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Research article

Elite Male Lacrosse Players' Match Activity Profile

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Abstract

Match demands in international men's lacrosse have yet to be explored. Therefore, this investigation quantified positional match demands of international men's lacrosse. This study quantified activity profiles of 50 lacrosse players [attack (AT): 11, midfield (MD): 22, defense (DF): 17] on Japan's national team, using a global positioning system (GPS), players' acceleration, and a heart rate (HR) apparatus to investigate their movement and physiological load. The study revealed that in thirteen international matches, distance, walk distance, jog distance, low-intensity acceleration, and low-intensity deceleration for the AT and DF groups was significantly greater than for the MD group, but the MD group's average speed and sprint distance were the highest. Multiple comparison tests showed that measurements for the AT and DF groups were significantly greater than the MD group for distance, low-intensity acceleration, medium-intensity decelerations, and low-intensity deceleration. This data can become the physical data for helping coaches with strength and conditioning training at the international level. For MD players, anaerobic power and load condition (long rest, high intensity) should be emphasized. In addition, coaches can decide on tactics and a running-quantity target for the next game by acquiring continuous activity data.

Key words: national competition, physical activity data, running performance, sports training.

Introduction

Believed to have originated in the 14th century, lacrosse is Native Americans' oldest known sport. Over the past several decades, lacrosse has grown in popularity in intercollegiate, inter-scholastic, club, and youth leagues (Plisk, 1994) at all levels, from junior to professional (Burger, 2006). Since 2001, participation in lacrosse youth leagues has increased by almost 325% in USA (U.S. Lacrosse, 2017). More than 42,508 athletes participate in National Collegiate Athletic Association (NCAA) lacrosse, a 59.4% growth since 2006 (U.S. Lacrosse, 2017). Obviously, lacrosse's popularity is growing at great rates (Enemark-Miller and Seegmiller, 2009).

Lacrosse combines elements of basketball, soccer, and hockey (U.S. Lacrosse, 2005) and is a physically demanding sport that requires athletes to sprint repeatedly and change directions quickly, all while manipulating the ball with the lacrosse stick (Pistilli et al., 2008; Tsuchiya et al., 2013). The primary goal is to "cage" the ball. Lacrosse is often described as "the fastest game on two feet." Therefore, shot and pass speed greatly influence game performance.

Victory or defeat in lacrosse is determined by a team having a higher score than their opponents within a game time of 80 minutes (20 min × 4 quarters). Lacrosse's basic form includes intermittent exercise, repeating high-strength dashes or jumps sandwiched between rest and low-strength campaigns (Tanisho et al., 2009). In total, various extreme movements are performed in starts, dashes, jogging, and cutting, among other movements, according to how others play. In other words, physical strength and stamina are necessary for repeated high power to control the competition. Lacrosse team positions include a goalkeeper (GK), defense (DF), midfielders (MD), and attackers (AT). DF can be further classified into bottom and long midfielders.

In recent years, the analysis of various activity profiles with a device allowing heart rate (HR) measurement coordinated with a global positioning system (GPS) has enabled the examination of whole-game and single-position movement characteristics, thus distinguishing needed training methods (MacLeod et al., 2009; Ryan et al., 2018a; 2018b; Tanisho et al., 2009; Townshend et al., 2008). Previous studies have used such examination to measure movement speed and distance in soccer, rugby, and Australian Rules football. Although similar reporting on match activity exists for lacrosse (Polley et al., 2015), match demands in international men's lacrosse have yet to be explored. Coaches, scientists, and medical professionals responsible for managing players' stress and recovery need awareness of typical loads sustained throughout competitive international matches. We can suggest the exercise load specialized in the position from this study. Therefore, this investigation quantified positional match demands of international Japanese men's lacrosse by using wearable GPS and HR technology. To the best of our knowledge, this is the first report on a national team that includes measured match running, acceleration, and deceleration distributions across positions using GPS.

Methods

This study investigated physiological demands of elite men's lacrosse competition; these demands were compared with those experienced during top-level games of male lacrosse, including position-specific physical demands. Data were collected during matches throughout a season's competitive phase. More specifically, players on Japan's national team were assessed from June 2017 to March 2018 during thirteen international top-level test matches against six highly ranked international teams of the 2014 World Lacrosse Championship.

