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Running Performance in a New and Easier Aerobic Field Test is Related to that in a Typical Aerobic Field Test and during Matches in Male Japanese College Soccer Players

Hayao Ozaki*, Atsushi Sado*, Songyun U* and Nariyasu Yasuhara*

*Department of Sport and Health Science, Tokai Gakuen Univeristy
21-233 Nishinohora, Ukigai, Miyoshi, Aichi 470-0207, Japan
ozaki.hayao@gmail.com

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This study had two primary aims: to confirm the relationship between the maximal multistage 20-m shuttle run test (MST) and the 5-min touchlines shuttle run test (TSRT) for soccer players, to evaluate the alternative validity of the tests measuring aerobic fitness, and to investigate the relationship between the 5-min TSRT results and high-speed running performance during matches. For the first aim, 95 Japanese college soccer players performed the MST and 5-min TSRT a week apart, and the relationship between the results of these tests was investigated. For the second aim, 42 players performed the 5-min TSRT, wore global positioning system devices, and played soccer matches a month before and after the day the test was conducted to evaluate running performance. A significant correlation was observed between the number of laps in the MST and the 5-min TSRT ($r = 0.712$, $p < .001$). The number of laps and total running distance were significantly lower in the 5-min TSRT than in the MST. The number of 68-m laps in the 5-min TSRT was significantly correlated with total distance covered, distance covered at 15 km·h^{-1} or more, and the number of sprints. In conclusion, running performance in the 5-min TSRT was related to that in the MST and during matches in male Japanese college soccer players.

Keywords: aerobic capacity; football; running performance

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1. Introduction

Soccer is an aerobic highly taxed and intermittent sport. During a 90-min soccer match, outfield players typically run between 9 and 14 km at 70–75% maximal oxygen uptake ($\dot{V}O_2max$) and 80–90% maximal heart rate (Bangsbo et al., 2006; Dolci et al., 2020; Haugen et al., 2014). Aerobic metabolism provides more than 90% of the total energy required for a match (Bangsbo, 1994; Dolci et al., 2020). Previous studies have shown that higher-level players have greater $\dot{V}O_2max$ (Slimani et al., 2019; Wisloff et al., 1998). Notably, aerobic fitness influences the technical performance during match play, specifically during the later stages (Russell and Kingsley, 2011), and players with poorer aerobic fitness have a greater risk of injury (Malone et al., 2018). Soccer is not a continuous endurance sport; however, intermittent movements are required in the match. Aerobic fitness is also an important factor influencing the ability to resist fatigue during repeated sprinting exercises (Gharbi et al., 2015). Thus, aerobic capacity is one of the most essential physical fitness parameters for continuing to run through a match, and a high level of aerobic capacity is required for outfield players.

Evaluating aerobic fitness is useful for talent identification and selection, training performance monitoring, evaluation of training program effectiveness, and training prescriptions (Bok and Foster, 2021). The gold standard for evaluating aerobic fitness is the direct measurement of $\dot{V}O_2max$ from running to exhaustion in a laboratory environment. As this method requires time, expensive equipment, and trained personnel, cheaper and easier field tests are required, particularly in a team-sport mass setting. Aerobic performance field tests, such as the maximal multistage 20-m shuttle run test (MST) and Yo-Yo intermittent endurance test (YIET), are widely used in team sports, including soccer. Although both the MST and YIET involve running at

various speeds across a 20-m distance, interspersed with frequent changes in direction similar to the movements observed in soccer, the MST involves a more continuous-type running protocol, while the YIET is principally intermittent. Aziz et al. (2005) demonstrated that the soccer players' MST performance was significantly correlated with $\dot{V}O_2max$; however, no significant correlation was observed for YIET, which might mean that YIET is a more favorable field-based endurance performance (Aziz et al., 2005). In any case, these tests take time and effort for a preparation of straight line to change direction and special sound and would take more than 10 min for players with high endurance performance.

