Paper : Game Analysis

Match Activity Characteristics in Second Division of Japanese Professional Football: Three Years of Full-Season Analyses Using Global Navigation Satellite System

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This investigation primarily aimed to quantify the movement profiles of soccer matches according to playing positions and tactical formations in the Japanese professional football league using the global navigation satellite system (GNSS). Over three years, 758 observations were obtained from 125 official matches of the second division of the Japanese professional football league. Data were integrated into tactical formations and playing positions. Match activity was assessed by the validating GNSS (OptimEye X4; Catapult Sports). Furthermore, the duration and distance of activities at different speed thresholds (>19.8, >24, and 19.8-24 km/h) were assessed. The duration and distance of activities at all speed thresholds significantly differed with respect to tactical formations and playing positions ($p<0.05$). Significant interactions between tactical formations and playing positions were identified when the total distance and distance at 19.8-24 km/h threshold were assessed ($p<0.05$). Additionally, the 3-5-2 tactical system and central defender playing position significantly differed from the other systems and positions ($p<0.05$). A shorter distance in the central defender playing position and a longer distance in the 3-5-2 tactical formation were significantly different features in match movement characteristics in the Japanese professional football league.

Keywords: global positioning system, tracking, soccer, game analysis, sprint

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1. Introduction

Recent technological advances have enabled the objective measurement of match activity (Ohashi et al., 2002). The use of video analysis systems and the global navigation satellite system (GNSS) is a conventional method for assessing match activity and can consistently obtain positioning information (Kawasaki et al., 2019; Varley et al., 2017). Evaluating the location information at a higher sampling rate can enable the accurate assessment of match activity characteristics, such as distance, speed, and acceleration (Di Salvo et al., 2007). Additionally, the number of continuous movements can be evaluated by analyzing time-course changes in location information. Thereafter, activity profiles are evaluated depending on their purposes by integrating the aforementioned law data over a specific time period, such as the entire match, first half, foxed minute, and/or training session. Hence, these systems are considered valuable for external load evaluation. Furthermore, video systems provide soccer-specific information, including how the ball was being handled (Kawasaki et al., 2019). On the other hand, the GNSS mainly comprises wearable devices on the player's back, and its main advantage is that the GNSS can consistently evaluate the external load in both matches and training sessions. Several investigations have consistently suggested that both systems can be used and that the information that they provide through the analyzed variables can be interchanged (Iseyama et al., 2015; Pons et al., 2019;

Taberner et al., 2019). This valuable information enables us to better understand specific soccer match activity characteristics.

Several investigations have already reported the match activity profiles of elite players, including those in the UEFA Champions League, European league, Premier League (England), Serie A (Italy), Bundesliga (Germany) (Andrzejewski et al., 2017; Konefal et al., 2020), La Liga (Spain) (de Souza et al., 2021), and FIFA World Cup (Tuo et al., 2019). Among 26 confederations, 449 observations were obtained from players during four seasons of the English Premier and Championships Leagues using the Prozone system (Di Salvo et al., 2013), and a total of 4,393 individual match observations from 350 soccer players in the German Bundesliga were analyzed (Andrzejewski et al., 2017). Differences in running performance among continental confederations were analyzed based on one confederation, and 508 match observations were generated from 559 players in 59 matches at the 2018 FIFA World Cup in Russia (Tuo et al., 2019). These investigations showed the variety of match movement patterns among soccer players, including the total distance covered during the entire match, the distance covered during high-intensity running, the acceleration and deceleration patterns, and the relationship of movement patterns with playing positions and tactical formations (Baptista et al., 2018; Bush et al., 2015; Rampinini et al., 2007; Tierney et al., 2016).

With respect to Japanese professional soccer, soccer tracking information has been studied since the 1970s or even earlier (Ohashi, 2020). Remarkably, the total distance covered by the Japanese team in the international match of Japan versus Korea for the Asian qualifying competition for the Mexican Olympic Games was measured using a curvimeter (Okano et al., 1976). The first conference of Medicine and Science in Soccer held in 1980 presented the results of a game analysis in which the distance covered during the entire match differed according to age categories, which ranged from children to elite players, as well as between the Japanese national team players and Argentinian players who participated in the world youth championship (Ohashi et al., 1980). The total distance covered by four elite soccer players, including two Japanese national team players, was 9,303-11,601 m during the entire match (Ohashi et al., 1988). Soccer match characteristics, which are considered to be associated with technological advances, have been objectively analyzed among Japanese players (Ohashi, 2020). Following the initiation of the Japanese professional football league, small decreases in the total distance traveled during the later stages of the match and frequent changes in speed were reported as specifications for world-class foreign players (Miyagi et al., 1999; Ohashi et al., 2002). Furthermore, the Japanese professional football league has published the distance and number of sprints for each player in the official J1 League match immediately after the match (J-League, 2021). Owing to the aforementioned environmental improvements and the spread of GNSS devices, most professional soccer teams are now able to obtain objectively evaluated match activity characteristics. However, to the best of our knowledge, no study has systematically analyzed the movement patterns of Japanese professional soccer games thus far. We hypothesized that the objectively measured tracking information significantly differed with respect to match results, ranking of the opposite team, location, playing positions and tactical formations among Japanese football players. As match activity information is interchangeable in validating procedures, the data analysis of the Japanese professional football league may provide useful evidence to compare the activities between Japanese players and those from top-performing countries.

