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# Characteristics of Physical Fitness for Field-based Team Sports Players in Terms of Energy Supply during Intermittent Sprint Exercise Test

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**The activity profiles of field-based team sports players (e.g. soccer, handball, and basketball) fluctuate randomly depending on game situation, from brief periods of maximal or near maximal intensity to longer periods of low-intensity activity. On the other hand, the activity patterns of track athletes are nearly constant. The purpose of this study was to compare the characteristics of physical fitness for field-based team sports players, endurance runners and sprinters from the viewpoint of energy supply during intermittent sprint exercise.**
**Twenty-four university-trained males (field-based team sports players: F; n = 8, endurance runners: E; n = 8 and sprinters: S; n = 8) completed an intermittent sprint exercise test. The test consisted of three 5 × 30m (every 40s) repeated-sprints, with sprints separated by a 4-min rest period. Sprint times were recorded during intermittent sprint exercise test from 0-15m, 15-30m, and 0-30m by electronic photo cells. Oxygen uptake ($\dot{V}O_2$), minute ventilation ($\dot{V}E$), heart rate (HR), and blood lactate concentration (La) were also measured during the test. An incremental treadmill test and a 40s anaerobic power test were also performed to determine maximal aerobic and anaerobic capacities.**
**The F group had a significantly faster 0-15m sprint time than E ($P < 0.05$), but not when compared with the S group; while, the F group had a significantly slower 15-30m sprint time than the S group ($P < 0.05$). The F group also had a significantly lower La during intermittent sprint exercise test than the S group ($P < 0.05$), but not when compared with the E group. In contrast, $\dot{V}O_2$ during intermittent sprint exercise test in the interval phase showed no significant differences among the groups. Although no significant differences were observed, lower La indicated a sufficient phosphocreatine resynthesis in the interval phase in the F and E groups.**
**These findings showed that the F group performed the repeated-sprint as fast as the S group from 0-15m with lower anaerobic energy supply. Furthermore, the results suggested the need for regular implementation of repeated-sprints in the F group. In conclusion, field-based team sports players have superior repeated-sprint ability than sprinters, especially over short distances such as 15m.**

**Keywords:** field-based team sports, repeated-sprint, oxygen uptake, blood lactate concentration

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## 1. Introduction

When examining the mechanism of energy supply during the reproduction of adenosine triphosphate, which is a direct source of energy for muscle contraction, physical exercise is classified into two major categories; anaerobic exercise, the explosive exertion of energy in a short period of time seen in sprints and throwing, and aerobic exercise, the continual submaximal-intensity exercise seen in long-distance running. Soccer and handball players are engaged in both anaerobic and aerobic exercise according to varying situations during games. In this study, sports in which players on two teams compete for points on the same court during a certain period of time such as soccer and handball were defined as field-based team sports (Spencer et al., 2005; The Ministry of Education, Culture, Sports, Science and Technology, 2009).

According to studies examining activity profile, and physiological characteristics (Bangsbo, 1994; McInnes et al., 1995; Lofting et al., 1996; Miyagi et al., 1997a; Miyagi et al., 1997b; Sibila et al., 2004), field-based team sports players maintain exercise speeds of 2 to 3 m/sec. which is similar to jogging speed, and repeat high-intensity exercise of more than 7 to 8 m/sec., which is similar to sprints. During relatively low-intensity exercise such as jogging, the proportion of energy supplied from the aerobic energy supply system increases. On the other hand, during high-intensity exercise such as sprints, the proportion of energy supplied from the anaerobic energy supply system increases.