The 5-min touchlines shuttle run test (5-min TSRT) that we devised is a simpler field test using only a typical soccer court, stopwatch, electronic whistle, and cones. This is a new continuous-type test, and players run back and forth as much as possible between two touch lines of the soccer pitch, spaced 68-m apart, for 5 min without setting the pace by sound. As the exercise duration to run at the velocity which corresponds to 100% $\dot{V}O_2max$ is approximately 5 min (Billat and Koralsztein, 1996; Hill and Rowell, 1996), in addition to containing changes in direction frequently looking similar to movements as observed in soccer, this test could be the simplest field test evaluating the aerobic capacity of soccer players. Furthermore, to improve the aerobic fitness, high-intensity interval training is often used at the intensity near 100% $\dot{V}O_2max$ for several minutes (Hostrup and Bangsbo, 2023). Thus, interval training using 5-min TSRT protocol can also be used as an effective training for aerobic fitness.

As described previously, because soccer is an aerobic highly taxed and intermittent sport, the 5-min TSRT could be a more useful test if it can evaluate high-speed running (HSR) performance during soccer matches in addition to aerobic fitness. Previous studies have shown that higher-level professional soccer players perform more HSR during matches (Mohr et al., 2003) and HSR has been performed with increasing frequency in professional soccer leagues (Pons et al., 2021), indicating the increasing importance of HSR performance for soccer players. However, no studies have clarified the relationship between the 5-min TSRT and HSR during soccer matches.

Thus, this study had two primary aims. First, to evaluate the alternative validity of the tests measuring aerobic fitness, we confirmed the relationship between the MST and 5-min TSRT in soccer players. The MST is one of the most frequently used field tests to evaluate aerobic fitness (Paliczka et al., 1987). Second, to demonstrate the usefulness of the 5-min TSRT, we investigated the relationship between the 5-min TSRT results and HSR performance during matches.

2. Methods

2.1. Study design

2.1.1. Experiment 1

For the first aim, 95 Japanese college male soccer players (age: 19.4 ± 1.2 years, height: 1.72 ± 0.07 m, body weight: 64.9 ± 7.2 kg) volunteered to participate in this experiment. The players belonged to a soccer team participating in the Tokai University student football league with approximately six training units, including matches, each lasting 90 min, and had competed for at least 6 years. They performed the MST and 5-min TSRT in June on an artificial grass field a week apart, wearing football cleats, and the relationship between the results of these tests was investigated. Both measurements were taken between 5 and 7 p.m., clear skies on sunny days and no strong winds.

2.1.2. Experiment 2

For the second aim, 42 Japanese male college soccer players (age: 19.7 ± 1.1 years, height: 1.75 ± 0.07 m, body weight: 68.2 ± 6.2 kg) belonging to the same team participating in experiment 1 volunteered to participate in this experiment. The number of players by position was as follows: 15 central defenders, 9 fullbacks, 5 central midfielders, 7 wide midfielders, and 6 forwards. The players performed the 5-min TSRT on an artificial grass soccer field, which was scheduled on the day following a rest day, at least 48 h after a match. The players also wore global positioning system (GPS) devices 1 month before and after the day the test was conducted, and played in soccer matches to evaluate their running performance. The GPS data of the participants who played full-time in matches were used to calculate the mean values and investigate the relationship between the 5-min TSRT results and HSR performance during matches. All matches included were official league matches, and no matches went into extra time. Data

were obtained from 1–6 matches (mean value: 2.2 ± 1.7) for each player and the mean value was used for analyses when there were multiple matches data.

The participants in experiments 1 and 2 were recruited through printed advertisements and word-of-mouth. Goalkeepers and patients taking any medication were excluded from the study. All participants were informed of the methods, procedures, and risks and provided consent before participating. This study was conducted in accordance with the principles of the Declaration of Helsinki and approved by the Ethics Committee for Human Experiments of Tokaigakuen University, Japan (Approval number: 2023-5).

