Sprinting Analysis of Japanese Female Soccer Players during Competitive Matches Using Video Analysis Software

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The aim of this study was to analyze the sprinting characteristics of female soccer players during matches using the global positioning system (GPS) device method combined with video analysis software. Eighteen Japanese collegiate female soccer players (age: 20.3 ± 1.3 years; height: 161.1 ± 5.7 cm; body mass: 55.6 ± 6.2 kg) were equipped with GPS (10 Hz), and sprinting (> 21 km/h) data during eight official matches was analyzed. Using video cameras, all games were filmed to record the situations when players were sprinting. The videos linked GPS data with the dedicated analysis software, and the data was extracted from the videos. We analyzed 790 samples of sprinting according to ball possession, play situation, and running direction for each playing position. The total number of sprints per match was 98.8 ± 11.2. The total number of sprints per match for each position was 26.7 ± 4.7 for forward, 30.4 ± 6.2 for side midfielder, 10.1 ± 3.9 for central midfielder, 18.6 ± 6.2 for side back, and 12.9 ± 2.1 for center back. The results of the chi-square test showed that the sprinting demonstrated during the game at each position depended on the situation. Our findings suggested that the characteristics of sprinting of Japanese collegiate female soccer players during a match differed depending on the situation and position the players faced.

Keywords: sprint, GPS, video analysis

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1. Introduction

Recent technological developments have significantly contributed to various aspects of sports coaching, such as planning training strategies and monitoring loading management. Global positioning system (GPS) devices are now widely used to understand the physical demands of soccer matches (Krustrup et al., 2005). GPS devices can measure total distance, distances traveled within velocity bands, movement speed, trajectory, and sprinting of all players at once during training and matches. However, it is difficult to analyze the situations wherein quantified movements are performed in matches, because it takes a lot of time and effort. To conduct a qualitative analysis, a separate video-based analysis is required, which also takes a significant amount of time and effort. Activity profile (Mohr et al., 2008; Suarez-Arrones et al., 2015; Varley et al., 2012) and time-motion analysis (Castellano et al., 2011a) are the major research tools using GPS devices as they can measure a large number of players simultaneously and analyze them in a short time. However, only a few studies have analyzed activities measured by GPS devices during matches (Ade, Fitzpatrick, and Bradley, 2016). Ade et al. (2016) analyzed the distance traveled in and without ball possession and the relationship between technical and tactical factors and high-intensity movements (> 21 km/h) using a computerized tracking system and video cameras positioned at the roof level of the stadium. However, issues with versatility exist because this method is limited in terms of mobility, installation cost, and partial manual correction (Faude et al., 2012). Therefore, linking video-based and GPS-based analysis while taking advantage of the GPS device method is a problem that needs to be solved quickly. By using analysis software, we can link GPS

data with video data in a short period of time, so we can analyze when, where, and in what situations the data were measured during a match.

Sprinting is the fastest category (> 21 km/h) (Ade et al., 2016; Passos et al., 2019) of high-intensity running (> 15 km/h) (Krustrup et al., 2005), although the definition of speed in soccer varies by gender and competition level. Sprinting is characterized as one of the most important factors in the outcome of a match (Andersson et al., 2010; Carling et al., 2008; Di Salvo et al., 2010). In a study of English Premier League players, the number and distance of the sprints performed during a match were higher for the players of higher-ranked teams in the league than for players of lower-ranked teams (Di Salvo et al., 2009). In previous study of female soccer, there were some comparisons of the distance and number of sprints during a match between competition levels and positions (Andersson et al., 2010; Vescovi, J. D. 2012). However, no studies have quantified sprinting during matches to analyze when, where, and how sprinting occurred in female soccer players.

This study aims to analyze the sprinting characteristics of female soccer players during matches using a GPS device method combined with video analysis software. This study analyzed in detail when, where, and how running is performed, which provides more useful information for training and tactical planning in the coaching field. In this respect, the findings of this study can contribute to developing women's soccer in Japan by assisting in planning training strategies.

