Title:

The running and technical performance of U13 to U18 elite Japanese soccer players during match play

Corresponding author:
Heita Goto
Kyusyu Kyoritsu University, Faculty of Sports Science, Kitakyushu, Fukuoka, Japan
+81-(0)93-693-3425
heitagoto@hotmail.com

Co-authors:
Chris Saward
Nottingham Trent University, School of Science and Technology, Nottingham, United Kingdom
+44 (0)115 848 3842
chris.saward@ntu.ac.uk

Journal of Strength and Conditioning Research - JSCR-08-12125R2

ABSTRACT

The aims of the current study were: 1) to examine age-related differences in match-running performance with two different approaches (speed vs metabolic power) in U13 to U18 Japanese elite soccer players; 2) to examine age-related differences in technical match performance in U13 to U18 Japanese elite soccer players. Participants were 110 field players from academies of two professional soccer clubs in Japan. Forty-eight 11-a-side official league matches (13, 6, 9, 7, 6 and 7 matches for U13, U14, U15, U16, U17 and U18 age groups, respectively) were analyzed (152 complete match-files). Global Positioning System (15Hz) and video analysis were employed to analyze running and technical performance during matches, respectively. Total distance covered in absolute terms (U13 < (U14 and U15) < (U16-U18), $P < 0.05$ for all), high-intensity running distance ((U13-U15) < (U16-U18), $P < 0.05$ for all) and distance covered during the metabolic power zone ≥ 35 $w \cdot kg^{-1}$ relative to match playing time ((U13 < U16), (U13-U15) < (U17 and U18), $P < 0.05$ for all), increased with age. The speed zone based approach (high-intensity running distance, ≥ 4.0 $m \cdot s^{-1}$) underestimated high-intensity demands compared to the metabolic power zone based approach (≥ 20 $W \cdot kg^{-1}$) by ~33% to ~57% ($P < 0.01$ for all), with the underestimation declining with age ($P < 0.001$). Pass accuracy improved with age from 73% at U13 to 85% at U18 ($P < 0.001$). Therefore, distance covered at high speeds and at high metabolic powers, and pass accuracy increase with age. Moreover, the speed zone based approach underestimates the demands of match play in Japanese elite youth soccer players. The current results could support coaches to develop players, identify talent and produce age-specific training programs.

Key words:

Association football, metabolic power, skills, match analysis, talent identification.

INTRODUCTION

Match performance in elite youth soccer is dependent on both physical and technical factors (33). Most research in this regard has focused on the physical demands of match-play by examining elite youth players' match-running performance (2,7,9,16,27,30). Such research has tended to use Global Positioning Systems (GPS) to measure total distance covered by players, and distances covered by players within certain speed zones. The studies have established that elite youth soccer players (10 to 18 years old) cover between 4500 and 7000 $m{\cdot}h^{-1}$ in a 60-90 min match with ~3 to ~30% of this distance being covered at high speeds ($\geq$ 4.2 $m{\cdot}s^{-1}$) (2,7,9,16,30). However, the majority of studies examining match-running performance in elite youth soccer have been conducted in Australia (12), Brazil (27), Denmark (32), England (16,30), Italy (8,9), New Zealand (2) and Qatar (7). Conversely, there is a dearth of match-running performance data on elite youth players from eastern Asia. In senior professionals, previous research has shown differences between national leagues in match-running performance (11), and thus, whether the findings from South American and European elite youth players extend to elite youth eastern Asian players remains unclear. Since soccer is one of the most popular sport in the world, contextual match-running data are required to support coaches, sports scientists and players in this region.

Match-running performance has conventionally been assessed using a speed-zone based approach whereby the distance covered by players within certain speed thresholds is measured (2,7,9,16,30). However, in recent years, researchers have estimated players' metabolic power as an alternative estimate of the physical demands of match-play in professional soccer players (25). Metabolic power is based on an assumption that accelerated/decelerated running on a horizontal level is energetically equivalent to uphill/downhill running at a constant speed on an ‘equivalent’ slope and is calculated by multiplying estimated energy cost of accelerated/decelerated running and running speed on a horizontal level (25). As energy costs are independent of the velocity and the energetics of uphill/downhill running can be estimated, an estimation of the energy costs of accelerated/decelerated running on a horizontal level can be obtained (25). Unlike the speed zone based approach, estimations of metabolic power account for the accelerations and decelerations made by players during match-play (25). Indeed, even running at low speeds, a high metabolic load may be imposed on soccer players if accelerations and decelerations are elevated.

Previous studies have examined the validity of GPS for estimating energy expenditure during field-sport locomotor movements (5,6,26). These studies reported that GPS-derived parameters underestimated energy expenditure by ~5% to ~45% depending on the movements compared to direct measurement of oxygen consumption using a portable gas analyzer (5,6,26). However, using GPS systems during match-play is more practical and feasible than using portable gas analyzers. When GPS-derived parameters are considered, the metabolic power zone based approach attempts to account for the energy demands of accelerations and decelerations, and is more closely related to energy expenditure than the speed zone based approach, and is thus potentially a more appropriate method to describe match-play demands in soccer (19).

The high-intensity demands of training and small-sided games have been assessed using speed zone based and metabolic power zone based approaches in professional soccer players (14,15). In these studies, high-intensity demands estimated via the speed zone based approach was considered to be distance covered at ≥4.0 $m \cdot s^{-1}$ and high-intensity demands estimated via the metabolic power zone based approach was considered to be distance covered at ≥20 $W \cdot kg^{-1}$. This was because 20 $W \cdot kg^{-1}$ is the metabolic power when running at a constant speed of approximately 4.0 $m \cdot s^{-1}$ on natural (25) and artificial (29) grass surfaces. Results demonstrated that the high-intensity demands of soccer were underestimated when applying the fixed speed zone based approach compared to applying the estimated metabolic power zone based approach. The underestimation was approximately 30-40% during training (14) and 45-350% during various small-sided games (15). In addition, such underestimation was ~45% during a professional soccer match (25). Whether the differences between the speed zone based and metabolic power zone based approaches in estimating match-running performance extends to elite youth soccer is yet to be investigated. Such data may provide coaches and sport scientists with a more realistic reflection of the demands of match play (15).