2.2. Maximal multistage 20-m shuttle run test (Experiment 1)

The MST was performed as previously described (Aziz et al., 2005). The players ran back and forth between two lines, spaced 20-m apart, in time with a beep sound. Each successful run of 20-m distance was considered the completion of a shuttle. The players ran at a speed of 8.5 km/h for the first minute and progressively increased their pace by 0.5 km/h every minute thereafter. The running pace was provided by an audio device that produced a beep sound at a volume that the players could hear. The players were warned if they did not reach the end line in time once. The test was terminated when the participant was unable to follow the set pace on two consecutive beeps and/or withdrew voluntarily. Verbal encouragement by caches to continue running for as long as possible was provided throughout the test. The number of 20-m laps completed and the total running distance were reported and used for data analysis. The running velocity in the last stage was defined as the maximum aerobic velocity during the MST.

2.3. 5-min touchlines shuttle run test (Experiments 1 and 2)

In the 5-min TSRT, the players ran back and forth as much as possible between the two touchlines of a soccer court, spaced 68-m apart, for 5 min. The players must be ready at the touchline and begin with the sound of an electronic whistle. The players were informed that steady running for 5 min was required for the best performance, and verbal encouragement by the same caches as in the MST to keep running as fast as possible was provided throughout the test. As shown in **Figure 1**, three cones were placed with marks as lines of the penalty area and the distance between the two touchlines was divided into four distances. The distances from the touch line to cones