2. Materials and Methods

2.1 Experimental approach to the problem

A cross-sectional analysis of the 33rd Kanto University Women Football League 2nd Division collegiate soccer team was conducted using the dedicated analysis software. Players were divided into five playing positions.

2.2 Subjects and match data

Eighteen collegiate female soccer players (age: 20.3 ± 1.3 years; height: 161.1 ± 5.7 cm; body mass: 55.6 ± 6.2 kg) from the same college league team participated in this study. Each outfield player was assigned to one of five positional groups (Datson et al., 2017) : forward (FW), side midfielder (SMF), central midfielder (CMF), side back (SB), or center back (CB). The same formation of 4-4-1-1, a variation of 4-4-2 with 1 of the strikers playing as a "second striker" was used and defined by the same coach in all matches, with the front line two players as FW. Changes of formation during the match were considered at the start of the match and substitutions, but not during in play system changes. Goalkeepers were excluded from this study. Prior to conducting the study, we obtained approval from the ethics committee of Faculty of Health and Sports Science in Juntendo University (Approved number: 30-120), and informed consent was obtained from the study subjects. Eight matches (weather: sunny or cloudy; temperature: 22.9 ± 4.5 ℃; humidity: 62.7 ±15.1 %) of the 33rd Kanto University Women Football League 2nd Division held from August 24 to November 10, 2019 were examined. The match times were a total of 90 minutes with 45-minute halves and a 15-minute interval between the halves.

2.3 Sprinting measurement and analysis

Sprint performance data were collected using portable GPS devices (OptimEye S5 and G5, Catapult Sports, Australia) operating at a sampling frequency of 10 Hz. This GPS system uses signals from the Global Navigation Satellite System to determine a player's position at a given time, allowing the calculation of movement speeds and distance traveled. Using this information, a receiver can calculate and record data on position, time, and velocity. The GPS device has been validated in terms of high levels of reliability and low levels of measurement error (Castellano et al., 2011b; Hoppe et al., 2018; Varley et al., 2012).

The players wore special harnesses that enabled these devices to be fitted to their upper backs. To extract and analyze the data of only those players who competed in the match, the match start time, the first half end time, the second half start time, and the full time were recorded based on the ratio clock. Moreover, the time of a player exiting and coming on as a substitute was regarded as her time of leaving and entering the soccer field, respectively. After recording, the data were uploaded into a PC and analyzed using the software package (Openfield version 2.2.0, Catapult Sports, Australia).

The velocity categories were defined based on a previous study of female soccer players (Passos et al., 2019): distance covered in walking (0 - 5.99 km/h), in jogging (6.00 - 11.99 km/h), in running (12.00 - 14.99 km/h), in high intensity (15.00 - 17.99 km/h), in very high intensity (18.00 - 20.99 km/h), and in sprints (> 21 km/h) (Casamichana et al., 2012; FIFA. 2011; Suarez-Arrones et al., 2015). Sprinting is defined as running at a speed of 21 km/h for at least one second after the running speed exceeds 21 km/h and just before the speed drops below 21 km/h (Suarez-Arrones et al., 2015). In this study, sprinting was the measurement item.

2.4 Filming of the match

The matches were filmed using a video camera (HDR - CX480, SONY, Japan. Resolution 1270 × 720 pixels). As capturing the entire field with a single video camera was difficult, two fixed cameras were used, and all players constantly wore the devices in the cameras.