The alactacid energy supply system during high-intensity activities over short periods of time, such as sprints, stores extremely low amounts of phosphocreatine (PCr), required for the resynthesis of adenosine triphosphate, which is usually consumed in approximately 5 to 7 seconds during maximum-intensity activity (Hirvonen et al., 1987). PCr used during exercise is resynthesized with energy supplied from the aerobic energy supply system (Yamamoto, 1994). According to Yamamoto (1994), an examination of the relationship between the index of each energy supply system and power exerted during high-intensity intermittent activity in male university students enrolled in physical education departments who performed 10 sets of 10-second maximum-intensity pedaling with 20-second rest periods in between revealed a significantly high correlation with the alactacid energy supply system index in a few sets in the first half and a significantly high correlation with the aerobic energy supply system index in a few sets in the second half. On the other hand, Yamamoto also reported that the lactacid energy supply system index showed no significant correlation in any set. According to Sakai et al. (1999), who asked male handball players at a university to perform 20 sets of 7-second maximum-intensity pedaling with 45-second rest periods in between, a group of subjects with high alactacid energy supply capacity revealed significantly higher power in first few sets compared with a group of subjects with low capacity, and the difference between the two groups decreased as they went through the course of sets. Meanwhile, the group with high aerobic energy supply capacity revealed significantly higher power in the sets in the second half compared with the group with low aerobic energy supply capacity, and the difference between the two groups increased as they went through the course of sets. Therefore, in order to repeat high-intensity exercise based on relatively low-intensity exercise such as the motion of field-based team sports players during games, it is especially important to have the supply capacities of both the alactacid and the aerobic energy supply systems.

Due to the frequent change in the exercise environment in field-based team sports, such as the positions of opponents, team members and the ball, players are required to respond to motion and stimuli. Therefore, the characteristics of physical fitness of field-based team sports players are different from the athletes whose activity is maintained at a certain level, such as athletics and swimming. Track and field athletes and swimmers, whose physical fitness factors are highly associated with their competitive performance, are considered to have obvious physical characteristics as opposed to field-based team sports players, whose activity changes frequently. Therefore, this study was carried out to clarify the physical characteristics of field-based team sports players through a comparison with players of other sports whose activity change to the same degree.

The purpose of this study was to clarify the characteristics of field-based team sports players who belong to a university sports activity club and regularly exercise for long periods of time. In order to do so, we focused on energy supply systems during repeated sprints, and compared endurance runners, whose training focuses on aerobic energy supply capacity, and sprinters, whose training focuses on alactacid energy supply capacity.

## 2. Methods

### 2.1. Subjects

Subjects were eight field-based team sports players (four soccer players and four handball players: field-based team sports players designated as the “F group”), eight endurance runners (endurance runners designated as the “E group”), and eight sprinters

**Table 1** Physical characteristics of the subjects

| Groups | Age (yrs) | Height (cm) | Weight (kg) |
|---|---|---|---|
| F (n = 8) | 19 ± 1 | 174.9 ± 5.4 | 66.4 ± 4.2 |
| E (n = 8) | 18 ± 0 | 174.6 ± 3.9 | 60.7 ± 4.9 |
| S (n = 8) | 19 ± 1 | 172.5 ± 3.6 | 64.4 ± 5.0 |

F : field-based team (soccer n = 4 , handball n = 4) , E : endurance runners , S : sprinters. Values are means ±SD.

(sprinters designated as the "S group"), all of whom belonged to the physical education department at a university. The physical characteristics of subjects in each group shown in **Table 1** revealed no significant differences between each item. However, the athletic careers in the F, E, and S groups were 10 ± 3 years, 5 ± 2 years, and 7 ± 2 years, respectively. The F group revealed significantly longer athletic careers than two other groups, and the S group revealed significantly longer athletic careers than the E group. The F group was engaged in two-hour daily training for six days each week during the survey period, the E group was engaged in three-hour daily training (one hour in the morning and two hours in the evening) for six days each week, and the S group was engaged in two-hour daily training for five days each week. For instance, soccer players in the F group had a 15-minute warm-up period using soccer balls, 30-minute shooting practice, 30-minute 7 to 7 games on half court, 30-minute 11 to 11 games on full court, and a 15-minute cooling-down period. Handball players in the F group had 20-minute coordination training using handballs, 20-minute 3 to 3 games on half court, 40-minute 7 to 7 games on full court, 30-minute shooting practice, and a 10-minute cooling-down period. Similarly, the E group had 20 minutes' jogging and stretching, 30 minutes' running on a 400m track at approximately 100 seconds per lap, 15 minutes' repeated 200m runs at the pace of 30 seconds per lap with one-minute rest in between runs, several strength training using their own weight, such as sit-ups and push-ups, and a 10-minute cooling-down period. The S group had a 20-minute jogging and stretching period, 20-minute coordination training using hurdles and ladders, 20-minute strength training using their own weight, 10 sets of 50 and 70m sprints on slopes. Between the sprints on slopes, subjects had approximately two-minute rest periods.