The subjects of the study were 50 lacrosse players

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(AT: 11; MD: 22; DF: 17) on Japan's national team. They were healthy with no history of severe trauma, injury, or surgery on their lower and upper limbs. Additionally, they had no symptoms that could interfere with walking or athletic activities during this experiment. Their physical characteristics were as follows: age 25.2 ± 4.8 years; height 177.8 ± 6.1 cm; and weight 73.4 ± 5.2 kg. Prior to the experiment, the study objective, contents, and associated risks were explained orally, as required by the ethics committee of our University. Then, informed consent for voluntary participation was obtained from all subjects, post which we got approval of the board of directors of the Japan Lacrosse Association on the use of GPS data. Furthermore, players were advised that they could discontinue study participation at any time.

Data were collected during three matches via commercially available GPS units (Polar Team Pro; Polar Electro, Kempele, Finland) that incorporated HR measurement at each player's chest. These devices were activated several minutes before the game began and deactivated immediately at its completion. Each quarter of the match was analyzed separately, considering only active minutes. According to manufacturer specifications, these GPS devices have a 10-Hz sampling rate and a built-in 200 Hz triaxial accelerometer. Registered data include HR, time, speed, distance, and the number and intensity of accelerations. After data collection, the GPS-derived information was downloaded to a personal computer and analyzed with the internet service provided by the manufacturer (Polar Team Pro web service; Polar Electro, Kempele, Finland).

Locomotive activities' frequency, duration, and distance were obtained from the percentage of total match-time play and the distance covered by players in each of six speed zones. Players' movement speeds were classified into four categories (Curtis et al., 2018) : standing or walking (0–7.19 km/h), jogging (7.2–14.39 km/h), running (14.4–21.59 km/h), and sprinting (<21.6 km/h). The work-to-rest ratio reflects total high/moderate running speed exercise versus total low-speed running time, following Suarez-Arrones et al. (Suarez-Arrones et al., 2012a; 2012b; 2012c). Locomotor categories were divided into two subcategories, to estimate work-to-rest ratios: (a) low-intensity activity (0.1–7.19 km/h) and (b) moderate- and high-intensity activity (<7.2 km/h). Accelerations were classified into the following categories (18): low intensity (0–1.99 m/s^2), moderate intensity (2.0–3.99 m/s^2), and high intensity (<4.0 m/s^2). We adopted an index termed high-speed running distance (HSD) (14.4 km/h or above) as total distance during running.

Heart rate was measured continuously throughout entire games via GPS units, which receive and record HR signals transmitted from a chest belt. For analytical purposes, the signal was expressed relative to each participant's maximum HR (HR max) measured at the end of the Yo-Yo IR1 test. HR recorded during matches was categorized into five zones (Suarez-Arrones et al., 2012a; 2012b; 2012c): 0%–60%, 61%–70%, 71%–80%, 81%–90%, and 91%–100% of the maximum. If during the game, a player reached a higher HR than his previously determined max, the maximum value obtained during the match was used as a reference for calculating percentages.

The Kolmogorov-Smirnov test revealed that all the data was normally distributed. To compare changes in running performance by quarter (Q), we performed one-way analysis of variance (ANOVA). To discriminate changes in running performance across playing positions, we performed two-way ANOVA (Q × position). We examined interactions and main effects, performing a multiple comparison test for factors in which these were confirmed. For multiple comparisons, we used Bonferroni's method, and each significance level was set at a risk ratio of $p<0.05$. The 95% confidence interval and effect size of ANOVAs (η^2, ηp2) were calculated. Generally, effect size was used to calculate power and to ascertain the possibility of Type II error. Based on previous studies, the classification of effect size was set so that 0.01 was small, 0.02–0.1 medium, and over 0.1 large (Cohen 1988; Clark-Carter 1997; Kittler et al. 2007). For analysis, we used SPSS (version 24.0, SPSS Inc., Chicago, IL, USA).

Results

Table 1 shows running performance for the three lacrosse positions. Significant interactions were not observe in the one-way ANOVA; therefore, the main effect was determined. The multiple comparison tests resulted in significantly greater distance for DF groups than for the MD group ($p = 0.008$). Average speed for the MD group was significantly greater than that for the AT ($p < 0.001$) and DF groups ($p < 0.001$). HSD distance for the MD group was significantly greater than that for the AT group ($p = 0.001$). Average HR did not show any significant difference. Walking distance for AT and DF groups was significantly greater than that for the MD group ($p < 0.001$, respectively). Sprint distance for the MD group was the highest compared with AT ($p < 0.001$) and DF ($p < 0.001$). Low-intensity accelerations and decelerations for DF groups were significantly greater than that for the AT ($p = 0.012$) and MD group (< 0.001). Average speed for the AT group was significantly smaller than for the DF group ($p = 0.04$), but greater than that for the MD group ($p = 0.042$). High-intensity decelerations for the MD group was significantly greater than that for the AT ($p = 0.009$) and DF group ($p = 0.001$).