2.5 Data analysis using video

Specialized analysis software was used to assess filmed matches and sprinting data extracted by the GPS-specific software package (Catapult Vision version 2.1.1, Catapult Sports, Australia). Both types of data were automatically integrated by matching the measurement start time to the match start time, and 790 samples of video data per sprint were extracted. Two of the samples were excluded from the analysis items described below because of the difficulty of video analysis, and 788 samples were included in the analysis. Based on the data, the following analysis was conducted: a) distribution of all sprints by distance, b) sprints completed with the respective players' team in possession and without possession of the ball, c) sprints by five categories, and d) sprints by eight directions.

a) distribution of all sprints by distance

The number of sprints by distance was analyzed with the reference (Di Salvo et al., 2010). The distance interval in this study was defined as 3m.

b) Sprints completed with the respective players' teams in possession and without possession of the ball

Di Salvo et al. (2009) analyzed total high-intensity running based on the players' team in possession and without possession of the ball. Referring to the analytical method of Di Salvo et al. (2009), we segregated the data by whether the subject's team was in possession of the ball when the sprint was performed. "Possession" is defined as a sprint when the subject's team is in possession of the ball, and "Without Possession" is a sprint when the opposing team is in possession. When the ball was moving when the sprint was measured, the sprint was judged "Possession" or "Without Possession" by whichever team's player kicked the ball.

c) Sprints by five categories

Based on the classification of Ade and Bradley (2016), we placed the situations when the players performed a sprint into categories ① to ⑤ .

① A sprint was performed by a player when she received a pass from the ball carrier of her team or attempted to engage in an attack (Start moving: SM). ② A sprint was performed when a player approached to put pressure on the opposing team's ball carrier (Approach: App). ③ A sprint was performed while chasing the ball in defense (Chasing the ball in defense: CH – DF). ④ A sprint was performed to return to her side of the field (Behind the ball: Be). ⑤ A sprint was performed during the shifting sideways motion (Slide: S).

d) Sprints by eight directions

Referring to Bloomfield et al. (2007), we categorized the directions of the players' sprints as shown in **Figure 1**. The attack direction set to forward (Forward: F), diagonally right forwards (Diagonally Right Forward: DRF), right (Right: R), diagonally right backward (Diagonally Right Backward: DRB), backward (Backward: B), or diagonally left backward (Diagonally Left Backward: DLB), Left (Left: L), and diagonally left forward (Diagonally Left Forward: DLF) were classified into eight directions. The eight directions were independently analyzed by the author based on the information in the video such as the lines of the soccer court. In the analysis of b) - d), Di Salvo et al. (2007) was used as a reference for the comparison of positions - FW, SMF, CMF, SB, and CB.