We provided detailed oral and written explanations of the content and risk of the survey in advance and obtained consent from all subjects prior to participation. This study was carried out upon approval from the Ethics Committee of the Chukyo University Graduate School of Health and Sport Sciences.

## 2.2. Exercise tests, measurement items, and method of the survey

Subjects were asked to perform three types of exercise with a greater than 36-hour interval in between. Subjects were instructed to have regular meals during the survey period, and to finish their meals three hours prior to measurement. The three types of exercises were performed on the day following a day off from exercise at the clubs that the subjects belong to or the day following a day on which the subjects were engaged in relatively low-intensity exercise.

### 2.2.1. Intermittent sprint exercise test

Intermittent sprint exercise test was conducted on a straight stretch of an indoor athletic track. Subjects were asked to perform three sets of five 30m maximum intensity repeated sprints (repeated every 40 seconds), with sprints separated four minutes. Items measured were the time required for each sprint during the repeated sprint, oxygen uptake, minute ventilation, heart rate, and blood lactate concentration. Details are provided below.

Subjects performed a 15-minute warm-up, took a 5-minute rest sitting in a chair, and started exercise on a signal from the examiner. Subjects were asked to jog back to the starting line after each sprint and to remain still for five seconds before starting the next sprint.

(1) Measurement of sprint time

Sprint time was measured using photo cells connected to a Multi-PAS Program (DKH, Japan), a response movement evaluation system. Photo cells were placed at 0, 15, and 30m points 50cm above ground to measure the time required to pass between 0 and 15m, 15 and 30m, and 0 and 30m. The starting line was set 1m away from the photo cell placed at 0m to avoid the impact of the reaction time.

(2) Measurement of oxygen uptake, minute ventilation, and heart rate

We measured the oxygen uptake, minute ventilation, and heart rate from five minutes prior to the start of exercise to five minutes after the finish of exercise. Oxygen uptake and minute ventilation were measured electronic variable sampling method using a portable metabolic system (VO2000: Medical Graphics Corporation, U.S.A.). The interval of measurement sampling was set at 10 seconds. Heart rate was measured by portable heart rate memory system (Polar Team System: Polar Electro, Finland). The interval of measurement sampling was set at 5 seconds. In order to analyze the measurement data, we set the first 10 seconds from the start of each sprint as the sprint phase (exercise phase), between 10 and 40 seconds as the interval phase (rest phase), and from 10 to 3 minutes and 50 seconds after the start of the fifth sprint of each set as the set interval phase.

(3) Measurement of blood lactate concentration

We collected 20μl blood from subject fingers using plastic capillary tubes (LG-70: EKF-Diagnostic GmbH, Germany) at the start line two minutes prior the start of the sprint, one minute and three minutes after the start of the fifth sprint in each set. The blood lactate concentration was analyzed by blood lactate measurement device (Biosen 5030: EKF-Diagnostic GmbH, Germany) calibrated with 12mmol/l standard lactic acid solution. Among the measured values obtained after each set, the highest value was used as the peak blood lactate concentration (La peak) during repeated sprint.

#### 2.2.2. Incremental treadmill test

Incremental treadmill test was conducted on a treadmill (BM-1000: S&ME Inc., Japan) applying the incremental load test method. Subjects performed a 15-minute warm up, remained still in a seated position for three minutes and then started running. The intensity of the incremental treadmill test was set at 210m/min. and 0% inclination initially. Running speed was gradually increased 30m/min. every three minutes up to 270m/min. After running at 270m/min., the inclination was increased by 1% every minute remaining at the running speed of 270m/min. until the exhaustion level was reached. Oxygen uptake, minute ventilation, and heart rate were measured during exercise.

Analysis of expired gas was performed by automatic metabolism measurement device (AE-300S: Minato Medical Science Co., Ltd., Japan), and heart rate measurement was performed by medical-use telemeter (ZB-910P: Nihon Kohden Corporation, Japan) and bedside monitor (BSM-2401: Nihon Kohden Corporation, Japan), with the sampling interval set at 30 seconds. Of the oxygen uptake obtained from this test, the maximal value at which the heart rate reached the maximum estimated from age (220 – age) and for which the respiratory exchange ratio was greater than 1.0 was used as the maximal oxygen uptake ($\dot{V}O_2max$) (Yamaji, 2001).

