Interchangeability of Sprinting Profiles by Setting Speed Threshold of 25 km/h Using Global Navigation Satellite System in the Japanese Professional Football League

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At the beginning of the 2023 season, the Japanese Professional Football League (J-League) changed the speed criterion of sprinting from > 24 km/h to > 25 km/h (SP24 and SP25). This study aimed to determine the interchangeability of the SP24 and SP25 in a professional football match using 10-Hz positioning information from a global navigation satellite system. Of the 70 match files that were randomly selected, 66 satisfied the inclusion criteria for the final study. SP24 and SP25 were defined as running for > 1 s with a speed of at least 24 and 25 km/h, respectively. The number of instances of SP25 was significantly lesser than that of SP24 (p < 0.01), and the relative deviation was -25.68 ± 20.74 %. The lower and upper agreement limits were -5.32 and 1.64 n/match, respectively. A significant relationship was observed between the deviation and average value (r = -0.681, p <0.01). Additionally, SP25 was significantly shorter in time and distance than was SP24 (p < 0.001). Our findings suggest that the SP profiles from the 2023 season (SP25) were not interchangeable with those from previous seasons of the J-League (SP24).

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

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1. Introduction

Sprint running (SP) profiles are key elements of running performance during a football game. A previous study reported that the outfield players covered longer sprint distances in games won than in games lost (Andrzejewski et al., 2018). Furthermore, SP performances appeared to be maintained over successive matches regardless of the playing position, whereas the reductions in other match-running categories varied between positions (Varley et al., 2018). Moreover, the SP activities were considered to be key determinants for successful performance (Carling et al., 2012). Therefore, the ability to sustain SP can be considered a key characteristic for football players to compete at the professional level (Chmura et al., 2017; Gualtieri et al., 2023).

SP is defined as running for > 1 s at the highest

speed an individual can run, based on the highfrequency observation of the positioning information (Gualtieri et al., 2023; Sweeting et al., 2017). Recent technological advances have enabled the provision of the total number or bout length of SP for each player during matches in real time. There are several definitions of an SP. A recent review suggested that there is no consensus on the absolute thresholds defining high-speed and sprint running in adult soccer players, and a rate of 20.0-25.0 km/h was used for speed threshold setting (Gualtieri et al., 2023). In the Japanese Football League (J-League), SP was defined as running at a speed of at least 24 km/h for ≥ 1 s (J-League, 2022); the speed threshold was altered to 25 km/h from the 2023 season (J-League, 2023), in consistency with the definition of the Federation International Football Association (FIFA) World Cup (FIFA, 2023). Thus, the SP profiles of the J-League

from 2023 can be compared with international data. In contrast, the new speed threshold would make it difficult to compare the current data with previous ones. Our preliminary analysis concerning the comparison of the first 10 matches between 2022 and 2023 (J-League, 2022) demonstrated that the number of instances of SP dramatically decreased from 195 \pm 19 n/match/team to 140 \pm 22 n/match/team. The difference achieved was -28.0 \pm 12 %, whereas the deviation of the total distance covered was only 1.5 \pm 22.4 % (116 \pm 5 vs 118 \pm 6 km/match/team). As this result was based on the analysis of different matches, there was no evidence regarding the SP profiles detected at 24 and 25 km/h in the same match. Therefore, the changes in the number of instances of SP remain unclear by increasing the speed threshold from 24.0 to 25.0 km/h. Although it is clear that a faster speed threshold leads to a lower SP based on a mathematical theory, the magnitude of the difference is vital information for the coaching staff to compare the SP values of the current season (2023) with those of past seasons (before 2022).

Thus, the primary purpose of the present investigation was to determine the interchangeability of the SP detected by speed threshold settings of 24 km/h and 25 km/h (SP24 and SP25) in a professional football match using 10-Hz positioning information from a global navigation satellite system (GNSS).

