

Physical match performance of Japanese top-level futsal players in different categories and playing positions

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ABSTRACT: To examine the substitution characteristics during official matches and the physical match performances of Japanese top-level futsal players in different categories and playing positions. Overall, 79 adult (age: 28.4 ± 4.6 years) and 59 youth (age: 17.1 ± 0.7 years) futsal players were classified into three groups based on the playing position (Pivot, Winger, and Defender). Physical match performance was assessed using active profiles from the semi-automatic tracking system. Speed and total distance covered were analysed for the in-play time. The in-play time was categorized based on the teams' ball possession status. The average total playing time per substitution was significantly higher in the youth (6.2 ± 2.1 min) than in the adult players (3.8 ± 1.1 min; $p < 0.05$). Furthermore, the proportion of high intensity exercise during matches was significantly higher in adults ($43.2 \pm 5.2\%$) than in youth players ($37.2 \pm 5.4\%$; $p < 0.05$). There was no significant difference in the average total distance covered between different playing positions. However, the average total distance covered with ball possession by Pivot (140 ± 15 m/min) was significantly lower than that by Winger (151 ± 15 m/min; $p < 0.05$) in adult players. Furthermore, the proportion of high intensity exercise without ball possession as Defender ($36.7 \pm 6.1\%$) was lower than that as Winger ($41.9 \pm 6.1\%$; $p < 0.05$) in adults but not in the youth players. Adult futsal players have higher physiological demands than youth players. The physical match performances vary between playing positions with or without ball possession. These results could be useful for youth development and position-specific training information.

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INTRODUCTION

Futsal is an intermittent sport with high physical, technical, and tactical demands from the players [1]. A futsal game includes four field players and one goalkeeper in an indoor court of 40 m × 20 m with no restrictions on substitutions [2]. The game time includes two 20-min halves, which do not include out-of-play time such as if the ball goes out, fouls, injuries, and court cleaning. Therefore, the whole game time is usually 75%–85% longer than 40 min [1]. A number of studies [1, 3] have reported that the total playing time of futsal players during matches is approximately 50% of the whole game time, while the remaining 50% is spent resting on the bench. However, in contrast with other sports [4], this has not been investigated in terms of effective playing (in-play) time per substitution, bench time, and the number of substitutions during official futsal matches.

Di Salvo et al. [5] demonstrated that match analyses are helpful in developing a specific training programme that mimics the physiological conditions of the game. Previous studies [1, 6] have concluded that the average total distance covered during an official match

by adult professional futsal players was approximately 3000–4500 m. However, the total distance covered cannot be taken as an indicator of performance in sports with unlimited substitutions; the distance covered per minute (relative distance) is more representative of the general intensity of the exercise [1]. Several studies [1, 3, 6, 7] have demonstrated that the total distance covered per minute during matches was 117–140 m/min in the whole game and 129–137 m/min in the in-play duration. Furthermore, the distance covered per minute during the in-play and whole game conditions decreases in the second half in comparison with the first half [6]. The exercise intensity (ratio of the heart rate to the maximum heart rate) during the game is 86–93%, which is very high exercise intensity when compared with football and other sports [1, 8].

Several studies [1, 3, 6, 7, 9, 10] have reported on the physical match performance of futsal players in different competition levels. For example, Makaje et al. [9] demonstrated that professional players had higher physiological demands than did amateur players in

unofficial matches. However, these previous studies used data from unofficial matches or included only adult players. No study has included youth players. The evaluation of the physical determinants of running performance during official matches according to age is required to improve talent detection procedures and long-term training interventions [11]. Development in youth players is also necessary for improving the competitiveness of the national team in future.

Futsal players are categorized into four positions: pivot, winger, defender, and goalkeeper [10]. Several studies [5, 12–15] have reported on the significant differences in physical match performance between different playing positions in other sports, such as soccer, rugby, and basketball, which are used to develop scientific bases for developing position-specific conditioning and training protocols. There are few studies on the physical performance of different playing positions in futsal [1, 10], and there is no detailed analysis, such as with or without ball possession. Di Salvo *et al.* [16] suggested that the differentiation between high intensity activity with or without ball possession during a football match enables the relative effectiveness of high intensity efforts in relation to crucial match actions to be evaluated.