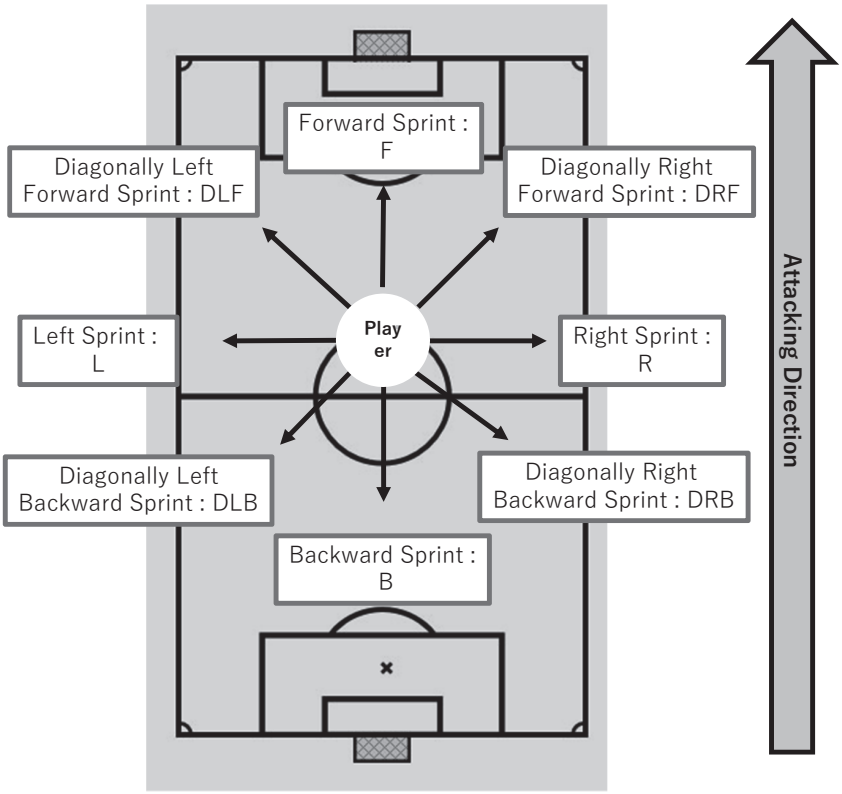

Figure 1 Definition of sprint direction

2.6 Statics analysis

Descriptive data were reported as means ± SD for each variable. To compare the number of sprints for each position, a chi-square test was conducted for each of the above analysis items. When chi-square values were significant, residual analysis was conducted. The significance was set at less than 1% or 5%. All statics processing was conducted with statistical analysis software (SPSS Statics version 22, SPSS Inc., Chicago, IL, USA).

3. Results

3.1 Distribution of all sprints by distance

A total of 790 sprints (including 2 missing sprints) were performed by 18 subjects in 8 games. The total number of sprints was 214 for FW, 243 for SMF, 81 for CMF, 149 for SB, and 103 for CB. The distribution of sprints by distance is shown in **Figure 2**. In this study, we used a Microsoft Excel 2016 histogram, which automatically generated 3 m as the distance interval. There was no sprint of 0 - 5m. The total number of sprints per match was 98.8 ± 11.2, which included 26.7 ± 4.7 (FW), 30.4 ± 6.2 (SMF), 10.1 ± 3.9 (CMF), 18.6 ± 6.2 (SB), and 12.9 ± 2.1 (CB).

3.2 Sprints completed with the respective player's team in possession and without possession of the ball

The total numbers of sprints in possession and without possession were 367 and 421, respectively. The number of sprints per match in possession and without possession is shown in **Table 1**. A chi-square test showed an association between position and ball possession ($\chi 2 = 148.6$, $p < 0.01$), and residual analysis showed that FW and SMF were more likely to be in possession than without possession. In the case of SB and CB, the players sprinted more often without possession ($p < 0.01$).

3.3 Sprints by five categories

The total number of sprints by five categories was 390 for SM, 212 for App, 65 for CH - DF, 105 for Be, and 16 for S. The number of sprints per match by five categories is shown in **Table 2**. The results showed an association between position and play situation ($\chi 2$

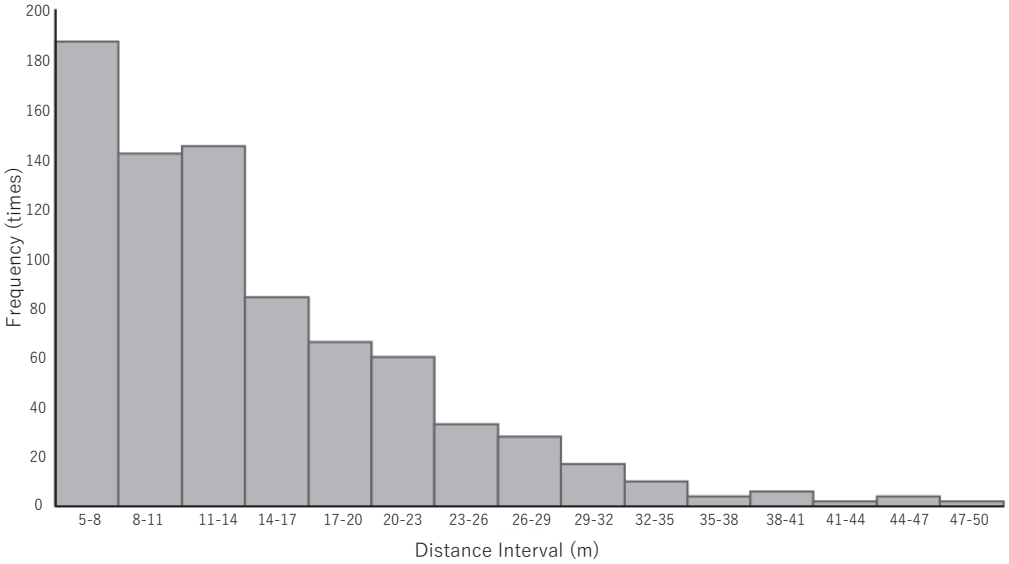

Figure 2 Number of sprints per distance segment (3 m) in eight matches

Table 1 The average number of sprints with ball possession and without possession in each position per match (Mean ± SD)