#### 2.2.3. 40-second anaerobic power test

Forty-second anaerobic power test was carried out using a bicycle ergometer with an electromagnetic braking system (POWERMAX-VII: Combi Wellness Corporation, Japan) (Miyashita, 1986). Subjects were engaged in 10-minute warm up, took a five-minute rest and then started exercise. Mean power and peak power were calculated by an installed computer program. After one, three, five, seven, and nine minutes of exercise, 20μl of blood was collected from subject fingers using plastic capillary tubes, and blood lactate concentration was analyzed by blood lactate measurement device calibrated with 12mmol/l lactic acid standard solution. Among the measured values obtained from this test, the highest value was used as the maximal blood lactate concentration (La max).

### 2.3. Statistical analysis

Data obtained from the test were shown as mean value ± standard deviation. Statistical analysis was carried out using software (SPSS 12.0 for Windows). Analysis of intermittent sprint exercise test were assessed using a two-way (measurement items during intermittent sprint exercise test and each set) analysis of variance (ANOVA) with repeated measures. A significant interaction was then analyzed by Bonferroni post hoc tests. Furthermore, one-way ANOVA was used for the measurement of physical characteristics and athletic careers of each group, incremental treadmill test, and 40-second anaerobic power test. A significant interaction was then analyzed by Bonferroni post hoc tests. Significance was set at $P < 0.05$.

## 3. Results

### 3.1. Intermittent sprint exercise test

#### 3.1.1. Sprint time

Mean values and standard deviations for the sprint time in each set are shown in **Figure 1**. Between 0 and 15m (**Figure 1-A**), mean values for the sprint time in each set of the F group were significantly faster than the E group (2.39, 2.36, 2.35 sec vs. 2.48, 2.47, 2.46 sec: $P < 0.05$), while not significantly different when compared with the S group (vs. 2.39, 2.39, 2.40 sec: $P > 0.05$). Between 15 and 30m (**Figure 1-B**), mean values for the sprint time in the 1st and 2nd sets of the F group were significantly slower than the S group (1.93, 1.91 sec vs. 1.80, 1.81 sec: $P < 0.05$). Between 0 and 30m (**Figure 1-C**), mean values for the sprint time in each set of the F and S groups were significantly faster than the E group (4.32, 4.27, 4.26 sec; 4.18, 4.20, 4.21 sec vs. 4.50, 4.47, 4.45 sec: $P < 0.05$); however, there were no significant differences between the F and S groups ($P > 0.05$). Furthermore, mean values for the sprint time in the 2nd and 3rd set of the F group were significantly faster than the 1st set ($P < 0.05$), and the mean values for the sprint time in the 3rd set of the S group were significantly slower than the 1st set ($P < 0.05$).