Therefore, this study primarily aimed to quantify the distance covered during the entire matches of the Japanese professional football league by objectively measuring movement patterns and to examine the associations of these patterns with playing positions and tactical formations. This investigation focuses on the distance and duration of activities as the basic index of match movement characteristics, as it aims to demonstrate fundamental quantitative data related to the movement characteristics of Japanese professional soccer matches. While several data on the GNSS, including acceleration, sprinting, and metabolic power, have enabled researchers to develop comparative data (Ayabe et al., 2020; Baptista et al., 2018; Higashino et al., 2018; Varley et al., 2017), analysis of second variables from law data, such as location, distance, and time, can be considered as the next research issue.

2. Methods

Match activity data were collected from 125 matches of the second division of the Japanese soccer league over three seasons between 2018 and 2020. Throughout these three seasons, the actual total number of matches played was 126; however, one of these games was excluded from the analysis because it was interrupted due to bad weather and was divided across two days. According to previous investigations (Di Salvo et al., 2007; Di Salvo et al., 2013), the selected data were limited to information on outfield players who completed entire matches. A total of 816 observations were obtained, and 58 observations (7.1%) were subsequently excluded due to data errors in wearable devices. Consequently, 758 observations were included in the final analysis (**Table 1**). There were 20 players in 2018, 20 players in 2019, and 18 players in 2020. The actual number of players over the three-year period was 31; 12 players were analyzed in only one of the three seasons, 11 were analyzed in two of the three seasons, and 8 were analyzed in all three seasons. The players' physical characteristics, including their age, height, and body weight, were acquired from officially published data from the J-League (J-League, 2021). Body mass index was calculated as body weight divided by height squared. This study was conducted in accordance with the principles embodied in the Declaration of Helsinki, and all procedures were approved by the ethics committee of Okayama Prefectural University.

According to previous investigations (Di Salvo et al., 2007; Rampinini et al., 2007), the players were classified into the following seven positional roles (**Figure 1**): central defenders (CD), fullbacks (FB), wingbacks (WB), central midfielders (CM), wide midfielders (WM), attacking midfielders (AM), and forwards (FW). Tactical systems were determined by the official match report and were divided as follows: 3-6-1 (3 CD, 2 CM, 2 WB, 2 AM, 1 FW), 3-5-2 (3 CD, 2 CM, 2 WB, 1 AM, 2 FW), 4-4-2 (2 CD, 2 FB, 2 CM, 2 WM, 2 FW), and 4-5-1 (2 CD, 2 FB, 2 CM, 2 WM, 1 AM, 1 FW). The numbers of observations for each playing position and tactical formation are presented in **Table 1**. Match results were obtained from the official match report and were divided to loss, draw, or win for the analysis. Among all 125 matches, there were 46 wins, 49 losses, and 30 draws. Furthermore, observations were divided according to match location—that is, whether a team was playing at its own ground (i.e., home) or at its opponent's ground (i.e., away). According to a specific team, 62 matches were played in the "home" stadium, whereas 63 matches were played in the "away" stadium.

Table 1 Characteristics of formations and players taken from the global navigation satellite system

		Year			
		All	2018	2019	2020
Observation	Number of observations (*n*)	758	262	278	218
	Number of matches (*n*)	125	41	42	42
	Players per match (*n*)	7±2	7±1	7±1	6±1
Players	Number of players (*n*)	58	20	20	18
	Matches per player (*n*)	25±22	14±11	14±13	13±13
	Age (yr.)	29±4	29±4	29±4	29±5
	Height (cm)	177.1±6.6	177.2±6.8	177.5±6.3	176.4±6.6
	Body weight (kg)	72.0±7.0	71.6±7.2	72.6±6.7	71.6±6.9
	Body mass index (kg/m^2)	22.9±1	22.8±1	23±0.9	23±1.2
Playing Position	Central defenders (*n*)	257	106	79	72
	Fullbacks (*n*)	123	65	58	
	Wingbacks (*n*)	64	64		
	Wide midfielders (*n*)	74	39	35	
	Central Midfielders (*n*)	161	49	65	47
	Attacking midfielders (*n*)	30	30		
	Forwards (*n*)	49	13	30	6
Tactical formation	3-5-2 (*n*)	100	100	-	-
	3-6-1 (*n*)	162	162	-	-
	4-4-2 (*n*)	489	-	271	218
	4-5-1 (*n*)	7	-	7	-