The physical attributes required for success in soccer are insufficient unless supplemented by an adequate grounding in the skills of the game (33). Whereas, the match-running performance of youth soccer players across a wide age range has been studied in recent years (16,30), technical match performance has only been reported in a limited number of age groups (35,36) or limited technical performance measures (22,36). Previous studies have reported that elite under-17 (U17) players perform a greater number of passes (~38 to ~45 passes) and demonstrate a better pass accuracy (77-82%) (35) during a match compared to elite U14 players (~31 passes and a pass accuracy of 72 %, respectively) (36) Whether such age-related differences in technical match performance of youth soccer players extend across a wider age range, remains unclear. An investigation examining both physical and technical aspects of match-play across a wide age range of youth soccer players is needed to provide a holistic understanding of match performance and its development in youth soccer.

To the authors' knowledge, there are no match-running and technical performance data regarding youth soccer players from Eastern Asia, no match-running performance data estimated using the metabolic power zone based approach in youth soccer, and limited match technical performance related studies in youth soccer players. The availability of such information could support coaches and sports scientists in developing players, identifying talent, and creating age-specific training programs. Therefore, the aims of the current study were: 1) to examine age-related differences in match-running performance using two different approaches (speed and metabolic power zone based approaches) in U13 to U18 Japanese elite soccer players; 2) to examine age-related differences in technical match performance in U13 to U18 Japanese elite soccer players.

METHODS

Experimental Approach to the Problem

Players (U13, U14, U15, U16, U17 and U18 age groups) were recruited from academies of two professional soccer clubs in Japan which represents the highest standard of youth soccer development in Japan. The running and technical performance during match play of these players were assessed across a playing season. This allowed age-related differences in the running and technical match performance of Japanese elite youth soccer players to be elucidated, which in turn, may support player development and talent identification at this level and provides the first norms for Japanese elite youth soccer players, allowing comparative data for other studies interested in this under-explored population.

To analyze match running performance in more detail, distance covered in particular speed zones and metabolic power zones was assessed using GPS (15Hz (5 Hz interpolated to 15 Hz), SPI HPU, GPSports, Canberra, Australia). This allowed the differences in match running performance between the two approaches in elite youth soccer players to be examined. Moreover, 11 variables were selected as technical performance measures; three related to defending, seven related to attacking, and one related to total involvement with the ball.

Subjects

The participants were 110 outfield players (age range = 12.2 to 18.7 years) who belonged to academies of two professional soccer clubs in Japan (see table 1 for mean age of each age group). There was one Japanese international player in the U13 and U16 age groups and two Japanese international players in the U15, U17 and U18 age groups. In each week during the season, the U13, U14 and U15 age groups generally participated in four 2-hour training sessions and a match, and the U16, U17 and U18 age groups generally had five 2-hour training sessions and a match. Players were provided with a written and verbal explanation of the study including all measurements to be taken. Each player signed an informed assent form and completed a health screen questionnaire prior to participation in the study. Each player's parent, guardian or care-giver signed a consent form prior to the start of the study. Players were free to withdraw from the study without giving any reasons and without any penalty regarding their academy position and this was explained to them verbally and in writing. Participants were withdrawn from the study if they did not have a satisfactory health status. The study was approved by a University Ethics Committee.

Match analysis

Match analysis was conducted on official league matches. All matches were played on international match size (length = 100-110 m, width = 64-75 m, Fédération Internationale de Football Association (FIFA)) flat artificial grass pitches (third generation astroturf). A total of 48 11-a-side matches were analyzed and 152 complete match-files were obtained (1-5 match-files per player, see table 1 for number of matches and match-files in each age group). Match duration was 60, 70, 80 and 90 min for U13, U14, U15 and U16-U18 age groups, respectively. To be included in the analysis, players were required to play a full match, play the same position throughout the match, and play in a 4-4-2 formation. This was because playing formation (3,31) and playing position (7,21,35) influence physical and technical performance. Playing position distribution was 41% central defenders, 14% wide defenders, 23% central midfielders, 5% wide midfielders and 18% strikers in all age groups. All match files were obtained from the teams who finished in the top half of the league except 18-45% of match files from the U16, U17 and U18 age groups (all teams finished in 8th out of 10 teams). In each age group, final league position of opposition teams was fairly evenly spread from the top to bottom and 55-77% and 29-57% of match-files were from home matches and matches won, respectively.

---------------------------------Table 1 here---

Match-running performance

The match-running performance of each player was analyzed with the assessment of distances covered at different speed zones (35) and distances covered at different metabolic power zones (23,25) (see table 2). Metabolic power was estimated by the previously reported equation and energy cost of running at constant speed was assumed as 3.6 $J \cdot kg^{-1} \cdot m^{-1}$ (25).

$$\text{Metabolic power} = EC \cdot v$$

Where, EC is the energy cost of accelerated running on grass ($J \cdot kg^{-1} \cdot m^{-1}$) = $(155.4 \cdot ES^5 - 30.4 \cdot ES^4 - 43.3 \cdot ES^3 + 46.3 \cdot ES^2 + 19.5 \cdot ES + 3.6) \cdot EM \cdot KT$, ES = the equivalent slope = $\tan(90 - \arctan g/a_f)$, g = Earth's acceleration of gravity; a_f = forward acceleration; EM = the equivalent body mass = $[(a_f^2 \cdot g^{-2}) + 1]^{0.5}$, KT = a constant = 1.29, v = running speed ($m \cdot s^{-1}$). The distances were expressed in absolute (meters per match) and relative (meters per hour of match playing time) terms.