Therefore, the aims of this study were to (1) examine the substitution characteristics of official futsal matches; (2) compare the physical match performance of adult and youth top-level futsal players; and (3) compare the physical match performances between different playing positions in Japanese futsal players.

MATERIALS AND METHODS

Data collection

In this study, the futsal players were video-filmed during the official matches and the physical match performance was assessed using active profiles from the semi-automatic tracking system [17]. In addition, the duration of the experiment was about two months. The games were conducted based on the international rules of futsal [2]. The game venue was an indoor court of 40 m × 20 m, and the game time included two halves of 20 minutes each. Data were collected from 79 top-league adult players (mean ± standard

deviation, age: 28.4 ± 4.6 years) and 59 top-level youth players (age: 17.1 ± 0.7 years) in Japan. They were classified into three positions in both adult and youth players (pivot: $n = 17$ and 15 ; winger: $n = 38$ and 23 ; defender: $n = 24$ and 21 , respectively). The matches of adult players that were analysed included six matches of the Japanese top league of the 2017–2018 seasons. In contrast, the matches of youth players that were analysed included five matches of the Japanese U-18 Championship from the 2017 season. The competitive matches of top-level youth players included only the U-18 Championship once a year and the number of matches was small. Therefore, we selected six matches because this number of matches adjusts to the U-18 Championship. Additionally, data of participants who participated for less than 8 minutes in the in-play time during a game were excluded.

Physical match performance

Physical match performance was evaluated based on image processing using the semi-automatic tracking system [17]. The videos were recorded by two commercially available high-density cameras (HDR-CX560, SONY, Japan). The cameras were fixed on tripods, and the left and the right courts were captured with each camera. Figure 1 is a composite image of two images recorded by the automatic tracking system. The size of each image was 1920×1080 pixels at a frame rate of 60 fps, and the videos were recorded in the progressive mode. The recording position was approximately 20 m away from the nearest touch line, and the height of the position was approximately 20–30 m from the court. The position information of the players was measured at a sampling interval of 1/20 seconds. In cases of tracking error due to overlapping of players in an image, the measured data of the target player were corrected by using a pen tablet (Intuos Draw CTL-490, Wacom, Japan). In this study, the automatic tracking rate was $82.4 \pm 3.7\%$. The player's positions were determined by applying a 19-point moving average filter to the measured data. From the determined player position, the movement distances and velocities were calculated every 1/20 second. A player's speed was determined using a 5-point median filter. The measurement



FIG. 1. Image processing.

accuracy depends on the spatial resolution of 1 pixel, which varies with the distance between the camera and position on the court. The approximate spatial resolution on the x-axis was 0.002–0.02 m and that on the y-axis was 0.002–0.10 m. Additionally, the reproducibility of the measurements of player positions by the automatic tracking was within ± 0.2 m [17].

The following speed categories were used [6, 18]: walking (0–6 km/h), low intensity running (LIR; 6.1–12 km/h), medium intensity running (MIR; 12.1–15.4 km/h), high intensity running (HIR; 15.5–18.3 km/h), and sprint (> 18.4 km/h). High intensity exercise (HIE) was defined as the sum of MIR, HIR, and sprint [19].

For whole-game analyses, we used an approach from a study on ice hockey [4], which has the same substitution characteristics as in futsal. Specifically, the total playing time (including out-of-play time), in-play time (with the ball in play), duration of resting on the bench between substitutions, and the number of substitution were recorded and expressed as frequency, mean time, and total in-play time [4]. Additionally, the in-play time was categorized according to the possession of the ball into possession and non-possession durations [20].