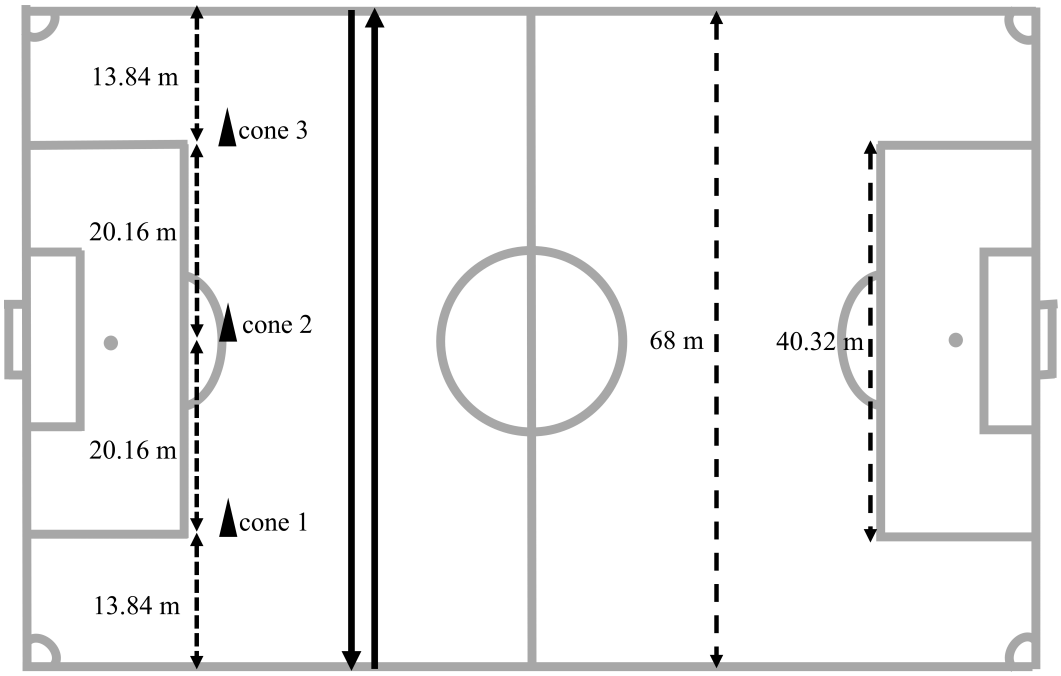

Figure 1 The 5-min touchline shuttle run test using a typical soccer court

1 and 3 and from cone 2 to cones 1 and 3 were 13.84 m and 20.16 m, respectively. The number of 68-m laps completed and the total running distance were reported and used for data analysis. For example, as shown in **Table 1**, the number of 68-m laps completed and total running distance were 18.25 and 1237.84 m, respectively, when a player ran to cone 1 after reaching 18 laps for 5 min. The distance to the cone reached within the test duration was recorded. The mean running velocity for 5 min was defined as the maximum aerobic velocity during the 5-min TSRT. Previous studies have shown that the duration of the running performance which is maintained at 100% of maximal aerobic velocity, varies from 3 to 8 min (Berthon et al., 1997; Billat and Koralsztein, 1996; Hill and Rowell, 1996).

Table 1 Numerical examples of the number of 68-m laps and total distance covered in 5-min touchlines shuttle run test

Number of laps	Total distance covered (m)
18.00	1224.00
18.25	1237.84
18.50	1258.00
18.75	1278.16
19.00	1292.00
19.25	1305.84
19.50	1326.00
19.75	1346.16
20.00	1360.00
20.25	1373.84
20.50	1394.00
20.75	1414.16
21.00	1428.00
21.25	1441.84
21.50	1462.00
21.75	1482.16
22.00	1496.00

2.4. Running performance during soccer matches (Experiment 2)

The total distance covered during a match (TD), distance covered by speed range, and the total number of sprints, accelerations (ACC; > 3 $m \cdot s^{-2}$), and decelerations (DEC; > -3 $m \cdot s^{-2}$) were measured using a 10-Hz Fieldwiz GPS device (Fieldwiz V2, ASI, Lausanne, Switzerland), integrating a 250-Hz triaxial accelerometer microsensor. This device has been shown to display low bias and a good coefficient of variation for TD and peak speed, indicating sufficient reliability for tracking team-sport load variables (Willmott et al., 2019). The players wore the same device to avoid inter-unit variability, which was worn on the player's upper back between the scapulae using a specifically designed vest. All devices were activated 15 min before data collection, as recommended by the manufacturer, and turned off as soon as the match was terminated. Based on previous studies (Douchet et al., 2024; Gualtieri et al., 2023), the distance covered by the speed range was analyzed for walking, jogging, low-speed running (LSR), moderate-speed running (MSR), HSR, and sprint at 0–5.9 $km \cdot h^{-1}$, 6.0–11.9, 12.0–14.9, 15.0–19.9, 20.0–24.9, and ≥ 25.0 $km \cdot h^{-1}$, respectively. The ratios of HSR and sprinting to TD (HSR/TD and Sprint/TD), which are considered the qualities of running, were also calculated.

2.5. Statistical analyses

Statistical tests were performed using SPSS 23.0 (SPSS Inc., Chicago, IL, USA). The results are expressed as means and standard deviations. Pearson's correlation analysis was performed to determine the relationships between the parameters. Paired t-tests were conducted to identify the differences between the MST and 5-min TSRT. Statistical significance was set at $p < .05$.

3. Results

3.1. Experiment 1

The paired t-test revealed that the number of laps and total running distance were significantly lower in the 5-min TSRT than in the MST (**Table 2**). Meanwhile, the maximal aerobic velocity was significantly faster in the 5-min TSRT than in the

Table 2 The values of performances in two shuttle run tests

	MST	5-min TSRT
number of laps	126.3 ± 13.5	19.6 ± 2.42*
total distance covered, m	2526.5 ± 270.2	1335.5 ± 57.0*
maximal aerobic velocity, km·h^{-1}	14.5 ± 0.5	16.0 ± 0.7*

Data are presented as means ± SD. MST, maximal multistage 20-m shuttle run test; 5-min TSRT, 5-min touchline shuttle run test.
*p < 0.001 vs. MST.

MST. A significant correlation was observed between the number of laps in the MST and 5-min TSRT (r = 0.712, p < .001).