Match running performance was analyzed with 15 Hz (5 Hz interpolated to 15 Hz) GPS technology (SPI HPU, GPSports, Canberra, Australia) which was positioned on the upper back in a custom-made vest. This device has been reported to possess an accuracy of greater than 99% when 8 laps of 165 m team sport simulation circuit with various movement speeds (walking to sprinting and fast deceleration) and change of directions at different angles (figure eight agility run and 90 degrees turning) was performed (18). Moreover, maximal speed during 10, 20 and 30 m sprints showed less than a 5% difference compared to the values measured by photoelectric timing gates (18). Inter-unit reliability (typical error expressed as coefficient of variation (CV)) for total distance covered, distance covered at < 3.9 $m \cdot s^{-1}$, 3.9-5.6 $m \cdot s^{-1}$ and >5.6 $m \cdot s^{-1}$ were 1.9, 2.0, 7.6 and 12.1%, respectively (18).

The validity and reliability of GPS for measuring accelerations and decelerations has been previously assessed with a 50 Hz Laveg laser (34). Validity (typical error (CV)) of accelerations and decelerations were 3.6-5.9% and 11.3%, respectively, and reliability (typical error (CV)) of accelerations and decelerations were 1.9-4.3% and 6.0%, respectively (34). Furthermore, validity of GPS for determining metabolic power has been examined using 32 Hz radar system (28). The study employed 70 m (35 + 35 m) of self-paced intermittent running involving walking, jogging, accelerations and decelerations during running and 70 m (35 + 35 m) of self-paced running (35 m) and sprinting (35 m) (28). The typical error (CV) of mean metabolic power, time spent at high metabolic power (> 20 $W \cdot kg^{-1}$) and time spent at very high metabolic power (> 25 $W \cdot kg^{-1}$) were 2.4%, 4.5% and 6.2%, respectively (28).

In the current study, the same GPS unit could not always be worn by a player in different matches due to logistical issues. At least 8 satellites (mean ± SD = 9.7 ± 0.9 satellites) were connected during data collection which is the minimum number of satellites required to allow an accurate measurement (34,37) and mean horizontal dilution of position was 1.2 ± 0.4. The distances covered in speed and metabolic power zones were calculated using Team AMS software version R1.2016.4 (GPSports, Canberra, Australia).

---------------------------------Table 2 here---

Technical match performance

Matches were recorded using a video camera (HC-V360M, Panasonic, Osaka, Japan) positioned 5 m away from the halfway line and 3 m above the ground level. Videos were transferred to PC and on-the-ball actions of each player were manually notated. The technical variables and associated operational definitions (Matchinsight, Prozone Sports Ltd®, Leeds, UK) are presented in table 3. To calculate the technical performance variables in relative terms, attacking and defending variables were adjusted for the team's ball possession duration and opposition's ball possession duration, respectively. This is because the ball possession time varies between the matches and the players can only perform attacking technical measures when the team is in possession of the ball and defensive technical measures when the opposition is in possession of the ball (20). All variables were expressed in absolute (per match) and relative (per hour of team's/opposition's ball possession time) terms.

All matches were analyzed by one analyst who possessed UEFA (Union of European Football Associations) "B" coaching license. The analyst had analyzed more than 20 matches prior to the analysis of the current data. The analyst independently coded the same randomly selected match twice with 6 months apart to assess intra-observer reliability. Cohen's Kappa was employed to examine the strength of agreement between observations on the technical performance variables. Overall, intra-observer reliability was very good ($\kappa = 0.88$, $p < 0.05$). Moreover, there was a very good agreement between observations for headers/shots ($\kappa = 1.00$, $p < 0.05$), successful passes ($\kappa = 0.92$, $p < 0.05$), crosses/dribbles ($\kappa = 0.89$, $p < 0.05$), passes/touches ($\kappa = 0.88$, $p < 0.05$), clearances ($\kappa = 0.82$, $p < 0.05$), and good agreement for tackles ($\kappa = 0.78$, $p < 0.05$) and blocks ($\kappa = 0.76$, $p < 0.05$) (1).

---------------------------------Table 3 here---

Statistical analyses

Data were not normally distributed as examined by Kolmogorov-Smirnov tests. Spearman's rank correlations (r_s) were employed to examine the relationship between age and match performance variables. The magnitude of correlation coefficients was considered as trivial ($r_s < 0.1$), small ($0.1 \leq r_s < 0.3$), moderate ($0.3 \leq r_s < 0.5$), large ($0.5 \leq r_s < 0.7$), very large ($0.7 \leq r_s < 0.9$) nearly perfect ($0.9 \leq r_s < 1.0$), and perfect ($r_s = 1.0$) (17).

Kruskal-Wallis tests were conducted to examine the effect of age-group on match performance variables. Pairwise comparisons with adjusted P-values were performed to assess differences (13). To examine differences between speed and metabolic power zone based approaches in estimating high-intensity demands during match-play, a Mann-Whitney U test was performed to compare high-intensity running and MP≥20 distances.

The effect size (r_{ES}) for the differences were calculated wherever appropriate by dividing z-score by square root N (13) and the values (r_{ES}) were considered as trivial ($r_{ES} < 0.01$), small to medium (0.1 to 0.3), medium to large (0.3 to 0.5) and large to very large ($r_{ES} > 0.5$) (10). The level of statistical significance was set at $p < 0.05$. Results are presented as mean ± SD and all the statistical analyses were performed using SPSS version 22.0 (IBM SPSS statistics for Windows, IBM, Armonk, New York, USA).