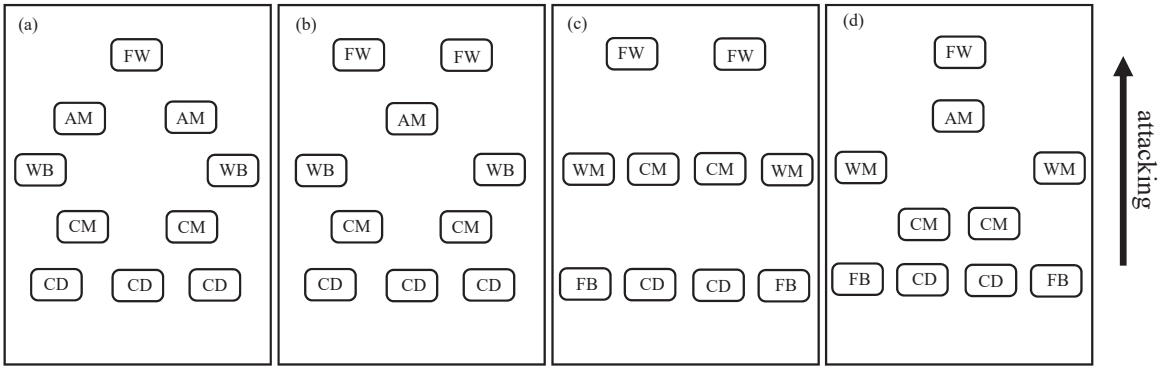

Figure 1 Tactical formations and playing positions across over three seasons
The illustrations the basic tactical formations and the playing positions for 3-6-1 (a), 3-5-2 (a), 4-4-2 (c), and 4-5-1(d).CD: Central defenders, FB: Fullbacks, WB: Wingbacks, CM: Central midfielders, WM: Wide midfielders, AM: Attacking midfielders, FW; Forwards.

Finally, the opposite team was divided according to the ranking of the final result; the opponents of 21 teams were categorized into seven teams as "high-ranking," "middle-ranking," and "low-ranking."

Match play demands were determined by a global position tracking system (Catapult OptimEye X4 system; Catapult Sports, Melbourne, Australia). All players placed this small device (96 mm × 52 mm) on the back pocket of their undershirt during the match. The data were downloaded to a portable computer after each match and were analyzed using a specific data program (Openfield, Catapult Sports, Melbourne, Australia). This device obtained location information at 10 Hz of the sampling rate. The validity of 10-Hz GNSS was reported as follows: the 10-Hz GNSS showed a sufficient level of accuracy for the quantification of distance covered at high speeds or time spent while intensively running (Johnston et al., 2014; Rampinini et al., 2015; Taberner et al., 2019) and has been used in previous investigations (Bishop et al., 2020; Slater et al., 2018). Based on changes in the location, the movement distance and speed were obtained. The total distance covered and the distance and duration at three different speed thresholds (19.8-24.0 km/h, >24.0 km/h, and >19.8 km/h) were analyzed. A speed of 19.9 km/h was defined as the speed threshold for high-intensity running (Di Salvo et al., 2007; Weston et al., 2011), whereas a speed of 24.0 km/h was considered as high-intensity sprinting (J-League, 2021; Konefal et al., 2020; Pons et al., 2019; Taberner et al., 2019).

Data are expressed as mean and standard deviations. Significant differences in the duration and distance according to season year, match results, opposite team, formations, and positions were analyzed using a one-way analysis of variance (ANOVA). As differences within groups were statistically significant, Scheffe's multiple comparison was used to compare each variable. To analyze the interactive effects of playing formations and tactical systems on the tracking information, significant interactions of formations and positions with duration and distance were analyzed using a two-way ANOVA. When the main effects and/or interactions were significant, Scheffe's multiple comparison was used to analyze the differences between formations and positions. A p-value <0.05 was considered statistically significant, and all statistical analyses were performed using SPSS version 26.0 (IBM Corp., NY, USA).

3. Results

Table 2 shows the differences in total distance, distance, and duration at thresholds of 19.8-24 km/h, >24 km/h, and >19.8 km/h according to season year, match results, opposite team, location, tactical formations, and playing positions. Across 758 observations obtained from 125 matches, the median distance covered during each match was 9,871±803 m/match and was significantly different by season year, tactical formations, and playing positions ($p<0.05$). The total distance was significantly shorter in 2020 than in 2018 and 2019 ($p<0.001$). Furthermore, the distance and duration at thresholds of 19.8-24 km/h, >24 km/h, and >19.8 km/h were also significantly different with respect to tactical formations and playing positions ($p<0.05$). However, the season year, match results, ranking of the opposite team, and location (home/away) did not have any

Table 2 Difference in activity profile by year, match result, opposite team, stadium, tactical formations, and playing positions in professional Japanese soccer matches