3.2. Experiment 2

The mean value of the number of laps and total running distance in 5-min TSRT were 20.05 ± 0.77 and 1365.52 ± 52.97 m, respectively. The TD, distance covered by the speed range, and the total number of sprints, ACC, and DEC are shown in **Table 3**. The TD, HSR, and HSR/TD were 10.19 ± 0.88 km, 0.44 ± 0.16 km, and 5.34 ± 1.86%, respectively, and the total number of sprints, ACC, and DEC were 9.6 ± 7.9, 45.0 ± 12.7, and 45.5 ± 12.9, respectively. The number of 68-m laps in 5-min TSRT was significantly correlated with TD, distance covered at 15 km·h^{-1} or more, HSR/TD, and sprint/TD (**Table 3**). Additionally, there were significant correlations between the number of 5-min TSRT laps and sprints, ACC, and DEC. Meanwhile, the results of the 5-min TSRT was not related to the distance covered less than 15 km·h^{-1} as shown in **Table 3**.

4. Discussion

This study revealed that the number of 68-m laps in the 5-min TSRT newly devised by us was significantly correlated with the number of 20-m laps in the MST, which is a typical field test evaluating aerobic capacity. This means that the result of the 5-min TSRT reflects aerobic fitness, which is a simple test that requires only a typical soccer court, stopwatch, electronic whistle, and cones. As the number of laps and total running distance were also significantly lower in the 5-min TSRT than in the MST, the 5-min TSRT could reduce the physical strain on players. Furthermore, the results of the 5-min TSRT was significantly running distance at a relatively high speed during matches. Thus, this test could also be useful for predicting the running performance of soccer players during matches.

Aerobic capacity is one of the most essential physical fitness parameters for continuous running throughout a soccer match, and a high level of aerobic capacity is required for outfield players (Bangsbo, 1994; Dolci et al., 2020; Slimani et al., 2019; Wisloff et al., 1998). Thus, evaluating aerobic fitness is useful for talent identification and selection, training performance monitoring, evaluation of training program effectiveness, and training prescriptions (Bok and Foster, 2021). Although the gold standard test for evaluating aerobic fitness is the direct measurement of $\dot{V}O_2$max, cheaper and easier field tests are required, particularly in team-sports mass settings. One reliable field test for aerobic performance is the MST, the result of which is significantly correlated with $\dot{V}O_2$max in young soccer players (r = 0.86) (Aziz et al., 2005). Several previous studies demonstrated that the mean values of the total running distance in the MST for young amateur-trained and semi-professional soccer players were approximately 1900 m and 2400 m, respectively (Mulazimoglu et al., 2018; Slettalokken and Ronnestad, 2014). However, in this study, for male college soccer players, it was approximately 2500 m, which is equivalent to a semi-professional player's value. This study revealed that the number of 68-m laps in the 5-min TSRT significantly correlated with the number of 20-m laps in the MST. Previous studies have shown that the duration of the running performance which is maintained at 100% of maximal aerobic velocity, varies from 3 to 8 min (Berthon et al., 1997; Billat and Koralsztein, 1996; Hill and Rowell, 1996). According

Table 3 Running performance during the soccer match and correlation coefficient for the number of 68-m laps in 5-min touchlines shuttle run test

	Mean value	Correlation coefficient value
Distance		
TD (km)	10.19 ± 0.88	0.351 #
walking (km)	3.50 ± 0.24	-0.151
jogging (km)	3.63 ± 0.40	0.136
LSR (km)	1.33 ± 0.31	0.275
MSR (km)	1.17 ± 0.30	0.383 #
HSR (km)	0.44 ± 0.16	0.448 †
Sprint (km)	0.11 ± 0.06	0.485 *
> 15 km・h^{-1} (km)	1.75 ± 0.51	0.511 *
> 20 km・h^{-1} (km)	0.55 ± 0.21	0.494 *
HSR/TD (%)	5.34 ± 1.86	0.467 †
Sprint/TD (%)	1.08 ± 0.60	0.450 †
Number		
Sprint	9.6 ± 7.9	0.387 #
ACC	45.0 ± 12.7	0.346 #
DEC	45.5 ± 12.9	0.376 #