RESULTS

Running performance during match play

Match-running performance of each age group is detailed in table 4. Absolute total distance covered during a match increased with age from 7388 ± 741 m for the U13 age group to 11469 ± 921 m for the U18 age group ($P < 0.001$, $r_{ES} = 1.04$). For absolute distance covered in all speed zones and metabolic power zones, there were significant between-age group differences, with older age groups completing greater distances ($P < 0.001$, $r_{ES} = 0.77\text{-}1.10$).

When match-running distance was adjusted to match playing time, total distance was similar between all age groups (~7000 $m \cdot h^{-1}$). For distance covered in particular speed zones, walking (~2200 to ~2400 $m \cdot h^{-1}$), jogging (~900 to ~1100 $m \cdot h^{-1}$) and running (~900 to ~1100 $m \cdot h^{-1}$) distances were not different between the age groups. Distance covered by high-speed running, sprinting, high-intensity running and very high-intensity running increased with age from the U13 to U17 age group (at least $P < 0.05$, $r_{ES} = 0.41\text{-}0.74$) (figure 1). There was a positive relationship between age and distance covered by high-speed running ($r_s = 0.54$), sprinting ($r_s = 0.58$), high-intensity running ($r_s = 0.34$) and very high-intensity running ($r_s = 0.56$) ($P < 0.001$ for all).

For the metabolic power zone based approach, distance covered per hour of match-play by the U13 to U18 age groups in LP, MedP, HP and MP≥20 were ~2700 to ~2900 $m \cdot h^{-1}$, ~2300 to ~2700 $m \cdot h^{-1}$, ~1200 to ~1400 $m \cdot h^{-1}$ and ~1700 to ~2000 $m \cdot h^{-1}$, respectively and there were no between-age group differences. Distance covered in EP, MaxP and MP≥35 increased with age from the U13 to U17 age group (at least $P < 0.01$ for all, $r_{ES} = 0.49\text{-}0.78$) (figure 2).

There was a positive relationship between age and distance covered in EP ($r_s = 0.38$), MaxP ($r_s = 0.61$) and MP≥35 ($r_s = 0.50$) ($P < 0.001$ for all).

---------------------------------Table 4 and figure 1&2 here---

Comparison of high-intensity running distance and distance covered in MP≥20

High-intensity running distance was ~600 to ~800 m shorter than distance covered in MP≥20 in all age groups ($P < 0.01$ for all, $r_{ES} = 0.49$-0.61). The percentage difference (%) between high-intensity running and MP≥20 distances declined with age from 56.9 ± 25.5% for the U13 age group to 30.4 ± 10.6% for the U17 age group ($P < 0.001$, $r_{ES} = 0.63$) (figure 3) and there was a negative relationship between age and percentage difference ($r_s = -0.45$, $P < 0.001$).

---------------------------------Figure 3 here---

Technical performance during match play

For absolute technical match performance, the number of passes, touches and involvements with the ball increased with age from the U13 to U18 age group ($P < 0.001$, $r_{ES} = 0.40$-0.55). Moreover, pass accuracy gradually improved with age by 12% from the U13 to U18 age group ($P < 0.001$, $r_{ES} = 0.58$) and there was a positive relationship between age and pass accuracy ($r_s = 0.33$, $P < 0.01$) (figure 4). No apparent trends were observed in the rest of technical performance variables.

There were no between-age group differences in team and opposition possession time (%) (table 4). When technical performance was adjusted for possession times, no between-age group differences were observed in all technical performance variables (table 5).

----------------------------------Table 4&5 and figure 4 here--

DISCUSSION

The current study is the first to examine the development of match-running performance, using speed and metabolic power zone based approaches, and technical match performance in U13 to U18 elite Japanese soccer players. The main findings of the present study were that: both absolute and relative distance covered at high speeds (sprinting: > 7.0 $m \cdot s^{-1}$ and very high-intensity running: ≥ 5.5$m \cdot s^{-1}$) and metabolic power (MaxP: > 55 $W \cdot kg^{-1}$ and MP≥35: ≥ 35 $W \cdot kg^{-1}$) increased similarly with age; high-intensity demands were underestimated by the speed zone based approach (≥ 4.0 $m \cdot s^{-1}$) compared to the metabolic power zone based approach (≥ 20 $W \cdot kg^{-1}$) in all age groups; the underestimation of high-intensity demands reduced with age; and finally, pass accuracy improved with age.

Total distance and distances covered at various speed zones during match-play increased with age. This is the first study to examine the development of match-running performance in elite youth soccer players from Japan. The current results are in-line with previous research into elite youth soccer players from Europe and western Asia that show similar age-related improvements in match-running performance (7,16). This is also the first study to provide data regarding the development of match-running distance using the metabolic power zone based approach in elite youth soccer. When match-running distance was calculated using the metabolic power zone based approach, the pattern of increases in distance covered with age was similar to the speed zone based approach data. However, when the distances were adjusted for match playing time, between-age group differences were less evident in total distance, distance covered at lower speeds (walking to running), and distance covered at lower metabolic powers (LP to HP), which is in line with previous studies (7,12,16). Conversely, when adjusted for playing time, distances covered within high speed and metabolic power zones still demonstrated improvements with age and improvements were more apparent in higher speed and metabolic power zones (i.e., sprinting, very high-intensity running, MaxP and MP≥35). The age-related differences in speed zone distances are similar to the previous studies on elite youth soccer players from England (16) and Qatar (7). Therefore, speed and metabolic power zone based approaches show similar improvements in match-running distance with age in both absolute and relative terms. Further, both approaches demonstrate the importance of distance covered at high intensity, which supports previous research showing that the distance covered at high speeds differentiate age groups in elite youth players (16) and the standard of play in professional senior soccer players (24).