Table 2 shows the measurement of distance, speed, and results. No significant interactions were observed in the two-way ANOVA; therefore, for distances, average speeds, HSD ratios, low-intensity (LI) decelerations, medium intensity (MI) decelerations, and LI accelerations, the main effect of each factor was determined. Multiple comparison tests showed that for AT and DF groups, the following were significantly greater than for the MD group: Distances (respectively, $p < 0.001$), LI decelerations ($p = 0.001$, $p = 0.045$), MI decelerations (respectively, $p < 0.001$), LI accelerations (respectively, $p < 0.001$), and MI accelerations ($p = 0.001$, $p = 0.003$). In the HSD, Significant main effects were observed for position. As a result of the multiple comparison tests, HSD did not show any significant difference. HSD ratio for the DF group was significantly smaller than for the MD group (p = 0.001), but greater than for the AT group (p = 0.002). Significant main effects were observed for position. As a result of the multiple comparison tests, the AT, DF groups was significantly smaller than the average speed for the MD group (p < 0.001, p = 0.002). Distance and HSD in the 3Q was significantly smaller than in the 1Q (p = 0.015, p = 0.02).

For HR max, players' percentages of match time were: 17.4 ± 15.6% from 91–100%; 32.9 ± 12.4% from 81–90%; 24.3 ± 8.9% from 71–80%; 17.3 ± 10.8% from 61–70%; and 6.0 ± 7.8% from 0–60%. No differences were found in HR among Qs in each zone. The work-to-rest ratio in games was 1:0.64 (AT: 0.51, MD: 0.71, DF: 0.59).

Table 1. Japanese national lacrosse team's load characteristics by position groups (mean ± SD).

Variables	Attack	Midfielder	Defender	P-value	Effect size
Distance (m)	4505 ± 1438	3028 ± 786	4239 ± 1093	< 0.001	0.3
Average speed (m/min)	67 ± 13	113 ± 13	85 ± 22	< 0.001	0.56
HSD distance (m)	911 ± 302	1078 ± 379	1011 ± 369	0.485	0.03
Average HR (%)	77 ± 7	80 ± 4	85 ± 22	0.345	0.04
Walk distance (m)	2213 ± 739	839 ± 229	1820 ± 729	< 0.001	0.53
Jog distance (m)	1381 ± 497	1073 ± 316	1407 ± 374	0.007	0.18
Run distance (m)	789 ± 244	817 ± 281	842 ± 302	0.862	0.01
Sprint distance (m)	121 ± 74	261 ± 125	169 ± 111	0.002	0.22
LI accelerations (n)	297 ± 93	195 ± 57	328 ± 113	< 0.001	0.35
MI accelerations (n)	47 ± 13	40 ± 13	48 ± 13	0.118	0.08
HI accelerations (n)	1 ± 1	1 ± 1	1 ± 2	0.822	0.01
LI decelerations (n)	347 ± 116	204 ± 61	364 ± 121	< 0.001	0.39
MI decelerations (n)	41 ± 11	36 ± 11	41 ± 13	0.366	0.04
HI decelerations (n)	1 ± 1	2 ± 2	1 ± 1	0.049	0.11

HSD = high-speed running distance (>14.4 km/h); HR = heart rate; LI = low intensity; MI = moderate intensity; HI = high intensity. Velocity zones: walking = 0–7.19 km/h, jogging = 7.20–14.39 km/h, running = 14.40–21.59 km/h, and sprinting =.21.6 km/h. Acceleration/deceleration zones: low intensity = 0–1.99 m/s^2, moderate intensity = 2–3.99 m/s^2, and high intensity = >4 m/s^2.

Table 2. Activity profile (mean ± SD) for each quarter of lacrosse match play.

