programs, it is necessary to set slightly higher rather than equivalent amounts and intensity of exercise than those in the actual games. Specific methods of setting exercise amount and intensity are described below utilizing the SH case.

According to the results of this study, SH moved 7000 m per game (80 minutes); therefore, the mean speed per minute was 87.5m/min. Setting the overload of the exercise to increase training program load by 20%, the mean speed is 105m/min. Setting the rules to maintain mean speed at a minimum of

105m/min during the small-sided conditioning game (SSG), which is a representative fitness training program, allows trainees to exercise under higher intensity than in actual games, which leads to improved performance. In addition, the HIR of the distances covered by SH by speed zone was 12.2%, which would convert to 15% at a 20% overload. Setting conditions to maintain HIR at a minimum of 15% during SSG allows trainees to exercise under higher intensity than in actual games, which leads to improved performance. These are examples that can be applied to the setting of exercise intensity in training programs. Furthermore, the results of this study can be used for the setting of exercise amounts in training programs. SH often suffer muscular cramps at the end of games. Some reasons are electrolyte loss due to dehydration, continual excitability of sympathetic neurons, muscle strength, and muscular endurance (Sato et al., 2007). Because SH show the greatest total distances covered, that distance may exert an excessive burden on skeletal muscle capacity, which may result in the muscular cramps. In this study, SH moved 7000m in 80 minutes. Therefore, setting overload 20% greater would make the distance 8400m. It is thought that setting the distance at 8400m or greater in training sessions would allow trainees to increase lower leg muscle endurance and prevent muscular cramps. Adding load to the values obtained from the game which had the highest load to set the load for training is also thought to be effective. Adjustment to the high-intensity exercise load based on the data obtained from the game with the highest load allows trainees to increase physical endurance for high intensity games.

4.2. Physical Demands by Time Zone

According to **Table 2**, the average of distances by time zones of all positional groups are 1507.3m (Q-1), 1445.3m (Q-2), 1472.5m (Q-3), and 1616.7m (Q-4). Comparison of distances by time zone showed Q-4 to be significantly longer than Q-2 and Q-3. In terms of distances by speed zone, Q-1 was shortest in SZ-1 followed by Q-3 and Q-2; and Q-4 was the longest. HIR in Q-3 and Q-4 were equivalent. Results of distances in each quarter, SZ-1, and HIR showed that exercise intensity lowered along with the progress of the game. Specifically, distance in Q-2 did not differ from Q-1; however, the ratio of SZ-1 increased, suggesting that exercise intensity lowered along with the progress of the game. Although distance in Q-4 was longer than Q-3, the HIR in Q-3 and Q-4 were the same, suggesting that exercise intensity lowered along with the progress of the game due to increase of the SZ-1 ratio. Such lowering of exercise intensity along with the progress of games exerts a negative influence on performance, suggesting the need to create training programs that address the problem.

5. Conclusion

This study was conducted to clarify distances covered and speed per rugby game to obtain basic data for the creation of training programs to increase competitiveness. Data of elite rugby players in games during a single season were collected utilizing GPS. This study clarified that physical demands in rugby differ by positional group and suggested the need to design specific training programs for each position. Therefore, the results of this study may be useful in the creation of training programs for each position.

Total distances covered are influenced by a wide range of factors such as physical factors of players, tactics used by each team, and game flow. Therefore, the data obtained from this study may not always show physical demands by positional groups. However, the data of each player that performed throughout all 14 games showed no significant difference in physical demands by game. In addition, this study focused on one team's players only; however, these subjects were all starting members in all games during the season (excluding those excluded from the study due to a history of health issues, etc.) and we used GPS to collect their data. For this reason, we believe the data is sufficient for use as an indicator of the physical demands by positional group. It is also important to determine the physical demands by positional group for each team considering the tactics and other factors utilizing the data of this study as an indicator.

In future, we would like to clarify more details of physical demands by positional group by increasing the number of subjects for each position, analyzing data of players changed during games, measurement of plays that cannot be measured by GPS. Plays such as scrum and maul, and the relationship between GPS data and game stats.

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