In the current study, high-intensity demands of soccer matches were underestimated by 33 to 57% in the U13 to U18 elite youth soccer players when match-running distance was calculated using a speed zone based approach ($\geq 4.0\ m \cdot s^{-1}$) compared to a metabolic power zone based approach ($\geq 20\ W \cdot kg^{-1}$). Similar underestimations (~45 to ~72%) have been reported from professional soccer players during 10 vs 10 small-sided-games (14) and match play (25). The underestimation of high-intensity demands declined with age from 57% in the U13 to 33% in the U17 age group. A possible explanation for this age-related variation in the underestimation of high-intensity running is that although high-intensity running distance ($\geq 4.0\ m \cdot s^{-1}$) increased with age, younger players are possibly producing a greater amount of high-intensity activities (i.e. acceleration and decelerations) at low speeds compared to older counterparts since running distance at high speeds in younger age groups were less than older age groups. Hence, it is important for coaches and sports scientists to know that the conventional speed zone based approach underestimates match demands of elite youth soccer players and such underestimation is greater in younger players.

To our knowledge, this study is the first to investigate differences in technical performance between six consecutive age groups (U13 to U18) in Japanese elite youth soccer players. The results demonstrated that pass accuracy improved with age from 73% for the U13 age group to 85% for the U18 age group and similar values have been demonstrated by U14 elite and sub-elite (36) and U17 elite players (35). Previous research has shown that pass accuracy was greater for teams with higher than lower ranking in an U17 international tournament (35) and was greater for the top three (82%) than the bottom three (75%) teams in the first division of Spanish professional soccer league (21). This suggests that pass accuracy distinguishes standard of play in professional and youth soccer players. The current study supports and extends previous work by showing that pass accuracy improves with age in elite youth soccer players, suggesting that it is an important technical performance measure for coaches to focus on during the process of player development and talent identification.

Moreover, the number of passes, touches, and involvements with the ball during a match increased with age in the U13 to U18 elite youth soccer players. However, the between-age group differences disappeared when these technical performance variables were adjusted for ball possession time. Nevertheless, the number of tackles, crosses, passes and shots in the current sample were similar to that of the U17 soccer players who were competing in the top division league of various countries (35). This suggests that the technical performance of elite youth Japanese soccer players is similar to that of elite youth soccer players from other countries. It is possible that at this high standard of play, the technical profiles seen in the current study (and previous research), are minimum requirements for performance in elite youth soccer, but that more sensitive measures of technical performance are possibly required to differentiate subgroups within this homogenous population. Future research may consider assessing factors such as success rates, passing distribution distance, location on the pitch etc. (3).

There were some potential limitations of the current study. Firstly, the team and opposition quality (4,21,35), match location (4,21) and match outcome (4,21) have been shown to influence physical and technical performance, and these factors were not considered in the current study. However, given that the team and opposition ball possession times are influenced by team and opposition strengths (4), no between-age group differences in the team and opposition ball possession times were observed in the current study. Moreover, the final league position of most teams was in the top half, and the final league position of opposition teams that each age group faced, was fairly evenly spread from the top to bottom. Hence, the team and opposition strength were possibly similar across the age groups. In addition, similar match location and outcome distributions were observed in each age group (55-77% and 29-57% of match-files in each age group were from home matches and matches won, respectively) that the influence of match location and outcome may be insignificant.

PRACTICAL APPLICATIONS

The current study highlights a similar trend in age-related improvements of match-running distance at high-speeds and at high metabolic powers in U13 to U18 elite Japanese soccer players. However, the speed zone based approach ($\geq 4.0\ m \cdot s^{-1}$) underestimates high-intensity demands of soccer matches compared to metabolic power zone based approach ($\geq 20\ W \cdot kg^{-1}$) and a greater underestimation was observed in the younger age groups which suggests that younger players produce a large proportion of high-intensity activities (accelerations and decelerations) at low speeds. Moreover, an improvement in pass accuracy with age was revealed. Therefore, coaches and sports scientists are recommended to carefully consider distance covered by high-speed and high metabolic power during match play especially when they compare match-running performance of players from different age groups. Moreover, an employment of metabolic power zone based approach rather than speed zone based approach is advised to estimate high-intensity demands of match play in youth soccer players and the current results would support coaches and sports scientists to produce age-specific training programs. For technical attributes, it is recommended to focus on pass accuracy when developing players and identifying talent in elite youth players.