Data are presented as means ± SD. The correlation coefficient value is with respect to the number of 68-m laps in 5-min touchlines shuttle run test. TD, total distance covered; LSR, low-speed running; MSR, moderate-speed running; HSR, high-speed running; HSR/TD, ratio of high-speed running to total distance covered; Sprint/TD, ratio of sprint to total distance covered; ACC, accelerations; DEC, decelerations.
*$p < 0.001$, †$p < 0.01$, #$p < 0.05$.

to Katch et al. (1973), running for more than 5 min at a steady pace is not necessary to significantly improve the correlation between directly measured $\dot{V}O_2$max and running performance (Katch et al., 1973). Berthon et al. (1996) showed a very strong correlation between the maximal aerobic velocity in a 5-min maximal continuous running field test and $\dot{V}O_2$max (r = 0.90), and the maximal aerobic velocity (r = 0.94) was directly measured on a treadmill (Berthon et al., 1997). Thus, it is most likely that the results of the 5-min TSRT reflect aerobic fitness, although this test includes a change in direction.

Determining the maximal aerobic velocity is more important than assessing aerobic capacity when prescribing training programs. Ahmaidi et al. (1992) demonstrated that maximal aerobic velocity determined by the typical MST (20-m of the shuttle-run) with changing direction was approximately 15% slower than that determined by the incremental running test to measure $\dot{V}O_2$max on the treadmill and the continuous running test without changing direction on a 400 m track when the individuals were paced using a special sound, as in the 1-min protocol used for the MST (Ahmaidi et al., 1992). Haydar et al. (2011) also investigated the effect of change of direction on maximal running speed in the 30–15 Intermittent Fitness Test consisting of a 40-m shuttle run (Haydar et al., 2011). As a result, maximal running velocity in the original test was approximately 10% slower when the participants ran continuously without changing direction on a 400-m track. As the 5-min TSRT in this study consisted of 68-m of shuttle runs, the velocity difference for continuous running without changing direction was

expected to decrease. Thus, it is plausible that the maximal aerobic velocity in the 5-min TSRT was approximately 10% faster than that in the MST. As increasing the length of the shuttle-run by 20–30 m appears to increase the velocity by approximately 5% based on the previous studies, the difference in maximal aerobic velocity between 5-min TSRT and continuous running might be approximately 5%. Based on these findings, it is important to select tests based on the running type and distance expected in the training program.

The 5-min TSRT seems to have several advantages for players and coaches over the MST. In addition to shorter test duration, the mean value of the total running distance in 5-min TSRT was 1335.5 ± 57.0 m, which is about half the value of the MST in this study. This could reduce the physical strain on the players. Furthermore, the shorter test duration and longer shuttle run length in the 5-min TSRT contributed to an overwhelmingly smaller number of laps compared with the MST. One of the major problems in shuttle-run-type tests is the difficulty in determining whether the foot reaches the line to change direction, particularly when cones are used instead of lines. If the players turn back before the line, the actual running distance is shorter than expected, resulting in more laps. Thus, a smaller number of laps in shuttle-run-type tests and the use of lines already drawn on the court to change direction would contribute to more accurate results. In addition, there is no need for special sound sources or preparation of straight lines to change direction, which also reduces the burden on the coaches.