2. Methods

Match activity data were collected from 10 matches in the second division of the Japanese soccer league in 2021. The matches were randomly selected from the all-match files of the 2021 season using a random number table. On the basis of previous studies (Di Salvo et al., 2007; Di Salvo et al., 2013), the selected data were limited to outfield players. To analyze the effect of the number of instances of SP on the relationship between the two algorithms, the data were not limited to those obtained from fulltime players. Of the 12–15 match outfield player files, seven player files were randomly selected using a random number table for each match, independent of the actual playing time. As SP could not be detected in four of 70 files, 66 match player files were included in the final analysis. The number of participants was verified using G-Power (University of Dusseldorf, Dusseldorf, Germany) analysis to obtain statistical significance (Faul et al., 2007). This study was

conducted in accordance with the principles of the Declaration of Helsinki, and all procedures were approved by the Ethics Committee of Okayama Prefectural University.

Match activity data were determined using a global position-tracking system (Catapult OptimEye X4; Catapult Sports, Melbourne, Australia). This small device (96 \times 52 mm) was placed in the back pocket of each player's undershirt during the match. The data were analyzed after each match using a specific data program (Openfield, Catapult Sports). This device obtained location information at a sampling rate of 10 Hz. The validity of the 10-Hz GNSS has been 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). The movement distance and speed were obtained based on the changes in location. The SP was defined in two different ways: 1) the speed maintained at least 24.0 km/h lasting > 1 s, which is the traditional algorithm in the J-League (Ayabe et al., 2021; Ayabe et al., 2022; J-League, 2022); and 2) the speed maintained at least 25.0 km/h lasting > 1 s, which is the current algorithm in the J-league from 2023 (J-League, 2023). The number, duration, and distance of instances of SP according to the two definitions were measured.

Data are presented as means and standard deviations. To examine the interchangeability between SP24 and SP25, a Bland-Altman plot and regression analysis was performed, while the effect size (ES) and kappa statistics (k) were also measured according to previous investigations (Ellens et al., 2022) (Buchheit et al., 2014; Taberner et al., 2019). Differences between the two variables were tested using paired t-tests. Besides, the ES for the post hoc paired comparisons was calculated using Cohen d_z (0.2-0.5, 0.5-0.8, and > 0.8 are considered small,medium, and large, respectively) (Lakens, 2013). The relationship between the two variables was analyzed using Pearson's correlation coefficient (r). The limit of agreement between the two variables was demonstrated using Bland-Altman plots (Bland & Altman, 1986). Furthermore, intraclass correlation coefficients (ICC, 2.1) (Koo & Li, 2016) and k values (Landis & Koch, 1977) were used to analyze the reliability of the two variables. The ICC was

evaluated according to the previous investigations (< 0.5: poor reliability; 0.5–0.75: moderate reliability; 0.75–0.9: good reliability; and > 0.90: excellent reliability). The *k* values were evaluated according to the previous investigations ($k \le 0.2$: poor; 0.2–0.4: fair; 0.4–0.6: moderate; 0.6–0.8: good; 0.8–1.0: very good). All the statistical analyses were performed using SPSS version 29.0 (IBM SPSS Statistics, IBM Corp., Armonk, NY, USA). The post-hoc sample size (statistical power:1– β) was calculated using the study data with the G-Power software v.3.1.9.4 (University of Dusseldorf) to determine the statistical power of the study (Faul et al., 2007). Values of *p* < 0.05 (two-tailed) were considered significant, unless otherwise noted.

3. Results

The number, duration, and distance of SP according

to the two definitions are presented in **Table 1**. The number of SP25 instances was significantly lower than that of SP24 instances (p < 0.001). Furthermore, the duration and distance of SP25 were significantly shorter than those of SP24 (p < 0.001). The ES (Cohen *d*) of the speed criteria was large (> 0.80) for the number and distance of the SP and small for the duration of the SP. The G-power (1- β) for the number and distance of SP was > 0.80.