	Mean (SD)	P value (F value/t value)					
		Season Year (18/ 19/ 20)	Match results (Win/ Draw/Lose)	Opposite*	Location (Home/Away)	Formations**	Position***
Total distance covered (m)	9871 (803)	**p = 0.001** (F = 7.335)	p = 0.314 (F = 1.162)	p = 0.473 (F = 0.749)	p = 0.584 (t = 0.548)	**p = 0 .036** (F = 2.863)	**p < 0.001** (F = 73.408)
Distance at >19.8 km/h (m)	565 (228)	p = 0.135 (F = 2.006)	p = 0.632 (F = 459)	p = 0.602 (F = 0.597)	p = 0.499 (t = 0.676)	**p < 0.001** (F = 6.350)	**p < 0.001** (F = 102.004)
Distance at >24 km/h (m)	145 (95)	p = 0.716 (F = 0.334)	p = 0.495 (F = 0.705)	p = 0.642 (F = 0.443)	p = 0.401 (F = 0.840)	**p = 0.013** (F = 3.598)	**p < 0.001** (F = 72.921)
Distance at 19.8-24 km/h (m)	420 (157)	p = 0.056 (F = 2.885)	p = 0.770 (F = 261)	p = 0.547 (F = 604)	p = 0.817 (F = 0.231	**p < 0.001** (F = 6.340)	**p < 0.001** (F = 92.983)
Duration at >19.8 km/h (sec)	91 (36)	p = 0.232 (F = 1.464)	p = 0.513 (F = 0.667)	p = 0.515 (F = 665)	p = 0.518 (t = 0.646)	**p < 0.001** (F = 6.620)	**p < 0.001** (F = 99.374)
Duration at >24 km/h (sec)	20 (13)	p = 0.775 (F = 0.255)	p = 0.768 (F = 0.264)	p = 0.498 (F = 0.698)	p = 0.920 (t = 0.100)	**p = 0.010** (F = 3.811)	**p < 0.001** (F = 71.147)
Duration at 19.8-24 km/h (sec)	71 (27)	p = 0.075 (F = 2.603)	p = 0.619 (F = 481)	p = 0.514 (F = 0.666)	p = 0.407 (t = 0.830)	**p < 0.001** (F = 6.729)	**p < 0.001** (F = 90.572)

Bold indicates statistical significance. *The opposite team was classified into one of three groups (upper, middle, or lower) based on its ranking in the J2 league at the end of each year. **Comparison of three tactical formations, including 3-5-2, 3-6-1, and 4-4-2, as the data from the 4-5-1 formation were excluded from the analysis because of the small sample size. ***The position was classified into one of seven positions, comprising central defenders, fullbacks, wingbacks, central midfielders, wide midfielders, attacking midfielders, or forwards.

significant effects on distance or duration.

Figure 2 shows the total distance covered during the entire match according to tactical formations and playing positions. The two-way ANOVA reveled significant interactions of tactical formations and playing positions with the total distance covered during the entire match ($p<0.001$). Irrespective of playing formations, CD covered significantly shorter distances than FB, WB, CM, and AM ($p<0.05$). Furthermore, significant differences in tactical formations within the same playing position were observed in CD; the CD in the 4-4-2 formation covered significantly shorter distances than the CD in the remaining two formations ($p<0.05$). After including all tactical formations, the total distance covered during each match significantly differed in terms of playing positions (CD < FW < FB, WM, CM, and AM; $p<0.05$). After including all playing positions, the total distance covered during each match significantly differed in terms of tactical formations (4-4-2 and 3-6-1 < 3-5-2; $p<0.05$).

Figure 3 shows the distance covered during the entire match at thresholds of 19.8-24.0 km/h, >24.0 km/h, and >19.8 km/h. The two-way ANOVA revealed significant interactions of tactical formations and playing positions with the distance covered during the entire match at a threshold of 19.8-24.0 km/h ($p=0.013$). This analysis also showed that there were no significant differences between the distance covered at speeds of >24.0 km/h and >19.8 km/h. There were significant main effects associated with playing formations at all speed thresholds ($p<0.001$). Furthermore, the significant effects associated with tactical formations were limited to the distance covered at thresholds of 19.8-24.0 km/h and >19.8 km/h ($p<0.001$). Irrespective of playing formations, CD covered significantly shorter distances than FB, WB, CM, and AM ($p<0.05$). Furthermore, significant differences in tactical formations within the same playing position were observed in CD; the CD in the 4-4-2 formation covered significantly shorter distances than the CD in the remaining two formations ($p<0.05$). After including all tactical formations, the total distance covered during each match significantly differed with respect to playing positions (CD < FW < FB, WM, CM, and AM; $p<0.05$). After including all playing positions, the total distance covered during each match significantly differed with respect to tactical formations (3-6-1 < 4-4-2 and 3-6-1; $p<0.05$).

Figure 4 shows the duration covered during the entire match at thresholds of 19.8-24.0 km/h, >24.0 km/h, and >19.8 km/h. The two-way ANOVA revealed significant interactions of tactical formations