Statistical analysis

All values are presented as mean \pm standard deviation (SD). Differences between two categories (adults vs. youth) were analysed using Student's unpaired *t*-test. Differences between possession and non-possession were determined using Student's paired *t*-test. Differences in the playing positions were determined using one-way analysis of variance, and in the case of significant differences, Bonferroni's post-hoc test was used to identify specific differences within the data. We also calculated the effect size (ES) with 95% confidence intervals (95% CI). ES values of < 0.2 , 0.2 – 0.5 , and > 0.8 were considered to represent small, medium, and large differences respectively [21]. Statistical significance was set at $p < 0.05$.

Ethics

The games were recorded with the permission of the Japan Football Association. Moreover, this study conformed to the recommendations of the Declaration of Helsinki and was approved by the University Ethics Committee. The Japan Football Association approved the analysis of the videos collected. Therefore, all data were anonymized

before analysis; no individual informed consent was obtained from the players taking part in the matches.

RESULTS

As summarized in Table 1, no significant differences were observed in the total playing time (ES = 0.4; 95% CI = 0.0–0.7) or bench time (ES = 0.1; 95% CI = -0.3–0.4) in both categories. However, the average in-play time in youth futsal players (22.3 ± 6.1 min) was significantly longer than that in adult players (18.7 ± 4.8 min; $p < 0.05$; ES = 0.7; 95% CI = 0.3–1.0). Furthermore, the number of substitutions during the youth matches (6.5 ± 3.4) was significantly lower than that in adult matches (8.2 ± 3.4 ; $p < 0.05$; ES = 0.9; 95% CI = 0.5–1.2). Additionally, the average total playing time per substitution (youth vs. adults: 6.2 ± 2.1 vs. 3.8 ± 1.1 min; $p < 0.05$; ES = 1.0; 95% CI = 0.7–1.4) and the in-play time (youth vs. adults: 4.6 ± 0.9 vs. 2.4 ± 0.5 min; $p < 0.05$; ES = 1.8; 95% CI = 1.4–2.2) during the match in youth players were significantly longer than those in adult players.

No differences were observed in the total distance covered in both categories (ES = 0.5; 95% CI = 0.1–0.8) (Table 2). However, the average total distance covered per minute during the in-play time in adult matches (141 ± 11 m/min) was significantly higher than that in the youth matches (131 ± 10 m/min; $p < 0.05$; ES = 0.9; 95%

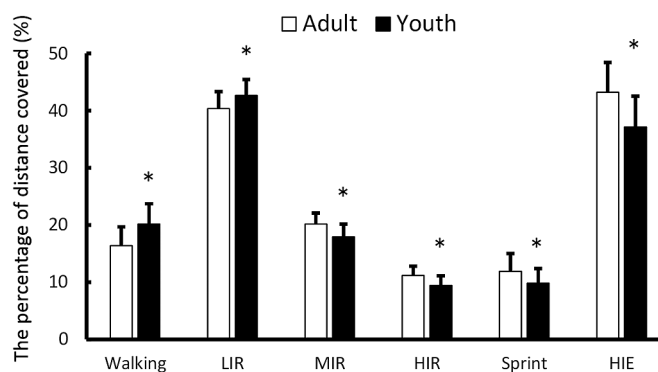


FIG. 2. The percentage of velocity in in-play during the matches between different categories.

Note: * $p < 0.05$ vs. adults.

TABLE 1. Substitution characteristics during official futsal matches in both categories.