The absolute deviations of SP25 from those of SP24 are listed in **Table 1**. The relative deviation of SP25 from SP24 was -25.68 ± 20.74 % in the number of SP instances, -13.18 ± 10.41 % in the duration of SP, and -10.59 ± 10.81 % in the distance of SP (**Figure 1**). There was a significant correlation between the numbers of SP24 and SP25 (r = 0.938, p < 0.001; **Figure 2**). The Bland-Atman plots are presented in **Figure 2**. The lower and upper agreement was -5.32 to 1.638 n/match. There was

 Table 1
 Number, duration, and distance of sprinting in a setting of 24 and 25 km/h of the speed threshold

	Speed criteria		Deviation	<i>t, p</i>	d	1 <i>-β</i>
	> 24 km/h	> 25 km/h	-			
Number (bouts/match)	6.50 ± 4.29	4.73 ± 3.22	$\textbf{-}1.84 \pm 1.74$	T = 8.477, p < 0.001	1.699	0.955
Duration (sec/bout)	2.06 ± 0.60	1.77 ± 0.48	$\textbf{-0.13} \pm 0.33$	T = 9.351, p < 0.001	0.255	0.532
Distance (m/bout)	16.47 ± 4.23	14.66 ± 3.74	$\textbf{-0.52} \pm 1.65$	T = 7.574, p < 0.001	1.949	0.989

Data are expressed as means with standard deviations



Figure 1 Deviations in sprint running profiles between > 24 km/h and > 25 km/h The deviation was calculated as follows: the value was obtained by subtracting SP24 from SP25, divided by SP24, and multiplied by 100.



Figure 2 Relationship of the number of instances of sprint running between > 24 km/h and > 25 km/h

The left illustration shows the scatterplots and the dashed line indicates the identity line (y = x). The right illustration shows Bland–Altman plots, while the solid and dashed lines indicate the mean and range of agreement of the deviation, respectively.

a significant relationship between the deviation and average value (r = -0.681, p < 0.01). The ICC between the number of instances of SP24 and of SP25 was ICC (2.1) = 0.813 (0.232–0.931) and was considered to indicate good reliability. The *k* value of the number of instances of SP was 0.586, which was considered to indicate moderate reliability.

4. Discussion

To our knowledge, the present investigation is the first to demonstrate the effects of the new SP criterion used in the J-League, which is defined as running with a speed > 25 km/h for > 1 s. Although several investigations have demonstrated running profiles by dividing them into speed categories, the present investigation is the first to reveal SP profiles using two-speed criteria. The number, duration, and distance of the SP decreased when the speed criterion increased from 24 km/h to 25 km/h. Although a strong relationship was found between SP24 and SP25, a deviation of approximately 25 % was observed between the two SP profiles. The results of the present investigation showed that SP25 was less frequent, of shorter duration, and shorter distance than SP24 in the J-League. Due to the large deviation

from the 2023 season would not be interchangeable with those from previous seasons. Furthermore, all J-League associates, including catching staff, scientists, players, and supporters, should pay special attention to improving the SP profiles of the J-League in 2023, particularly when comparing them to the corresponding ones of past seasons. The results of the present investigation are not ambiguous because fewer SP based on the fasterspeed criteria are mathematically apparent. Although

ambiguous because fewer SP based on the fasterspeed criteria are mathematically apparent. Although the present investigation first adopted two-speed criteria for the same players in a football match, a recent review also demonstrated that faster-speed criteria resulted in a lower number of instances of SP (Gualtieri et al., 2023; Sweeting et al., 2017). The ES of the present investigation between the two algorithms is consistent with that of a previous study (Varley et al., 2017). Finally, the results of the G-power analysis demonstrated that the present investigation has enough statistical power; the deviations in the number of instances of SP between the two algorithms was indicated by $1-\beta = 0.989$. Therefore, the results of the present investigation can be considered reliable and applicable to future studies.

between the two speed thresholds (> 25 %) and the

large ES, regardless of the strong relationship, it can

be concluded that the SP profiles of the J-League

An interesting finding of the present investigation is that the magnitude of the difference between SP24 and SP25 was significantly associated with the total number of SP instances. This relationship suggests that the magnitude of the decrease in the number of SP instances between 2022 and 2023 will be greater for players with a larger number of instances of SP24. Although the present investigation completely demonstrates the background of this phenomenon, it can be speculated that a large number of instances of SP have a larger variability in average speed associated with fatigue. Thereafter, slower speeds ranging from 24.0 to 25.0 km/h were not defined by SP25. Further investigation is required to determine the inter-player variability of the effects of the speed threshold on the magnitude of the differences, whereas it is apparent that a faster threshold detects fewer number of SP instances.