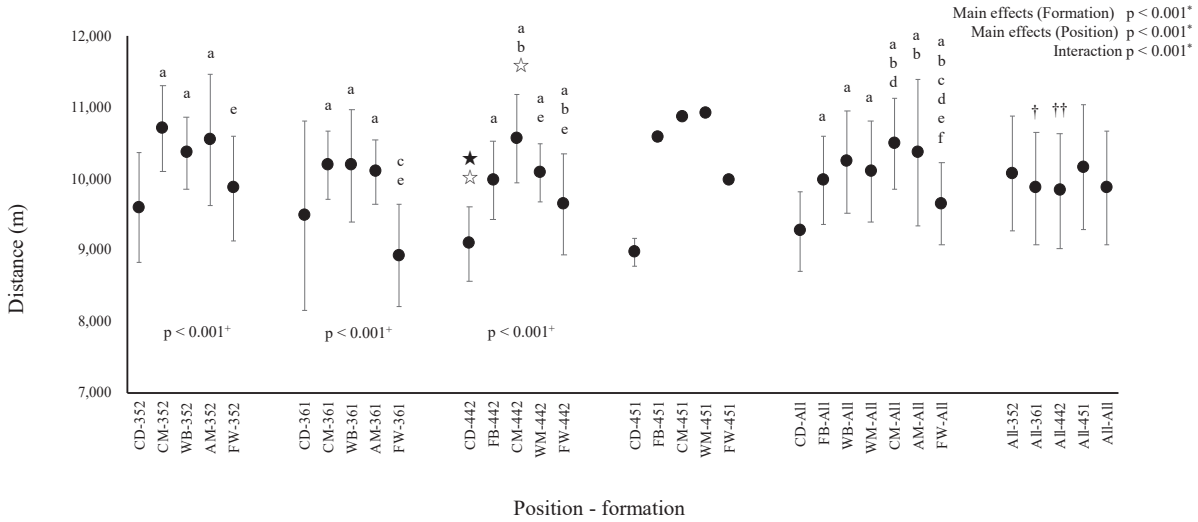

Figure 2 Comparison of total distance covered during entire match among tactical formations and playing positions

The X-axis shows the tactical formations and the playing positions, 352, 3-5-2 (100 observation in 2018); 361, 3-6-1 (162 observation in 2018); 442, 4-4-2 (271 observation in 2019 and 218 observations in 2020); 451, 4-5-1 (7observation in 2019), All; Averaged over all formations, CD; Central defenders, FB; Fullbacks, WB; wingbacks,CM; Central Midfielders, WM; Wide midfielders, AM; Attacking midfielders, FW; Forwards, All; Averaged over all positions. *P value show the results of the 2 way – ANOVA by the formation and the position, the data from 4-5-1 formation was excluded from the analysis due to the small sample size, +P value show the results of the one way – ANOVA by the formation. $^{\dagger, \dagger\dagger}$ Significantly different compared with "3-5-2" ($^{\dagger}p < 0.05$, $^{\dagger\dagger}p < 0.01$), $_{a\text{-}f}$ Significantly different compared within same formation compared with $_{a}$ CD, $_{b}$ FB, $_{c}$ WB, $_{d}$ WM, $_{e}$ CM, $_{f}$ AM, ($p < 0.05$). ★☆ Significantly different compared within same position compared with ★ 3-5-2 and ☆ 3-6-1 ($p < 0.05$).

and playing positions with the distance covered during the entire match at the threshold of 19.8-24.0 km/h (p=0.011). The analysis also showed that there were no significant differences in the distance covered at thresholds of >24.0 km/h and >19.8 km/h. There were significant main effects associated with playing formations at all three thresholds (p<0.001). Furthermore, the significant effects associated with tactical formations were limited to the distance covered at thresholds of 19.8-24.0 km/h and >19.8 km/h (p<0.001). Significant differences in the duration of high-intensity running were similar to those of the entire match. Particularly, position-specific differences were obtained in CD over three tactical formations regardless of speed thresholds (p<0.05). The average running duration at all playing positions at thresholds of 19.8 km/h and >19.8 km/h significantly differed among the three tactical formations (4-4-2 and 3-6-1 < 3-5-2, p<0.05).

4. Discussion

This investigation showed the objectively measured match activity characteristics of soccer matches among Japanese professional soccer players using the GNSS. Match movement patterns, including the distance covered during the entire match, duration of the match, and high-intensity running were analyzed in 758 observations from 125 matches over three calendar seasons. Consequently, this investigation found significant effects of playing formations and tactical systems on the distance covered during the entire match and its duration. Nevertheless, this investigation was unable to find significant effects of season year, match results, ranking of the opposite team, and location on the distance and duration at all three thresholds, whereas the total distance covered significantly differed over three seasons. Because of coronavirus disease 2019 (COVID-19), the 2020 season of the J2 League was different from the past two years. Previous investigations demonstrated that the total distance covered, high-intensity distance, sprint distance, and number of sprints were not significantly affected by the number of matches per week, that is, one versus two (Dupont et al., 2010). However, recent meta-analyses have found that the effect of fixture congestion on the total distance covered during the entire match was insignificant (Julian et al., 2021). Therefore, these