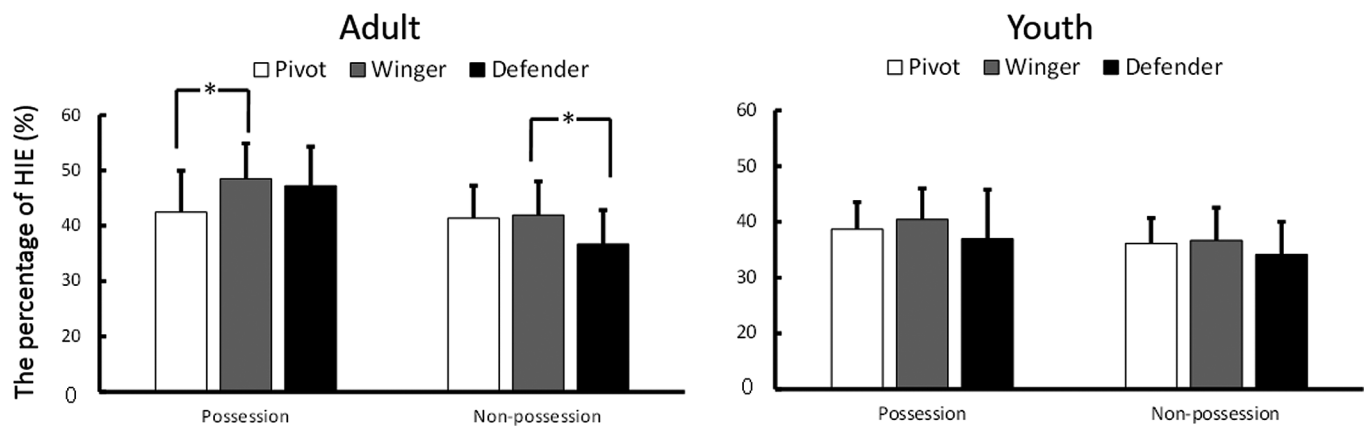
	Total playing time (min)	In-play time (min)	Number of substitutions	Total playing time per substitutions (min)	In-play time per substitutions (min)	Bench time (min)
Adult	35.9 ± 9	18.7 ± 4.8	8.2 ± 3.4	4.6 ± 0.9	2.4 ± 0.5	5.4 ± 1.9
Youth	39.7 ± 11	$22.3 \pm 6.1^*$	$6.5 \pm 3.4^*$	$6.2 \pm 2.1^*$	$3.8 \pm 1.1^*$	5.5 ± 2.1

Note: * $p < 0.05$ vs. adults.

TABLE 2. Total distance covered during the whole and in-play times with possession and non-possession of the ball in both categories.

	Total distance (m)	Total distance (m/min)	In-play (m/min)	Possession (m/min)	Non-possession (m/min)
Adult (n=79)	4151 ± 942	116 ± 9	141 ± 11	149 ± 15 [#]	136 ± 13
Youth (n=59)	4670 ± 1202	118 ± 8	131 ± 10*	135 ± 13* [#]	129 ± 10*

Note: *p < 0.05 vs. adults; # p < 0.05 vs. non-possession.

**FIG. 3.** Proportion of high intensity exercise (HIE) during the matches in different playing positions.

Note: * p < 0.05

CI = 0.6–1.3). Furthermore, the average total distance covered per minute during ball possession was significantly longer than that without ball possession in both categories (ES = 0.5–0.9; 95% CI = 0.2–1.3). Additionally, the proportion of HIE during adult matches ($43.2 \pm 5.2\%$) was significantly higher than that in the youth matches ($37.2 \pm 5.4\%$; $p < 0.05$; ES = 1.2; 95% CI = 0.8–1.5) (Fig. 2).

In both categories, there was no significant difference in the average total distance covered between different playing positions

(ES = -0.4–0.2; 95% CI = -0.7–0.8). However, in adult players, the average total distance covered per minute with ball possession in the pivot position (140 ± 15 m/min; $p < 0.05$; ES = 0.7; 95% CI = 0.1–1.3) was significantly lower than that in the winger position (151 ± 15 m/min) (Table 3). Additionally, the proportion of HIE without ball possession in the defender position ($36.7 \pm 6.1\%$; $p < 0.05$; ES = 0.9; 95% CI = 0.3–1.4) was lower than that in the winger position ($41.9 \pm 6.1\%$) in adults but not in youth players (ES = 0.4; 95% CI = -0.2–1.0) (Fig. 3).

TABLE 3. Total distance covered between different playing positions in both categories.