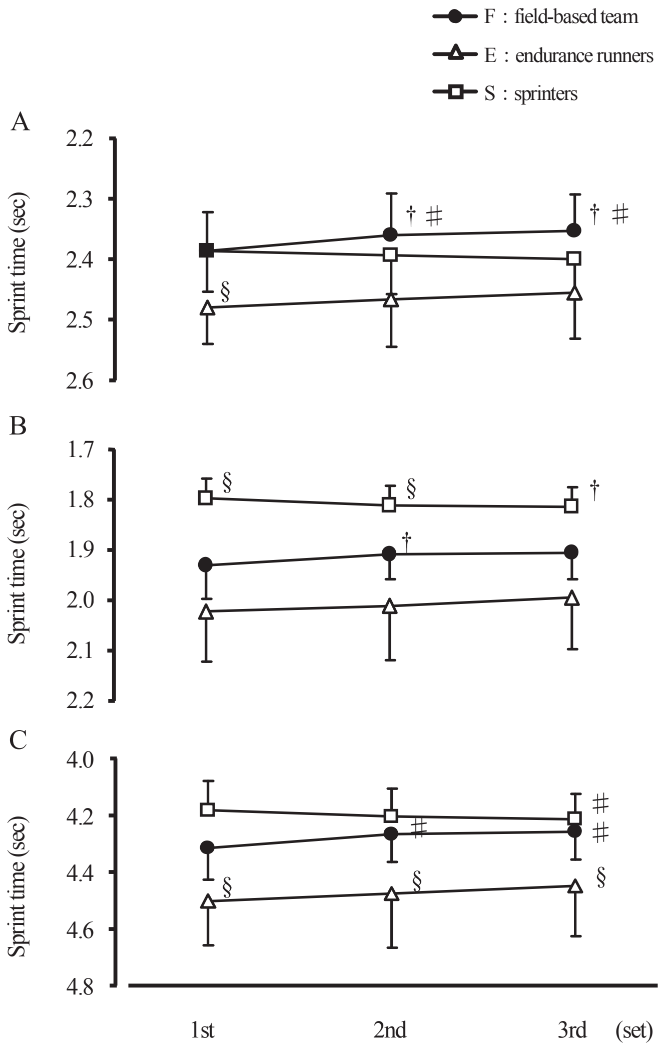


**Figure 1** Mean (±SD) sprint time (A) from 0 to 15m, (B) from 15 to 30m and (C) from 0 to 30m during the intermittent sprint exercise test for F (● n = 8), E (△ n = 8) and S (□ n = 8). § Significantly different from the other groups. † Significantly different from E. #Significantly different from 1st ($P < 0.05$).

### 3.1.2. Oxygen uptake

Mean values and standard deviations for the oxygen uptake in each set during the interval and set interval phases of each group are shown in **Figure 2**. During the interval phase (**Figure 2-A**), there were no significant differences in the mean oxygen uptake values in each set among all groups (F group: 34, 36, 36ml/kg/min vs. E group: 37, 38, 38ml/kg/min vs. S group: 37, 38, 36ml/kg/min: $P > 0.05$). During set interval phase (**Figure 2-B**), mean oxygen uptake in the 1st set of the S group was significantly higher than the E group ($P < 0.05$).

### 3.1.3. Blood lactate concentration

Mean values and standard deviations for the La of each group at two minutes before the start of the sprint, and La peak of each group after each set are shown in **Figure 3**. Mean values for the La peak

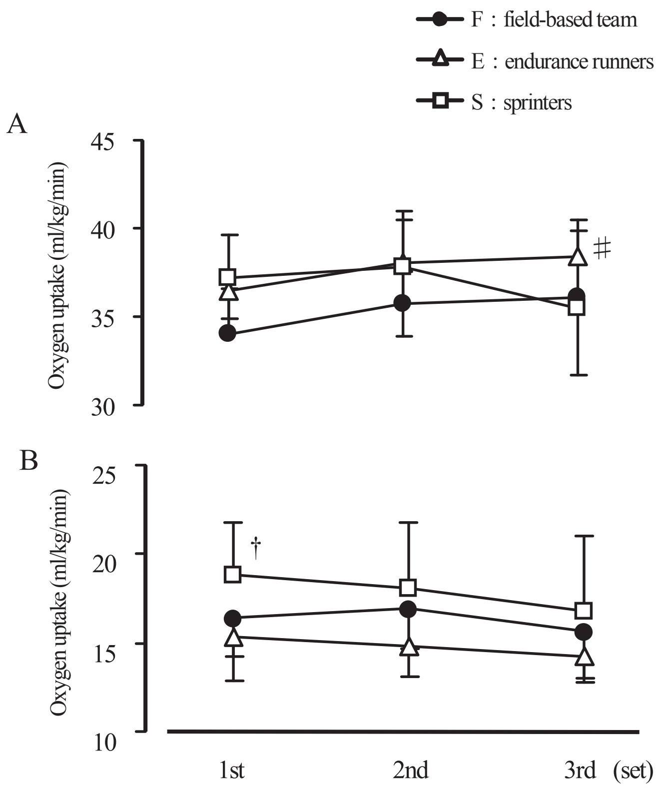


**Figure 2** Mean (±SD) oxygen uptake (A) in "interval phase" and (B) in "set interval phase" during the intermittent sprint exercise test for F (● n = 8), E (△ n = 7) and S (□ n = 7). † Significantly different from E. #Significantly different from 1st ($P < 0.05$).

after each set of the F group were significantly lower than the S group (6.91, 7.79, 8.31 mmol/l vs. 9.79, 11.84, 12.97 mmol/l : P < 0.05);however, there were no significant differences when compared with the E group (vs. 5.77, 5.44, 5.62 mmol/l : P > 0.05). Furthermore, the La peak of the S group increased significantly as subjects went through each set (P < 0.05).