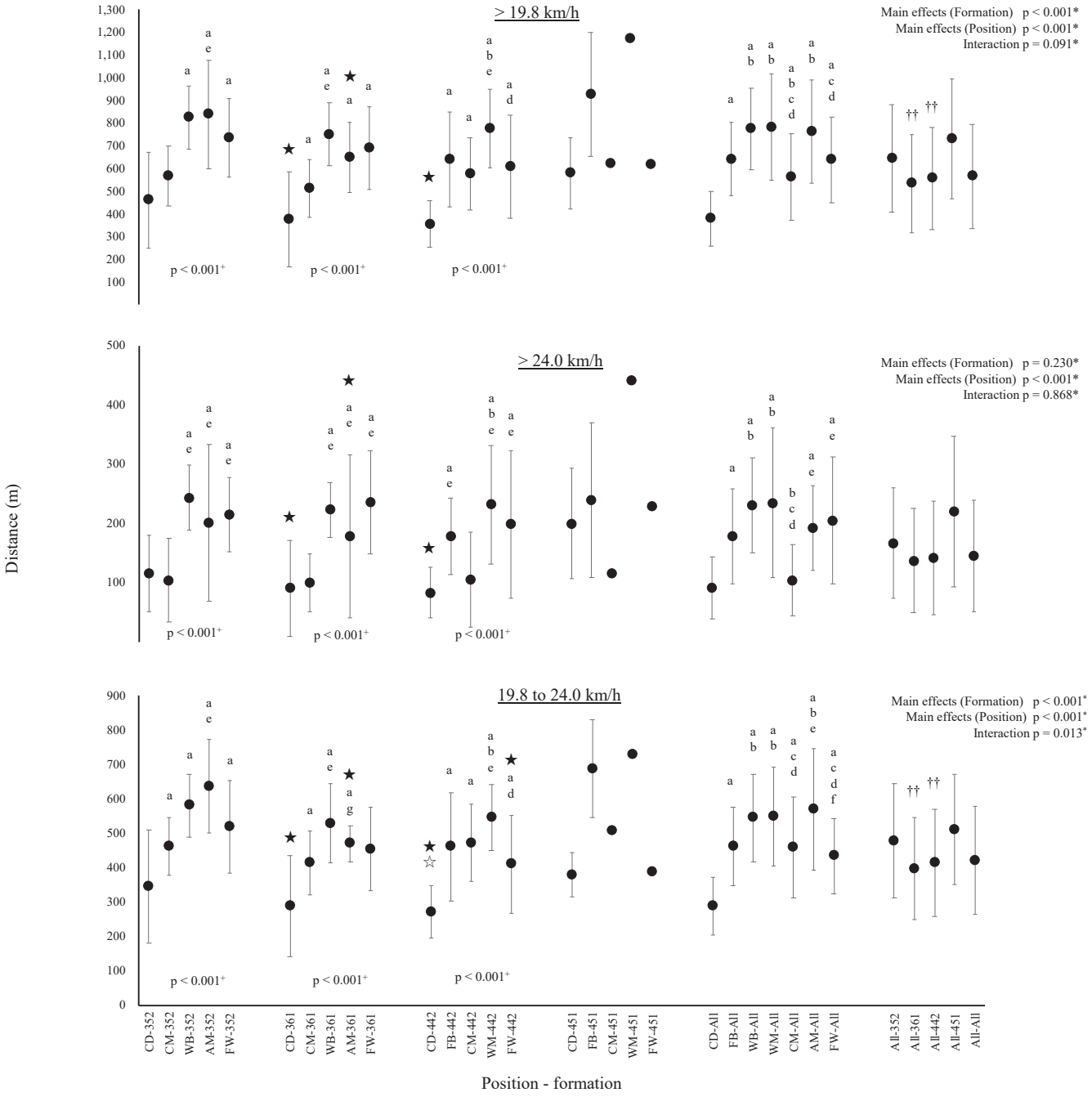

Figure 3 Comparison of distance covered by high intensity run during entire match among tactical formations and playing positions

The X-axis shows the tactical formations and the playing positions, 352, 3-5-2 (100 observation in 2018); 361, 3-6-1 (162 observation in 2018); 442, 4-4-2 (271 observation in 2019 and 218 observations in 2020); 451, 4-5-1 (7 observation in 2019) , All; Averaged over all formations, CD; Central defenders, FB; Fullbacks, WB; wingbacks, CM; Central Midfielders, WM; Wide midfielders, AM; Attacking midfielders, FW; Forwards, All; Averaged over all positions. *P value show the results of the 2 way – ANOVA by the formation and the position, the data from 4-5-1 formation was excluded from the analysis due to the small sample size, +P value show the results of the one way – ANOVA by the formation. †, †† Significantly different compared with "3-5-2" († $p < 0.05$, †† $p < 0.01$) , a-f Significantly different compared within same formation compared with a CD, b FB, c WB, d WM, e CM, f AM, ($p < 0.05$) . ★☆ Significantly different compared within same position compared with ★ 3-5-2 and ☆ 3-6-1 ($p < 0.05$) .

seasonal differences in the total distance were caused by the playing positions and tactical formations rather than COVID-19-associated fixture congestion. Subsequently, the results of the two-way ANOVA showed significant interactions of playing positions and tactical formations with activity characteristics. The results suggested that, regarding the total value added to outfield players, the 3-5-2 tactical system