	Quarter	AT	MD	DF	P-value	Effect size
Distance (m)	1	1638 ± 202	759 ± 253	1346 ± 516	Interaction (quarter × position): 0.741	0.077
	2	1377 ± 663	791 ± 350	1184 ± 526	Main effect	
	3	1358 ± 423	710 ± 306	1105 ± 413	Quarter: 0.557	0.092
	4	1131 ± 534	763 ± 296	1237 ± 401	Position: <0.001	0.779
Average speed (m/min)	1	71 ± 11	105 ± 16	98 ± 39	Interaction (quarter × position): 0.503	0.114
	2	74 ± 9	107 ± 16	86 ± 28	Main effect	
	3	73 ± 7	116 ± 17	93 ± 26	Quarter: 0.264	0.169
	4	69 ± 9	112 ± 11	82 ± 24	Position: <0.001	0.907
HSD (m)	1	218 ± 184	248 ± 138	271 ± 158	Interaction (quarter × position): 0.897	0.049
	2	250 ± 161	277 ± 122	281 ± 179	Main effect	
	3	215 ± 149	266 ± 117	239 ± 107	Quarter: 0.853	0.036
	4	226 ± 103	288 ± 133	221 ± 162	Position: 0.105	0.276
HSD ratio (%)	1	19 ± 5	32 ± 9	29 ± 17	Interaction (quarter × position): 0.996	0.014
	2	19 ± 4	35 ± 9	27 ± 12	Main effect	
	3	20 ± 4	38 ± 9	26 ± 13	Quarter: 0.614	0.081
	4	21 ± 8	37 ± 9	22 ± 12	Position: <0.001	0.851
LI decelerations (n)	1	127 ± 11	54 ± 17	121 ± 61	Interaction (quarter × position): 0.076	0.229
	2	104 ± 53	50 ± 21	95 ± 46	Main effect	
	3	100 ± 32	51 ± 24	91 ± 43	Quarter: 0.792	0.047
	4	90 ± 48	52 ± 24	111 ± 41	Position: 0.002	0.593
MI decelerations (n)	1	13 ± 4	9 ± 4	13 ± 7	Interaction (quarter × position): 0.602	0.098
	2	14 ± 7	9 ± 4	10 ± 5	Main effect	
	3	11 ± 4	7 ± 4	10 ± 4	Quarter: 0.175	0.206
	4	10 ± 5	10 ± 5	12 ± 5	Position: <0.001	0.843
LI accelerations (n)	1	109 ± 10	52 ± 15	107 ± 59	Interaction (quarter × position): 0.795	0.068
	2	90 ± 46	49 ± 22	80 ± 39	Main effect	
	3	86 ± 28	46 ± 22	85 ± 41	Quarter: 0.379	0.134
	4	75 ± 36	50 ± 23	104 ± 35	Position: <0.001	0.819
MI accelerations (n)	1	15 ± 4	11 ± 5	16 ± 6	Interaction (quarter × position): 0.543	0.108
	2	15 ± 7	10 ± 4	12 ± 6	Main effect	
	3	13 ± 4	9 ± 5	12 ± 6	Quarter: 0.458	0.114
	4	13 ± 5	10 ± 4	14 ± 6	Position: 0.543	0.497

HSD = high-speed running distance (>14.4 km/h). HSD ratio = HSD/Distance; LI = low intensity; MI = moderate intensity; Acceleration/deceleration zones: low intensity = 0–1.99 m/s^2; moderate intensity = 2–3.99 m/s^2

Discussion

This study is the first to investigate a match play activity profile, that is, the quantity and intensity of running by male players during international lacrosse matches, using GPS and HR monitoring. Polley et al. (2015) found that male lacrosse players covered distances during a lacrosse match at average speeds, as follows: AT: 87 m / min; MD: 100 m / min; DF: 79 m / min. International level MD in this study had higher load than the national level MD of Polley et al. (2015). Therefore, it is necessary to train at this level of exercise strength as it is assumed as a game at the international level. Because these Japanese MDs use measurable running power, we can predict greater distance by time in a field. Additionally, Japanese MDs walked only sparingly, but sprinted frequently, and, generally, the players accelerated and decelerated less often. Because MDs run in a wide area compared with DF and AT, sprints and high-speed running are very important for dominating opponents during crucial plays. The study showed that during games, MDs had 28% HSD sprinting and high-speed running compared with AT, at 20%, and DF, at 24%. A previous study showed their greater contribution of running (18%) and sprinting (7%) than AT (10% and 4%, respectively) (Romas and Isles et al., 1986). In other words, both this study and the previous one revealed that MDs had significantly greater sprint distances (21.6 km/h or above) than AT and DF during matches, implying that to mimic game demands, specific sprint training should reflect number of sprints according to position. MD's less playing time (6.8 minutes / Q) than AT and DF (18 min / Q; 15 min / Q) accounted for MD's greater running intensity. In a previous study, when compared by position, MDs played less time (53%) (Romas and Isles et al., 1986). Therefore, MD players need position-specific exercise physiology characteristics (short time, high velocity).