ACKNOWLEDGEMENTS

This work was supported by JSPS KAKENHI Grant Number 26350804

REFERENCES

1. Altman, D. G. (1991). Practical statistics for medical research. London: Chapman & Hall.
2. Atan, SA, Foskett, A, and Ali, A. Motion Analysis of Match Play in New Zealand U13 to U15 Age-Group Soccer Players. *J Strength Cond Res* 30: 2416-2423, 2016.
3. Bradley, PS, Carling, C, Archer, D, Roberts, J, Dodds, A, Di Mascio, M, et al. The effect of playing formation on high-intensity running and technical profiles in English Fa premier league soccer matches. *J Sports Sci* 29: 821-830: 2011.
4. Bradley, PS, Lago-Peñas, C, Rey, E, and Sampaio, J. The influence of situational variables on ball possession in the English premier league. *J Sports Sci* 32: 1867–1873, 2014.
5. Brown, DM, Dwyer, DB, Robertson, SJ, and Gastin PB. Metabolic Power Method: Underestimation of Energy Expenditure in Field-Sport Movements Using a Global Positioning System Tracking System. Int J Sports Physiol Perform 11: 1067-1073, 2016.
6. Buchheit, M, Manouvrier, C, Cassirame, J, and Morin, JB. Monitoring locomotor load in soccer: is metabolic power, powerful. Int J Sports Med 36: 1149-1155, 2015.
7. Buchheit, M, Mendez-Villanueva, A, Simpson, BM, and Bourdon, PC. Match running performance and fitness in youth soccer. *Int J Sports Med* 31: 818–825, 2010.
8. Castagna, C, D'Ottavio, S, and Abt, G. Activity profile of young soccer players during actual match play. *J Strength Cond Res* 17: 775–780, 2003.
9. Castagna, C, Impellizzeri, FM, Cecchini, E, Rampinini, E, and Alvarez, J. Effects of intermittent-endurance fitness on match performance in young male soccer players. *J Strength Cond Res* 23: 1954–1959, 2009.
10. Cohen, J. *Statistical power analysis for the behavioural sciences (2nd ed.)*. Hillsdale, NJ: Lawrence Erlbaum, 1988.

11. Dellal, A, Chamari, K, Wong, DP, Ahmaidi, S, Keller, D, Barros, R, et al. Comparison of physical and technical performance in European soccer match-play: FA Premier League and La Liga. *Eur J Sport Sci* 11: 51-59, 2011.
12. Duthie, GM, Thornton, HR, Delaney, JA, Connolly, DR, and Serpiello, FR. Running Intensities in Elite Youth Soccer by Age and Position. *J Strength Cond Res* 32: 2918-2924, 2018.
13. Field, A. *Discovering Statistics using IBM SPSS Statistics (4th ed.)*. London, UK: Sage Publications Ltd, 2013.
14. Gaudino, P, Iaia, FM, Alberti, G, Hawkins, RD, Strudwick, AJ, and Gregson, W. Systematic bias between running speed and metabolic power data in elite soccer players: influence of drill type. *Int J Sports Med* 35: 489-493, 2014.
15. Gaudino, P, Iaia, FM, Alberti, G, Strudwick, A, Atkinson, G, and Gregson, W. Monitoring training in elite soccer players: Systematic bias between running speed and metabolic power data. *Int J Sports Med* 34: 963–968, 2013.
16. Goto, H, Morris, JG, and Nevill, ME. Motion analysis of U11 to U16 elite English premier league academy players. *J Sports Sci* 33: 1248–1258, 2015.
17. Hopkins, WG. (Last updated in 2013). *A Scale of Magnitudes for Effect Statistics.* Available at: http://www.sportsci.org/resource/stats/index.html. Accessed March 2018.
18. Johnston, RJ, Watsford, ML, Kelly, SJ, Pine, MJ, and Spurrs, RW. Validity and interunit reliability of 10 Hz and 15 Hz GPS units for assessing athlete movement demands. *J Strength Cond Res* 28: 1649-1655, 2014.
19. Highton, J, Mullen, T, Norris, J, Oxendale, C, and Twist, C. Energy expenditure derived from micro-technology is not suitable for assessing internal load in collision-based activities. *International Journal of Sports Physiology and Performance,* 20: 957-961, 2017.

20. Liu, H., Gomez, MA, Lago-Penas, C, and Sampaio, J. Match statistics related to winning in the group stage of 2014 Brazil FIFA World Cup. *J Sports Sci* 33: 1205–1213, 2015.

21. Liu, H, Gomez, MA, Gonçalves, B, and Sampaio, J. Technical performance and match-to-match variation in elite football teams. *J Sports Sci* 34: 509-518, 2016.

22. Malcata, RM., Hopkins, WG, and Richardson, S. Modelling the progression of competitive performance of an academy's soccer teams. *J Sports Sci Med* 11: 533–536, 2012.

23. Manzi, V, Impellizzeri, F, and Castagna, C. Aerobic fitness ecological validity in elite soccer players: a metabolic power approach. *J Strength Cond Res* 28: 914-9, 2014.

24. Mohr, M, Krustrup, P, and Bangsbo, J. Match performance of high-standard soccer players with special reference to development of fatigue. *J Sports Sci* 21: 519–528, 2003.

25. Osgnach, C, Poser, S, Bernardini, R, Rinaldo, R, and Di Prampero, PE. Energy cost and metabolic power in elite soccer: A new match analysis approach. *Med Sci Sports Exerc* 42: 170–178, 2010.

26. Oxendale, CL, Highton, J, Twist, C. Energy expenditure, metabolic power and high speed activity during linear and multi-directional running. J Sci Med Sport 20: 957-961, 2017.

27. Pereira Da Silva, N, Kirkendall, DT, and De Barros Neto, TL. Movement patterns in elite Brazilianyouthsoccer. *J Sports Med Phys Fitness* 47: 270-275, 2007.

28. Rampinini, E, Alberti, G, Fiorenza, M, Riggio, M, Sassi, R, Borges, TO, et al. Accuracy of GPS devices for measuring high-intensity running in field-based team sports. Int J Sports Med 36: 49-53, 2015.

29. Sassi, A, Stefanescu, A, Menaspa', P, Bosio, A, Riggio, M, and Rampinini, E. The cost of running on natural grass and artificial turf surfaces. *J Strength Cond Res* 25: 606-611, 2011.

30. Saward, C, Morris, JG, Nevill, ME, Nevill, AM, and Sunderland, C. Longitudinal development of match-running performance in elite male youth soccer players. *Scand J Med Sci Sports* 26: 933-942, 2015.

31. Schuth, G, Carr, G, Barnes, C, Carling, C, and Bradley, PS. Positional interchanges influence the physical and technical match performance variables of elite soccer players. *J Sports Sci* 34: 501-508, 2016.