	FW	SMF	CMF	SB	CB	Total
Possession	17.8 ± 4.2^{++}	18.0 ± 6.4^{++}	3.8 ± 2.3	6.3 ± 4.1^{--}	0.1 ± 0.3^{--}	45.9 ± 12.6
Without Possession	9.0 ± 3.0^{--}	12.4 ± 4.8^{--}	6.4 ± 3.2	12.4 ± 4.2^{++}	12.8 ± 1.9^{++}	52.9 ± 9.0
Average	26.8 ± 4.7	30.4 ± 6.2	10.1 ± 3.9	18.6 ± 6.2	12.9 ± 2.1	98.8 ± 11.2

FW: Forward, SMF: Side Midfielder, CMF: Central Midfielder, SB: Side Back, CB: Center Back
$^{++}$: significantly higher value ($p < 0.01$), $^{+}$: significantly higher value ($p < 0.05$),
$--$: significantly less value ($p < 0.01$), $-$: significantly less value ($p < 0.05$)

Table 2 The average number of sprints by situations in each position per match (Mean ± SD)

	FW	SMF	CMF	SB	CB	Total
Start moving	19.4 ± 4.5^{++}	18.6 ± 6.5^{++}	4.3 ± 2.3	5.9 ± 4.2^{--}	0.1 ± 0.3^{--}	45.5 ± 12.4
Approach	6.5 ± 1.7^{--}	8.1 ± 4.5^{--}	2.6 ± 2.2^{-}	5.6 ± 2.6^{+}	3.6 ± 1.8^{++}	48.6 ± 12.0
Chasing the ball in defense	0.6 ± 0.7	0.9 ± 0.8	0.3 ± 0.4	2.4 ± 1.2	4.0 ± 1.1	8.1 ± 2.0
Behind	0.1 ± 0.3^{--}	2.4 ± 1.0^{--}	2.5 ± 1.2^{++}	3.3 ± 2.3	4.9 ± 1.5^{++}	13.0 ± 3.6
Slide	-	0.3 ± 0.4	0.5 ± 0.7	1.0 ± 0.9^{++}	0.3 ± 0.7	2.0 ± 1.2
Average	26.8 ± 4.7	30.4 ± 6.2	10.1 ± 3.9	18.6 ± 6.2	12.9 ± 2.1	98.8 ± 11.2

FW: Forward, SMF: Side Midfielder, CMF: Central Midfielder, SB: Side Back, CB: Center Back
$^{++}$: significantly higher value ($p < 0.01$), $^{+}$: significantly higher value ($p < 0.05$),
$--$: significantly less value ($p < 0.01$), $-$: significantly less value ($p < 0.05$)

= 283.7, $p < 0.01$), and residual analysis showed that FW and SMF were associated with SM, CMF with Be, and SB with S; for CB with CH - DF and Be, the number of sprints was higher ($p < 0.01$).

3.4 Sprints by eight directions

The total number of sprints by eight directions were 199 for F, 119 for DRF, 32 for R, 72 for DRB, 111 for B, 63 for DLB, 22 for L, and 170 for DLF.