This study produces the same results of a preceding study in that the distance and HSD reveal a difference between 1Q and 3Q. Unlike team results in Polley at al.'s study (2015), the Japanese team's physical performance did not drop for the game's 2Q and 4Q. Polley et al. (2015) showed that mileage and player load decreased every quarter. Similarly in rugby and soccer, according to GPS measurement, sprint frequency decreased in the second half of games (Russell et al., 2016). Because the Japanese played from 1Q to 3Q, the distance and HSD decreased only in the 3Q mainly and the physical condition decreased from 3Q onward. Because many reserve members participated in the 4Q, physical condition did not decrease.

During matches analyzed for this research, lacrosse players' internal load was 78.8 ± 5.2% of HR max. In a previous study of match load for NCAA soccer, players had 77–79% of HR max, a value similar to this study's. On the other hand, elite footballers had 87% of HR max (Sparks et al., 2017). For lacrosse players, both physiological intensity and relative distances (92.7 ± 24.6 m/s) were lower than for elite footballers (113m/s) (Sweeting et al., 2017). In addition, a previous study on women's rugby showed that players spent more than 90% of HR max for an average match time of 46.9% (Suarez-Arrones et al., 2014). As previously reported for male rugby union players, backs and forwards spent respectively 41.4% and 51.1% of total match time at over 90% of HR max (Cunniffe et al., 2009).

Despite the finding of Mohr et al. (2003) that higher-standard teams have characteristically higher intensity work rates, lacrosse's AT and DF may experience some low HR and movement by time because they participate much less during play, especially with DF almost standing still during offensive play. Conversely, AT almost stands still during defensive play. Furthermore, lacrosse does not depend so much on physical activity (running, sprinting), but instead focuses on moving the ball and approaching the goal. However, the exercise load may increase in the future because of rule revision from 20- to 15-minute Qs. Another rule change that will possibly increase physical intensity is a time limit on holding the ball before shooting.

In this study, the work-to-rest ratio was 1:0.64 (i.e., for every minute of work, 0.64 minutes of rest), thus clarifying a ratio in international matches. Because analysis and the method of zone-setting differed from those of other studies, they could not be compared, but that lacrosse's rest time is generally shorter than rugby's (<6km/h) became clear (Suarez-Arrones et al., 2014). Lacrosse's rest time predictably refreshes players' exercise strength. Improvement via load-setting conditions will occur with the intermittent training that is almost a competition form for lacrosse. Specifically, besides setting exercise strength, anoxic energy's contribution is known to increase because aerobic energy's contribution extends a spell adversely by shortening a spell (Tanisho et al., 2009). Cunniffe et al. (2009) showed that the work-to-rest ratio was similar to that of other rugby unions, and from this work-to-rest ratio we could suggest high-intensity anaerobic training for top lacrosse players based on a specific training principle.

This study might have a limitation worth discussing. First, measurement environments (weather, temperature, humidity, and surface) were different, and GPS data was analyzed data from 13 international games. Therefore, these data can be compared with the previous study. A second limitation could be the opponent's level of play, which could affect the score and the game's characteristics, as well as possibly revealing differences in positions and quarters of play.

Conclusion

Our study provides groundwork for future investigations in which data on physiological fitness might be utilized. Their data may help in developing new training programs. Additionally, these data can be used for fitness programs that could better prepare athletes for lacrosse's physical demands. Particularly, an intermittent method congruent with the exercise pattern during actual competitions should be used in training, so this study is useful for developing training programs for game tactics according to positional characteristics.

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Key points

- This study showed that during international test matches, players moved 3800 m at an average speed of 94 m / min; AT: 81 m / min, MD: 110 m / min, DF: 87 m / min.
- MD has low drop of physical between Q.
- Because the Japanese team participated including a bench player thoroughly at all positions, there was only more 1Q in only Distance, HSD than 3Q.

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