The present study had some limitations. First, we obtained tracking data from the second division of the J-League. As the present investigation did not limit the included players to "full-time" players,

the number of SP instances was limited to 6.50 \pm 4.29 n/match, and was apparently fewer than the corresponding one in a previous investigation where the average number of SP instances was almost 15 n/ match over 1,645 official J-League matches (Ayabe et al., 2022). Furthermore, the magnitude of deviation between the two algorithms is associated with the total frequency of the SP. Therefore, the absolute effects of the new speed criteria (25 km/h) should be reconfirmed in the first division of the J-League, whereas the setting of > 25 km/h results in an SP lower than that of > 24 km/h, regardless of the player categories, study sample, and tactical-technical situations. Second, this investigation used validated GNSS devices. Although the findings of the present investigation are reliable and inter-changeable, analysis using a different device, such as a 10-Hz GNSS device and/or multi-camera technology, results in minor inconsistencies.

In conclusion, the results of the present investigation suggest that the SP profiles from the 2023 season are not interchangeable with those from previous seasons of the J-League. Furthermore, all J-League associates, including catching staff, scientists, players, and supporters, should pay special attention to improving the SP profiles of the J-League in 2023, particularly when comparing them to the corresponding ones of past seasons.

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References

- Andrzejewski, M., Chmura, P., Konefał, M., Kowalczuk, E., and Chmura, J. (2018). Match outcome and sprinting activities in match play by elite German soccer players. J. Sports Med. Phys. Fitness, 58, 785-792.
- Ayabe, M., Murai, S., Oyama, T., Kumahara, H., Ssunami, S., and Ishizaki, S. (2021). Match activity characteristics in second division of Japanese professional football: Three years of full-season analyses using global navigation satellite system. Football Science, 18, 81-91.
- Ayabe, M., Sunami, S., Kumahara, H., and Ishizaki, S. (2022). Effects of substitute allowance on match activity characteristics in Japanese professional football across 2019, 2020, and 2021 seasons. J. Sports Sci., 40, 2654-2660.
- Bishop, C., Read, P., Stern, D., and Turner, A. (2020). Effects of soccer match-play on unilateral jumping and interlimb asymmetry: A repeated-measures design. J. Strength Cond. Res.
- Bland, J.M., and Altman, D.G. (1986). Statistical methods for assessing agreement between two methods of clinical measurement. Lancet, 1, 307-310.