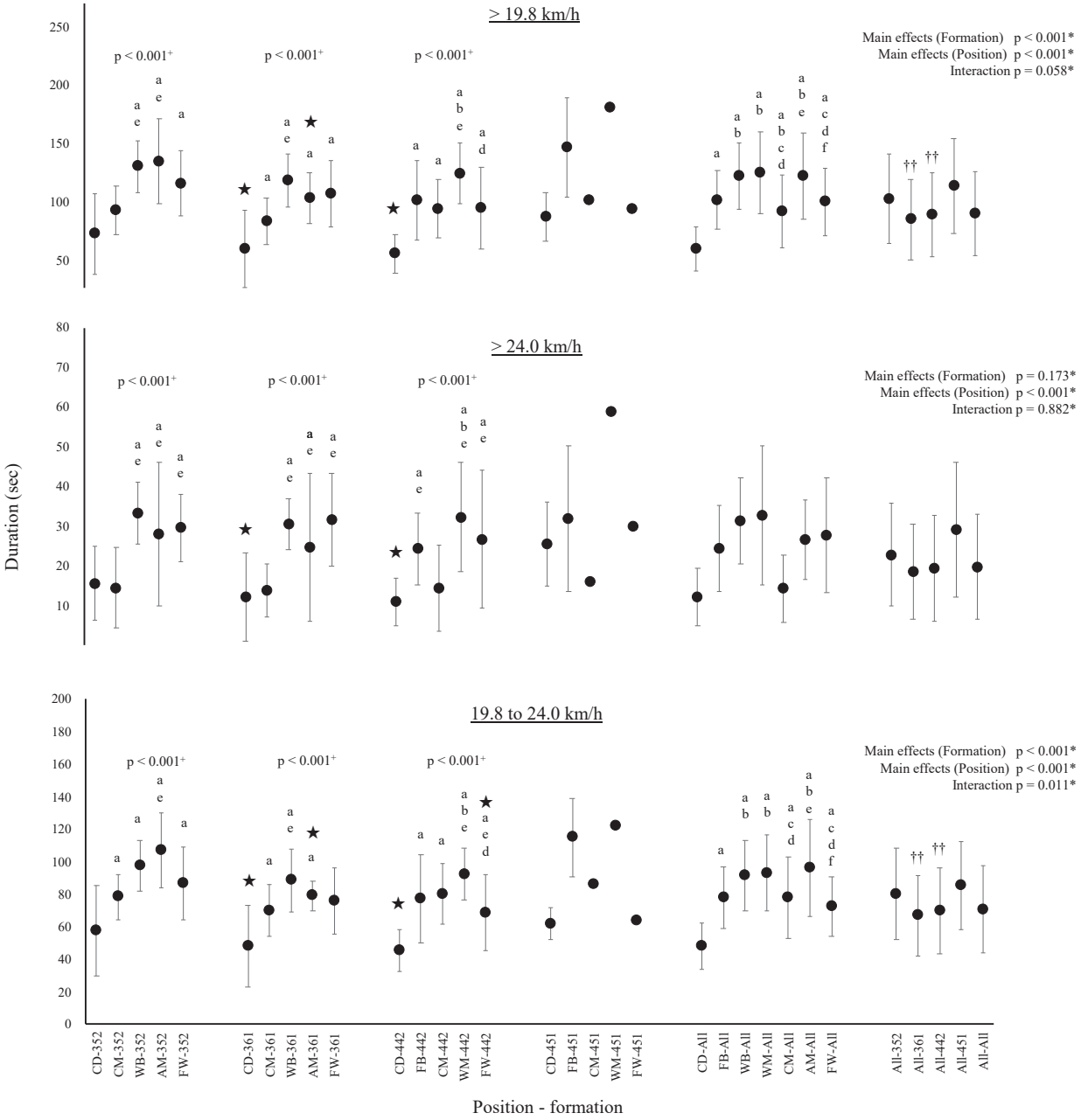

Figure 4 Comparison of duration for high intensity run during entire match among tactical formations and playing positions

The X-axis shows the tactical formations and the playing positions, 352, 3-5-2 (100 observation in 2018); 361, 3-6-1 (162 observation in 2018); 442, 4-4-2 (271 observation in 2019 and 218 observations in 2020); 451, 4-5-1 (7 observation in 2019), All; Averaged over all formations, CD; Central defenders, FB; Fullbacks, WB; wingbacks, CM; Central Midfielders, WM; Wide midfielders, AM; Attacking midfielders, FW; Forwards, All; Averaged over all positions. *P value show the results of the 2 way – ANOVA by the formation and the position, the data from 4-5-1 formation was excluded from the analysis due to the small sample size, +P value show the results of the one way – ANOVA by the formation. †, †† Significantly different compared with "3-5-2" († $p < 0.05$, †† $p < 0.01$) , $_{a\text{-}f}$ Significantly different compared within same formation compared with $_a$ CD, $_b$ FB, $_c$ WB, $_d$ WM, $_e$ CM, $_f$ AM, ($p < 0.05$). ★☆ Significantly different compared within same position compared with ★ 3-5-2 and ☆ 3-6-1 ($p < 0.05$) .

may demand larger amounts of running than those in the 4-4-2 and 3-6-1 systems. Additionally, it may be apparent that the CD covered a shorter distance and duration than those in other playing positions during the soccer match regardless of tactical formations. These results were supported by previous findings, and a shorter distance in CD and a longer distance in the 3-5-2 system have already been reported (Baptista et al., 2018; Rampinini et al., 2007; Tierney et al., 2016). The investigation of elite European players

showed that the total distance, high-intensity running distance, and very-high-intensity running distance were significantly shorter in CD than in other playing positions (Rampinini et al., 2007). Similar results were obtained in elite Norwegian soccer players; elite Norwegian CD and CM had significantly lower work rates in sprints, decelerations, and accelerations than FB, WM, and central FW (Baptista et al., 2018). Moreover, a 3-5-2 formation was reported to elicit a higher total distance, running speed, and high metabolic load distance than all other formations, including the 4-4-2, 4-3-3, 3-4-3, and 4-2-3-1 formations in elite English male footballers (Tierney et al., 2016). Thus, it is highly suspected that a shorter distance in CD and a longer distance in the 3-5-2 formation can be considered as features of significant differences in match movement characteristics in the Japanese professional football league.