Table 3 The average number of sprints directions in each position per match (Mean ± SD)

	FW	SMF	CMF	SB	CB	Total
Forward	7.6 ± 2.6	11.9 ± 4.4^{++}	1.6 ± 1.8^{-}	3.8 ± 2.6	0.1 ± 0.3^{--}	25.0 ± 4.9
Diagonally Right Front	6.9 ± 3.3^{++}	4.5 ± 2.3	1.3 ± 1.0	2.1 ± 2.4	0.3 ± 0.4^{--}	14.9 ± 6.9
Right	0.9 ± 0.9	1.5 ± 1.4	0.3 ± 0.7	0.8 ± 1.1	0.5 ± 0.7	4.5 ± 3.2
Diagonally Right Back	0.5 ± 0.5^{--}	1.6 ± 1.0^{+}	1.9 ± 0.8^{++}	2.1 ± 1.4	3.0 ± 1.7^{++}	9.1 ± 3.1
Backward	0.3 ± 0.4^{--}	3.6 ± 1.9	1.9 ± 1.3	3.1 ± 2.1	5.0 ± 2.1^{++}	13.9 ± 4.4
Diagonally Left Back	0.1 ± 0.3^{--}	0.8 ± 0.8^{--}	1.0 ± 1.2	2.3 ± 0.8^{+}	3.8 ± 2.1^{++}	7.9 ± 2.2
Left	0.8 ± 0.8	0.5 ± 0.7	0.4 ± 0.5	0.9 ± 1.4	0.3 ± 0.4	2.8 ± 1.7
Diagonally Left Front	9.8 ± 3.0^{++}	5.9 ± 1.5	1.9 ± 1.2	3.6 ± 1.8	-	21.3 ± 4.8
Average	26.8 ± 4.7	30.4 ± 6.2	10.1 ± 3.9	18.6 ± 6.2	12.9 ± 2.1	98.8 ± 11.2

FW: Forward, SMF: Side Midfielder, CMF: Central Midfielder, SB: Side Back, CB: Center Back

$^{++}$: significantly higher value ($p < 0.01$), $^{+}$: significantly higher value ($p < 0.05$),

$--$: significantly less value ($p < 0.01$), $-$: significantly less value ($p < 0.05$)

The number of sprints per match by eight directions is shown in **Table 3**. The results of the chi-square test showed an association between position and play ($\chi 2 = 334.6$, $p < 0.01$), and residual analysis indicated that FW sprinted more often in the DRF and DLF directions, SMF in the F direction, CMF in the DRB direction, and CB in the DRB, B, and DLB directions ($p < 0.01$).

4. Discussion

This is the first study in Japan to analyze sprint and video data of college-level female soccer players during a match. The results showed that about 10 - 30 sprints were performed per player in each position, and more sprinting was required in offensive positions such as FW and SMF than in defensive positions such as CMF, CB, and SB. Moreover, the analysis results of characteristics such as ball possession and non-retainment, play situation, and direction of play suggest that the positional characteristics of sprinting during a match depend not only on the players' characteristics (Hoppe et al., 2018) and playing style (Ade et al., 2016; Di Salvo et al., 2007), but also on the playing situation. In the present study, the number of sprints was the highest in short sprints of 5 - 8 m, as shown in **Figure 2**, and it seemed to decrease as the distance increased. The analysis results showed that the number of sprints at short distances (0 - 5 m) was the highest, and it decreased as the distance increased (Di Salvo et al., 2010). The distribution of sprinting was similar regardless of gender and competition level. However, in practice, sprint speed measurement is based on the movement occurring prior to the sprint, and the sprint speed is reached with acceleration (Vescovi, 2012). Because this study did not consider the acceleration phase, it is necessary to analyze the distance per sprint, including the acceleration phase distance, which will lead to the accumulation of scientific evidence in sprinting of Japanese female soccer players.

FW and SMF players were found to have sprinted more when possessing the ball, while SB and CB players sprinted more when not possessing the ball (**Table 1**). In the English Premier League, players doing high-intensity running (> 19.8 km/h) when possessing the ball of the FW and SMF players covered more, while the SB, CB, and CM players covered more when without possession (Di Salvo et al., 2009). This suggests that regardless of gender or competition level, players in offensive positions like FW and SMF sprinted more when their team possessed the ball, while players in defensive positions mostly sprinted when the opposing team possessed the ball. However, since there are only two examples, the English Premier League and the Kanto University Women Football League, it is necessary to accumulate and analyze data in various categories, team formations and team tactical styles in the future.