32. Stroyer, J, Hansen, L, and Klausen, K. Physiological profile and activity pattern of young soccer players during match play. *Med Sci Sports Exer* 36: 168– 174, 2004.

33. Unnithan, V, White, J, Georgiou, A, Iga, J, and Drust, B. Talent identification in youth soccer. *J Sports Sci* 30: 1719–1726, 2012.

34. Varley, MC, Fairweather, IH, and Aughey, RJ. Validity and reliability of gps for measuring instantaneous velocity during acceleration, deceleration, and constant motion. *J Sports Sci* 30: 121–127, 2012.

35. Varley, MC, Gregson, W, McMillan, K, Bonnano, D, Stafford, K, Modonutti, M, et al. Physical and technical performance of elite youth soccer players during international tournaments: influence of playing position and team success and opponent quality. *Sci Med Football*, 1: 18-29, 2017.

36. Waldron, M, and Murphy, A. A comparison of physical abilities and match performance characteristics among elite and subelite under-14 soccer players. *Pediatr Exerc Sci* 25: 423–434, 2013.

37. Waldron, M, Worsfold, P, Twist, C, and Lamb, K. Concurrent validity and test-retest reliability of a global positioning system (GPS) and timing gate to assess sprint performance variables. *J Sports Sci* 29: 1613 – 1619, 2011.

Figure captions

Figure 1. Pass accuracy of the U13 to U18 elite soccer player (%). Significantly different at $p < 0.05$ vs. a: U13, b: U14, c: U15, d: U16. **P < 0.001.

Figure 2. Distance covered by running, high-speed running, sprinting, high-intensity running and very high-intensity running in the U13 to U18 elite soccer players relative to match playing time. Significantly different at $p < 0.05$ vs. a: U13, b: U14. *P < 0.01. **P < 0.001.

Figure 3. Distance covered by HP (high power), EP (elevated power), MaxP (maximal power), MP≥20 (≥ 20 $W \cdot kg^{-1}$) and MP≥35 (≥ 35 $W \cdot kg^{-1}$) in the U13 to U18 elite soccer players relative to match playing time. Significantly different at $p < 0.05$ vs. a: U13, b: U14, c: U15. *P < 0.01. **P < 0.001.

Figure 4. Percentage differences in high-intensity running and MP≥20 distances (%) in the U13 to U18 elite soccer players. Significantly different at $p < 0.05$ vs. a: U13, b: U14, c: U15. **P < 0.001.

Tables

Table 1. Age, number of matches, number of players and complete match files of the U13 to U18 elite youth soccer players

Age group		U13	U14	U15	U16	U17	U18
Age (years)	Mean	13.1	14.0	15.0	15.9	17.1	18.1
	SD	0.4	0.4	0.3	0.5	0.4	0.3
Number of matches		13	6	9	7	6	7
Number of players		30	14	20	16	14	16
Complete match-files (no.)		35	17	25	22	22	31

Table 2. Speed and metabolic power categories

Speed categories ($m \cdot s^{-1}$)		**Metabolic power categories ($W \cdot kg^{-1}$)**	
Standing	0.0-0.2	Lower power (LP)	0-10
Walking	0.2-2.0	Medium power (MedP)	10-20
Jogging	2.0-4.0	High power (HP)	20-35
Running	4.0-5.5	Elevated power (EP)	35-55
High speed running	5.5-7.0	Maximal power (MP)	> 55
Sprinting	> 7.0	MP≥20	≥ 20
High intensity running	≥ 4.0	MP≥35	≥ 35
Very high intensity running	≥ 5.5		

Table 3. Technical performance variables and their definitions

Defending variables	
Block:	An opposing player, in close proximity, prevents the ball from reaching its intended target. This can take place anywhere on the pitch.
Clearance:	A defensive touch undertaken by a player under pressure from the opposition or with no intended target.
Tackle:	Dispossession or attempted dispossession of an opponent by physical challenge or pressure when actual challenge/tackle is attempted.
Attacking variables	
Cross:	Any ball played from a wide area into the box with the aim of creating a goal scoring opportunity.
Dribble:	Any run with the ball that involves either multiple touches with a directional change or beating an opponent.
Header:	Any touch of the ball with a player's head except a shot using head.
Pass:	Any attempt by a player to play the ball to a team-mate.
Pass accuracy:	A ratio calculated from successful passes divided by all passes (presented in percentages).
Shot:	Any attempt at goal with any part of the body.
Touch:	Any touch other than a block/clearance/cross/dribble/pass/shot/tackle taken by a player with any part of his body except his head, includes mis-controls of the ball.
Involvement with the ball:	Sum of count values of all attacking and defending variables (except pass accuracy).

Table 4. Physical and technical performances during a match in the U13 to U18 elite youth soccer players (absolute values)