		Total playing time (min)	Total distance (m)	Total distance (m/min)	In-play (m/min)	Possession (m/min)	Non-possession (m/min)
Adult	Pivot (n=17)	35.5 ± 10.6	4050 ± 1038	116 ± 6	140 ± 11	140 ± 15*	139 ± 12
	Winger (n=38)	35.6 ± 9.2	4226 ± 1011	118 ± 8	144 ± 12	151 ± 15 [#]	139 ± 13
	Defender (n=24)	35.9 ± 6.6	4105 ± 774	115 ± 9	139 ± 10	151 ± 15 [#]	130 ± 11*
Youth	Pivot (n=15)	36.6 ± 11.0	4382 ± 1200	121 ± 5	132 ± 5	135 ± 10	131 ± 9
	Winger (n=23)	41.1 ± 11.1	4859 ± 1198	119 ± 8	134 ± 9	137 ± 9 [#]	131 ± 10
	Defender (n=21)	40.4 ± 10.6	4667 ± 1226	116 ± 6	128 ± 12	131 ± 15 [#]	125 ± 9

Note: * p < 0.05 vs. Winger; # p < 0.05 vs. non-possession.

DISCUSSION

This is the first study to examine the substitution characteristics during official matches and the physical match performances of adult and youth futsal players. Furthermore, we performed detailed analyses between playing positions with and without ball possession in futsal. These results demonstrate that adult futsal players have higher physiological demands than youth players, and that the physical match performances between positions and categories in futsal vary.

Several studies [1, 3] have reported that the total playing time of futsal players is approximately 50% of the whole game time but they did not investigate the in-play time. The present results demonstrate that the in-play time of futsal players was approximately 50% (18–22 min) of the whole official game time (Table 1). These results indicate a playing time to bench time ratio of approximately 1:1. Additionally, the average in-play time in youth futsal players (22.3 ± 6.1 min) was significantly longer than that in adult players (18.7 ± 4.8 min), most certainly due to the fewer substitutions in youth competition (Table 1). A novel aspect within the present investigation was the analysis of the number of substitutions. In this study, the percentage of moderate and high intensity and sprint exercise during the game in the youth was significantly lower than that in the adults (Fig. 2). One of the reasons for this may be the low number of substitutions in the youth players. De Oliveira et al. [6] suggested that coaches may consider a higher number of substitutions during the match to prevent decreased physical performance. Additionally, the findings of this study highlight that the Japanese top-league players played for approximately 4.6 min with an average recovery time of 5.4 min, which they repeated approximately eight times in one match. Castagna et al. [18] reported that the average total playing time per substitution was 10 min during official matches. Our data suggest that futsal games have become increasingly intensive and that this may change in the foreseeable future.

There was no significant difference between adult and youth players in terms of the total distance covered during a match (Table 2). Previous studies [1, 3, 7] have reported that the average total distance covered is approximately 4–4.5 km during futsal matches, regardless of the competition levels and countries. The results of this study demonstrate that the total distance covered during a game of Japanese players was also approximately 4–4.5 km, regardless of the age. Barbero et al. [1] reported that the greatest total distance covered in the matches was 8040 m. In this study, the maximum total distance covered was 6661 m in adult players and 7463 m in youth players. The distance covered during a futsal game depends on the total playing time because there is no restriction on substitutions. Therefore, the main players require special additional endurance capacity to participate for longer durations during games.

The average of the total distance covered per minute and HIE in the in-play time during futsal matches in the adult players were significantly higher than those in the youth players (Table 2 and Fig. 2). These differences could indicate the differences in physical

capacity due to age. Several studies [22, 23] have reported that the distance covered in the Yo-Yo Intermittent Recovery Test Level 1 is greater in adults than in younger futsal players. Furthermore, Makeje et al. [9] reported that the mean heart rate, blood lactate level, and total distance during unofficial matches of professional futsal players were significantly higher than those of amateur futsal players. It is possible that the development of the ability to perform repeated high intensity exercise is necessary for improving the physical match performance in futsal.