An original aspect of this investigation is that we quantified the variability of match movement characteristics in the Japanese professional football league based on objectively measured parameters in a comparative sample size. As previously mentioned, regarding elite Japanese football players and/or the Japanese professional football league, the match movement characteristics of one very talented player in the Japanese national team have been reportedly analyzed; furthermore, currently the movement distance and number of sprint runs can be obtained immediately after any match in the J1 League (J-League, 2021; Miyagi et al., 1999; Ohashi, 2020; Ohashi et al., 2002; Ohashi et al., 1980; Ohashi et al., 1988; Okano et al., 1976). The strengths of this investigation were as follows. First, the match movement characteristics were objectively measured using a reliable 10-Hz GNSS device. The GNSS system is one of the most useful and validating assessments of movement characteristics in soccer matches (Rampinini et al., 2015; Varley et al., 2017) and provides data that are interchangeable with those obtained through video analysis systems (Buchheit et al., 2014; Pons et al., 2019; Taberner et al., 2019). Second, the data sample size, which included 758 observations from 125 official matches over three calendar seasons, provides additional strength to the generalizability of the study findings to football fields. To the best of our knowledge, this study is the first to include foreign elite/semi-elite players as well as elite Japanese professional football players in the analysis of match movement patterns using the GNSS. Furthermore, the present investigation is the first to analyze patterns using all official league matches throughout the season. The 758 observations from 125 matches in this investigation are possibly comparable to those of previous GNSS-based investigations of the European national league (Baptista et al., 2018; Hoppe et al., 2017; Martín-García et al., 2018). We accordingly believe that this investigation provides novel evidence on quantitative match movement characteristics of Japanese professional soccer players.

Remarkably, the speed threshold was inconsistently associated with differences in playing positions and tactical formations. This investigation revealed that the distance covered during an entire match was significantly more associated with a low threshold (<24.0 km/h) than with a high threshold (>19.8 km/h or 24.0 km/h). This result is unexpected as previous investigations have shown significant differences in the distance covered between high- and low-speed running (Baptista et al., 2018; Rampinini et al., 2007; Tierney et al., 2016). Furthermore, there was no consensus on the number of sprints associated with speed thresholds and interruption treatments (Varley et al., 2017). Although the Japanese professional football league defined the sprint as the movement at the speed completely maintained at 24.0 km/h or faster for 1 second or longer (J-League, 2021), the speed threshold was ranged from 20.0 to 25.0 km/h, the time interval is also inconsistent from 0.5 to 1 second, furthermore, some investigation allowing the slower movement less than speed threshold some investigation allowing the slower movement less than speed threshold (Bush et al., 2015; Di Salvo et al., 2010; Di Salvo et al., 2013; Rampinini et al., 2007; Weston et al., 2011). Thus, there is no consensus on the appropriate speed threshold to obtain movement patterns associated with playing positions and tactical formations. Furthermore, researchers should focus on the interchangeability based on movement index definition. Nevertheless, this investigation is insufficient to understand the match activity of Japanese professional football players because European studies have analyzed a huge number of observations by integrating teams and seasons based on video analysis systems, such as the 972 observations among seven confederations in the German Bundesliga (Konefal et al., 2020), the 26,449 observations in the English Premier and Championships Leagues (Di Salvo et al., 2013), and

the 14,700 observations in the English Premier League (Bush et al., 2015). As the Japanese professional football league published the performance of matches in the J1 League, at least 3,000 observations (5 outfield players playing for more than 90 min/match, 18 teams, and 34 matches/year) can be included in the dataset.

This study has several limitations. First, as the present investigation analyzed only one second division team, the results of this investigation do not represent the top level of Japanese professional football players. Second, this study was observational. Similar to numerous previous investigations, the tracking data during the official soccer match was not reliable. Not only the opponent team but also environmental factors and the players' physiological conditions could not be controlled for research purposes in actual official soccer matches that include professional players. These two limitations are potentially inevitable in observational investigations of elite athletes. Therefore, future studies are expected to analyze the next elite players by summarizing various confounders. Based on the findings of this study, the details of the match activity profiles of professional Japanese soccer players may aid us in progressively understanding the movement patterns of players. Finally, as previously mentioned when discussing the objective of this research, the GNSS provides us with not only the distance and duration of movements but also several secondly calculated variables, including bout duration, acceleration, deceleration, metabolic power, heart rate, and different sensor outputs. Additionally, all information can be analyzed not only during the entire match but also at specific time intervals. Therefore, the analysis of soccer match activity based on positioning information, irrespective of video analysis or GNSS, has several undeveloped research issues, particularly in Japanese professional football.

In summary, this investigation showed the objectively measured match activity characteristics of Japanese professional soccer players using the GNSS in 758 observations from 125 matches over three calendar seasons. The present investigation consequently revealed the significant effects of playing formations and tactical systems on the distance and duration of movements. The shorter distance in the CD playing position and the longer distance in the 3-5-2 tactical formation may be considered as features of significant differences in match movement characteristics in the Japanese professional football league. To understand the specificity of Japanese soccer players, multiple confounders such as team category, match information, and physiological conditions of players should be analyzed. Significant findings can be obtained by extensively analyzing location information using not only the GNSS but also video analysis.

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