Age group		U13	U14	U15	U16	U17	U18	r_{ES}
Total playing time (min)	Mean	64.6	76.5	84.2	94.7	95.2	95.1	
	SD	4.1	5.7	1.4	0.7	1.9	1.7	
Percentage time team possessed the ball (%)	Mean	34	35	33	32	32	34	
	SD	5	8	3	6	5	7	
Percentage time opponents possessed the ball (%)	Mean	28	29	30	29	28	28	
	SD	5	6	6	7	6	7	
Time ball out of play (%)	Mean	38	36	37	39	40	38	
	SD	8	7	4	4	3	3	
Total distance (m)	Mean	7388	9305^{a}	9846^{a**}	11257^{a**b*c}	11223^{a**b*c}	$11469^{a**b**c*}$	0.41-1.04
	SD	741	1271	821	746	954	921	
Speed zone based approach								
Walking (m)	Mean	2569	2789	3343^{a**}	3653^{a**b**}	3827^{a**b**}	3774^{a**b**}	0.58-1.02
	SD	231	425	300	266	332	332	
Jogging (m)	Mean	3584	483^{a*}	4782^{a**}	5210^{a**}	4966^{a**}	5325^{a**}	0.54-0.89
	SD	642	1085	696	685	748	642	
Running (m)	Mean	995	1391	1316	1718^{a**c}	1743^{a**c}	1670^{a**c}	0.40-0.77
	SD	311	490	446	357	416	355	
High-speed running (m)	Mean	190	262	340a	534^{a**b*}	$561^{a**b**c}$	$569^{a**b**c}$	0.40-0.84
	SD	123	143	133	269	193	202	
Sprinting (m)	Mean	14	20	52^{a*}	91^{a**}	115^{a**}	117^{a**}	0.45-0.81
	SD	22	27	41	87	87	90	
High-intensity running (m)	Mean	1199	1673	1707	2343^{a**bc}	2418^{a**bc*}	2355^{a**bc}	0.44-0.87
	SD	396	536	539	550	574	576	
Very high-intensity running (m)	Mean	204	281	391a	625^{a**b*}	$675^{a**b**c}$	$686^{a**b**c}$	0.43-0.86
	SD	138	159	166	337	260	267	
Metabolic power zone based approach								

LP (m)	Mean	3009	3410	3951[a**b*]	4323[a**b**]	4523[a**b**c*]	4470[a**b**c*]	0.52-1.10
	SD	174	382	219	202	243	271	
MedP (m)	Mean	2572	3477[a*]	3461[a**]	3783[a**]	3582[a**]	3918[a**]	0.54-0.93
	SD	438	817	514	486		499	
HP (m)	Mean	1305	1769[a]	1706[a]	2088[a**c]	2014[a**]	1996[a**]	0.40-0.83
	SD	343	518	406	346		373	
EP (m)	Mean	411	525	563	790[a**b*c]	806[a**b*c*]	782[a**b*c*]	0.50-0.92
	SD	118	135	139	199		161	
MaxP (m)	Mean	91	123	165[a]	267[a**b*]	297[a**b**c*]	302[a**b**c*]	0.40-0.91
	SD	67	58	58	120		118	
MP≥20 (m)	Mean	1806	2417	2433[a]	3144[a**bc*]	3118[a**c]	3080[a**c]	0.41-0.90
	SD	429	603	512	516	622	538	
MP≥35 (m)	Mean	501	648	728[a]	105[a**b*c]	1104[a**b**c*]	1084[a**b**c*]	0.38-0.93
	SD	177	184	174	306	243	253	
Technical performance								
Block (no.)	Mean	1	1	2	2	1	1	
	SD	1	1	2	1	1	1	
Clearance (no.)	Mean	2	2	3	4	5	3	
	SD	2	2	2	3	3	3	
Tackle (no.)	Mean	3	3	3	6[ac]	4	4	0.41-0.46
	SD	3	3	3	4	3	3	
Cross (no.)	Mean	1	1	1	1	1	1	
	SD	1	2	1	2	2	2	
Dribble (no.)	Mean	11	13	14	13	9	11	
	SD	7	8	6	9	8	10	
Header (no.)	Mean	5	4	5	6	8[ab*]	7	0.39-0.56
	SD	3	2	3	3	4	5	
Pass (no.)	Mean	29	37	38	37	43[a]	50[a**]	0.40-0.51

	SD	12	17	13	13	17	23	
Shot (no.)	Mean	1	1	1	1	1	1	
	SD	2	1	2	1	1	1	
Touch (no.)	Mean	14	20	18	21	28^{a*}	32^{a**}	0.51-0.54
	SD	6	8	6	9	17	20	
Involvement with the ball (no.)	Mean	68	82	85	90	100^{a*}	110^{a**}	0.47-0.55
	SD	23	32	21	26	35	45	

LP = low power (0-10 $W \cdot kg^{-1}$); MedP = medium power (10-20 $W \cdot kg^{-1}$), HP = high power (20-35 $W \cdot kg^{-1}$); EP = elevated power (35-55 $W \cdot kg^{-1}$); MaxP = maximal power (> 55 $W \cdot kg^{-1}$); MP≥20 (≥ 20 $W \cdot kg^{-1}$); MP≥35 (≥ 35 $W \cdot kg^{-1}$). Significantly different at $p < 0.05$ vs. a: U13, b: U14, c: U15, d: U16. *$P < 0.01$. **$P < 0.001$.

Table 5. Technical performance of the U13 to U18 elite youth soccer players (adjusted to possession time)

Age group		U13	U14	U15	U16	U17	U18
Block (no.)	Mean	4	4	4	3	3	3
	SD	5	3	4	3	3	4
Clearance (no.)	Mean	8	7	7	10	11	7
	SD	7	6	6	8	8	6
Tackle (no.)	Mean	11	9	7	14	9	9
	SD	10	7	6	10	8	7
Cross (no.)	Mean	2	2	2	2	2	3
	SD	2	3	3	3	3	4
Dribble (no.)	Mean	29	30	30	23	17	18
	SD	16	19	13	15	15	14
Header (no.)	Mean	13	9	11	13	16	14
	SD	9	5	8	7	9	11
Pass (no.)	Mean	78	83	82	72	84	88
	SD	25	36	29	19	31	31
Shot (no.)	Mean	4	2	3	2	1	2
	SD	5	2	4	2	2	3
Touch (no.)	Mean	38	44	40	40	54	57
	SD	14	14	13	18	32	35
Involvement with the ball (no.)	Mean	187	189	186	179	198	201
	SD	48	67	49	40	64	68