HSR is performed with increasing frequency during matches in professional soccer leagues (Pons et al., 2021), indicating the increasing importance of HSR performance for soccer players. A systematic review demonstrated that the HSR and sprinting distance during a match were approximately 760 m (range: 618–1001 m) and 200 m (range: 153–295 m), respectively, in professional male soccer players (Gualtieri et al., 2023), which are higher than those for male college soccer players in this study. These results are reasonable because previous studies have demonstrated that higher-level soccer players perform more HSR during games (Mohr et al., 2003). Furthermore, the results of the 5-min TSRT were significantly correlated with TD, HSR, and sprinting distance during matches, in addition to HSR/TD, sprint/TD, number of sprints, ACC, and DEC in this study. In several previous studies, significant correlation was observed between running performance in aerobic tests and during soccer matches (Castagna et al., 2010; Redkva et al., 2018). For example, Redkva et al. (2018) demonstrated that significant correlations were found between the total running distance in the Yo-Yo endurance test with TD, running distance at a speed between 15.9 and 24 km•h^{-1}, and the number of sprints (> 24 km•h^{-1}) in professional soccer players (Redkva et al., 2018). Aerobic metabolism provides more than 90% of the total energy required for the game (Bangsbo, 1994; Dolci et al., 2020) and enables rapid recovery of the anaerobic system after high intensity efforts (Bishop et al., 2004; Gharbi et al., 2015; Helgerud et al., 2001). Increased aerobic capacity through training could also contribute to improved running performance during matches. Helgerud et al. (2001) also demonstrated that high-intensity aerobic interval training increased the $\dot{V}O_2$max from 58.1 ± 4.5 ml•kg^{-1}•min^{-1} to 64.3 ± 3.9 ml•kg^{-1}•min^{-1}, lactate threshold from 47.8 ± 5.3 ml•kg^{-1}•min^{-1} to 55.4 ± 4.1 ml•kg^{-1}•min^{-1}, TD by 20%, the number of sprints by 100% in male elite junior soccer players (age: 18.1 ± 0.8 years) (Helgerud et al., 2001). Thus, aerobic capacity is closely related to running performance, such as TD, HSR, and the number of sprints during matches, and it is plausible that the result of the 5-min TSRT could also be useful in predicting the soccer players' running performance during matches.

Although a limitation of this study is the lack of directly measured $\dot{V}O_2$max, it is plausible that the 5-min TSRT could evaluate the aerobic capacity, considering that a very strong correlation between the results of a 5-min maximal continuous running test and $\dot{V}O_2$max has been observed in a previous study. Moreover, data during soccer matches were obtained from 1–6 matches for each player to evaluate their running performance in this study and the mean value was used for analyses when there were multiple matches data. Future studies are needed to determine the number of matches required to evaluate each player's running performance and the reproducibility of data obtained from multiple matches. Lastly, because running performance during matches depends not only on the physical fitness, such as aerobic capacity, but also on the tactical role of each player in the team, this warrants further investigation.

5. Conclusion

In conclusion, the number of 68-m laps in the 5-min TSRT significantly correlated with that of 20-m laps in the MST, which is a typical aerobic field test in Japanese college male soccer players. The shorter test duration and total running distance in this new test would contribute to reducing the physical strain on players. This is a simpler test that requires only a typical soccer court, stopwatch, electronic whistle, and cones, which reduces the burden on coaches. Furthermore, the results of the 5-min TSRT were significantly related to the distance and number of runs at a relatively high speed during the matches. Thus, this new test could be useful in predicting the running performance of soccer players during matches.

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Name:
Hayao Ozaki

Affiliation:
Department of Sport and Health Science, Tokai Gakuen Univeristy

Address:
21-233 Nishinohora, Ukigai, Miyoshi, Aichi 470-0207, Japan

Brief Biography:
2022- Associate Professor, Tokaigakuen University
2019- Lecturer, Tokaigakuen University
2015- Assistant professor, Juntendo University
2012- JSPS Research Fellow (PD), Juntendo University

Main Publications:
- Ozaki, H., Abe, T., Loenneke JP. and Katamoto, S. (2020) Stepwise load reduction training: A new training concept for skeletal muscle and energy systems. Sports Medicine. 50: 2075-2081.
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Membership in Learned Societies:
- Japanese Society of Physical Fitness and Sports Medicine
- Japan Society of Training Science for Exercise and Sport
- Japan Society of Science and Football