This is also the first study to compare physical match performance between ball possession and without ball possession in futsal. The total distance covered with ball possession was significantly higher than that without ball possession in both categories (Table 2). During offensive play, a high requirement for movement patterns in attacking players is probably a function of the need to complete fast movements away from defending players to generate space or capitalize on goal-scoring opportunities [16]. Additionally, the futsal court is narrow when compared to the football field, and the offensive player must shake off the opponent's defender before receiving the ball. Consequently, playing with ball possession required more action of high intensity in comparison with play without ball possession.

There was no significant difference in the total distance covered according to the playing positions in both categories. The results of this study were consistent with those of previous studies [1, 10]. Additionally, the analysis of ball possession demonstrated significant differences between playing positions. The average total distance covered with ball possession in the pivot position (140 ± 15 m/min) was significantly lower than that in the winger position (151 ± 15 m/min; $p < 0.05$) in adult players. Sarmiento et al. [24] demonstrated that the offensive sequence is developed through a pass to the pivot player during a futsal game. The pivot received the ball in the front line and performed a pass to another player (winger or defender) who finished and scored [24]. It appears that the pivot is the target during the offensive phase and the winger runs to support the pivot. Therefore, the intensity in the pivot position may be low during offensive play. In contrast, HIE without ball possession of the defender was significantly lower than that of the winger in adult players (Fig. 3). During defensive play, the defender marks the opponent's pivot in their own territory and the pivot or winger marks the opponent's defender or winger in the opponent's territory. If an opponent's pivot receives the ball, the pivot or winger hurries back into their own territory to prevent a goal. It appears that the defender may stay behind the line during the defensive phase, and therefore the intensity may be low. Futsal players are involved in attack and defence because HIE of the pivot is low when attacking and the intensity of the defender is low when defending. These results suggest the necessity of position-specific fitness training in futsal.

In contrast, there were no differences between the playing positions of the youth players. It appears that they have little experience playing futsal; therefore, tactical movement may still be immature. Japan has a short history with futsal, and there are few specific futsal

coaches in the youth age group. In the future, with the development of Japanese futsal, there may be a necessity to play futsal from a young age.

One of the limitations of this study is that the number of matches analysed was small. It is considered that more detailed aspects on physical performance can be clarified by analysing a larger number of matches. In addition, we should clarify the characteristics of the playing position to examine the differences in formation and tactical aspects, in future.

Practical applications

These findings can help create simulation games because the characteristics of substitutions during a futsal match were clarified. Previous studies, a decade ago [18], indicated that the average total playing time per substitution was 10 min during official matches. However, this study clarified that the average total playing time per substitution was about 5 min. Therefore, we need to create a new simulation game that comprises 2.5 min (in-play time) × 8 set with a 5 min rest interval between periods. Additionally, the simulation game may be useful for further detailed studies to investigate parameters such as nutrition, recovery strategies, and physiological response during a match. Furthermore, the present data may support coaches and strength and conditioning specialists in developing tactics, substitution times, and training design. The results of this study

indicate that futsal players require high intensity exercise during matches. Therefore, we suggest that fitness training such as high intensity aerobic training and speed endurance training is necessary. In addition, coaches should observe carefully the total playing time per substitution of players because long playing time may lead to a decrease in intensity. Furthermore, there was a significant difference in the total distance covered with or without the ball between the playing positions. We suggest that coaches should consider the characteristics of playing positions.

CONCLUSIONS

This study has examined the substitution characteristics and physical match performance during official matches in adult and youth futsal players with and without ball possession in Japan. Our results demonstrate that adult futsal players have higher physiological demands than youth players. Additionally, the winger position is more physiologically demanding than the pivot position with the ball and the defender position without ball possession in adults. These results could be used to create a game simulation protocol and could be useful in youth development and position-specific training in futsal.

Conflict of interest

The author declares no potential conflict of interest regarding the publication of this manuscript.

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