Furthermore, FW and SMF players sprinted about the same number of times as SB and CB players, even when the opposing team possesses the ball.

The analysis results of the number of sprints by situation showed that most of the sprints were attempts to get involved in the attack (SM), and they were performed on the way back to the own goal (Be), with the SM occurring mostly in the attacking positions of the FW and SMF and the Be occurring mostly in the CMF and CB (**Table 2**). This suggests that sprinting is specific between positions and that it is essential for attacking FW and SMF players when they try to participate in the attack and for CMF and CB players when they return to their own position.

For the sprint direction, F sprints were most common, and SMF were most common in each position (**Table 3**). DRF and DLF were more common in FW. This position is related to the technical elements of attack (crosses and shots) (Ade et al., 2016), which may provide an additional explanation as it requires sprinting in the play in attack. In contrast, CB often sprint backward (including DRB and DLB) in the opposite direction of the attack (Backward: B), and the sprint characteristics by direction reflect both the attacking and defending roles. SB often sprint forward and backward as they move up and down the entire field for offense and defense, and CMF are required to move all over the center of the field (Di Salvo et al., 2007), and these positional features were reflected in the results. The directional sprints are considered to reflect the roles of the respective positions: offensive and defensive. This suggests the necessity of position-specific training (Ade et al., 2016) by considering the sprint direction and the number of times and distance.

In the past, this kind of analysis required a lot of time and effort as it was necessary to manually check video data and GPS data one by one. However, Catapult Vision (Version 2.1.1, Catapult Sports, Australia), with its time-synchronization feature, provided an immediate visualization of GPS data measurements (in this case, sprints). It is possible to see the GPS data measured at any point in the game in a short time. This will provide coaches and players with faster visualization of GPS data in the field.

This study's results focused on the sprinting of collegiate female soccer players during a match and analyzed the situations in which sprinting was performed. Because the effects of neither the team's tactics nor those of the opposing team were considered, validation of the data considering tactics may be necessary. However, this method of analysis can be utilized for all genders and age groups as it allows us to check for sprinting during a game quickly by simply importing both GPS and video data from the video camera into the analysis software.

In this study, sprinting was defined as running faster than 21 km/h (Casamichana et al., 2012; FIFA. 2011; Suarez-Arrones et al., 2015). Bridget. et al. (2020) studied 12 male collegiate soccer players and 16 female soccer players and investigated high-intensity running above 21.1 km/h during matches. In comparison of sprint between male and female, male accumulated a significantly greater the number of sprints and distance. When the definition of sprint is the same for male and female, male showed significantly higher values than female, even at the top level players in Europe (Paul. et al., 2013).

The measurements in this study did not consider environmental factors such as time of year and weather. However, since previous studies have reported no variation in the total distance traveled and sprinting by season and weather (Lago-Ballesteros et al., 2012; Lago et al., 2010), this was not considered to affect the results. In the future, examining data other than sprinting (e.g., acceleration, deceleration, and change of direction) using this system is necessary. Furthermore, because this analysis could be applied to sprinting in top-level female soccer players in Japan and male soccer players and data from high-ranking soccer countries and in other sports by changing the speed threshold, comparisons of data from them will provide a scientific basis for training and tactical planning of Japanese female soccer players in the field of coaching.

In conclusion, this study is the first to collect qualitative information on the sprinting performance of female players during a match using a wearable device and specific video analysis software. We found that the characteristics of the sprinting performance of female soccer players during a match depend on the situations and positions. To improve the competitiveness of female soccer players, it is necessary to coach players through practice that is more in line with actual competition, such as position-specific, match situation-specific, and direction-specific sprint training.

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- Japanese Society of Science and Football
- Japan Society of Physical Education, Health and Sport Science
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