- Buchheit, M., Allen, A., Poon, T.K., Modonutti, M., Gregson, W., and Di Salvo, V. (2014). Integrating different tracking systems in football: Multiple camera semi-automatic system, local position measurement and GPS technologies. J. Sports Sci., 32, 1844-1857.
- Carling, C., Le Gall, F., and Dupont, G. (2012). Analysis of repeated high-intensity running performance in professional soccer. J. Sports Sci., 30, 325-336.
- Chmura, P., Andrzejewski, M., Konefal, M., Mroczek, D., Rokita, A., and Chmura, J. (2017). Analysis of motor activities of professional soccer players during the 2014 World Cup in Brazil. J. Hum. Kinet., 56, 187-195.
- Di Salvo, V., Baron, R., Tschan, H., Calderon Montero, F.J., Bachl, N., and Pigozzi, F. (2007). Performance characteristics according to playing position in elite soccer. Int. J. Sports Med., 28, 222-227.
- Di Salvo, V., Pigozzi, F., González-Haro, C., Laughlin, M.S., and De Witt, J.K. (2013). Match performance comparison in top English soccer leagues. Int. J. Sports Med., 34, 526-532.
- Ellens, S., Hodges, D., McCullagh, S., Malone, J.J., and Varley, M.C. (2022). Interchangeability of player movement variables from different athlete tracking systems in professional soccer. Sci. Med. Footb., 6, 1-6.
- Faul, F., Erdfelder, E., Lang, A.G., and Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav. Res. Methods, 39, 175-191.
- FIFA. (2023). FIFA Training center. https://www.fifatrainingcentre. com/en/. (accessed 03-11-2022).
- Gualtieri, A., Rampinini, E., Dello Iacono, A., and Beato, M. (2023). High-speed running and sprinting in professional adult soccer: Current thresholds definition, match demands and training strategies. A systematic review. Front. Sports Act. Living, 5, 1116293.
- J-League. (2022). J-League Stat. https://www.jleague.jp/stats/. (accessed 2022-07-31).
- J-League. (2023). J-League Stat. https://www.jleague.jp/stats/. (accessed 2023-03-31)
- Johnston, R.J., Watsford, M.L., Kelly, S.J., Pine, M.J., and Spurrs, R.W. (2014). Validity and interunit reliability of 10 Hz and 15 Hz GPS units for assessing athlete movement demands. J. Strength Cond. Res., 28, 1649-1655.
- Koo, T.K., and Li, M.Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. J. Chiropr. Med., 15, 155-163.
- Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: A practical primer for t-tests and ANOVAs. Front. Psychol., 4, 863.
- Landis, J.R., and Koch, G.G. (1977). The measurement of observer agreement for categorical data. Biometrics, 33, 159-174.
- Rampinini, E., Alberti, G., Fiorenza, M., Riggio, M., Sassi, R., Borges, T.O., and Coutts, A.J. (2015). Accuracy of GPS devices for measuring high-intensity running in field-based team sports. Int. J. Sports Med., 36, 49-53.
- Slater, L.V., Baker, R., Weltman, A.L., Hertel, J., Saliba, S.A., and Hart, J.M. (2018). Activity monitoring in men's college soccer: A single season longitudinal study. Res. Sports Med., 26, 178-190.
- Sweeting, A.J., Cormack, S.J., Morgan, S., and Aughey, R.J. (2017). When Is a sprint a sprint? A review of the analysis of team-sport athlete activity profile. Front. Physiol., 8, 432.

- Taberner, M., O'Keefe, J., Flower, D., Phillips, J., Close, G., Cohen, D.D., Richter, C., and Carling, C. (2019). Interchangeability of position tracking technologies; Can we merge the data? Sci. Med. Footb, 4, 76-81.
- Varley, M.C., Di Salvo, V., Modonutti, M., Gregson, W., and Mendez-Villanueva, A. (2018). The influence of successive matches on match-running performance during an under-23 international soccer tournament: The necessity of individual analysis. J. Sports Sci., 36, 585-591.
- Varley, M.C., Jaspers, A., Helsen, W.F., and Malone, J.J. (2017). Methodological considerations when quantifying highintensity efforts in team sport using global positioning system technology. Int. J. Sports Physiol. Perform., 12, 1059-1068.



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- Ayabe, M., Kamo, H., Ishihara, Y., Sunami, S., and Ishizaki, S. (2022). Determinants for duration of drink breaks in J-League in 2021: Special references for COVID-19 temporary amendment. Football Science, 19: 85-89.
- Ayabe, M., Murai, S., Oyama, T., Kumahara, H., Sunami, S., and Ishizaki, S. (2021). Match activity characteristics in second division of japanese professional football: Three years of full-season analyses using global navigation satellite system, Football Science, 18: 81-91.
- Ayabe, M., Okita, Y., Higashino, Y., Morimura, K., Kumahara, H., and Ishizaki, S. (2020). Cardiorespiratory responses to recreational small-sided walking soccer in community-dwelling middle-aged to older adults with mild metabolic disorders. Football Science, 17: 11-15.

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