## 3.2. Incremental treadmill test

### 3.2.1. Maximal oxygen uptake

Mean $\dot{V}O_2max$ values and standard deviations for each group are shown in **Figure 4**. Mean $\dot{V}O_2max$ values of the E group were significantly higher than the F and S groups (66.7 ml/kg/min vs. 57.0, 56.2 ml/kg/min: P < 0.01); however, there were no significant differences between the F and S groups (P > 0.05).

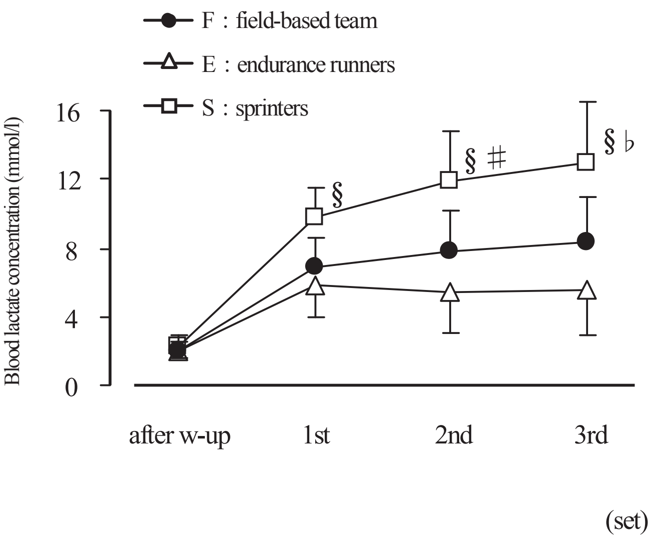


**Figure 3** Peak (±SD) blood lactate concentration during the intermittent sprint exercise test for F (● n = 8), E (△ n = 8) and S (□ n =8). § Significantly different from the other groups. #Significantly different from 1 st. ♭Significantly different from previous set (P < 0.05) .

## 3.3. 40-second anaerobic power test

### 3.3.1. Maximal blood lactate concentration

Mean La max values and standard deviations for each group are shown in **Figure 5**. Mean La max values for the S group was significantly higher than the E group (15.83 mmol/l vs. 11.77 mmol/l: P < 0.001); however, there were no significant differences between the F and S groups (13.93 mmol/l vs. 15.83 mmol/l: P > 0.05).

### 3.3.2. Mean power and peak power

Mean values and standard deviations for the mean power and peak power of each group are shown in **Table 2**. The mean power and peak power of the E group were significantly lower than the F and S groups (Mean power: 479W vs. 546W, 560W: P < 0.05, P < 0.01; Peak power: 629W vs. 744W, 776W: P < 0.05, P < 0.01).

## 4. Discussion

### 4.1. Subjects relating to the research method

### 4.1.1. Physical characteristics of subjects

Physical characteristics of subjects of this study were compared with previously-reported data for top athletes. The field-based team sports players in this study showed $\dot{V}O_2max$ values similar to top-level soccer (Miyagi et al., 1997a; Reilly, 2000) and handball players (Rannou et al., 2001; Chaouachi et al., 2009), which indicate that the field-based team sports players in this study demonstrated high aerobic capacity. The La max values after 40-second

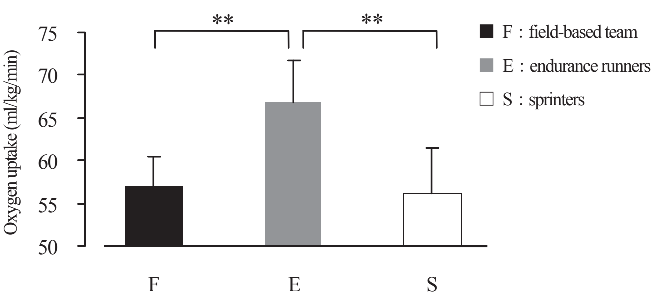


**Figure 4** Maximal (±SD) oxygen uptake during the incremental treadmill test for F (■ n = 8), E (■ n = 8) and S (□ n = 8). **Significantly different (P < 0.01).

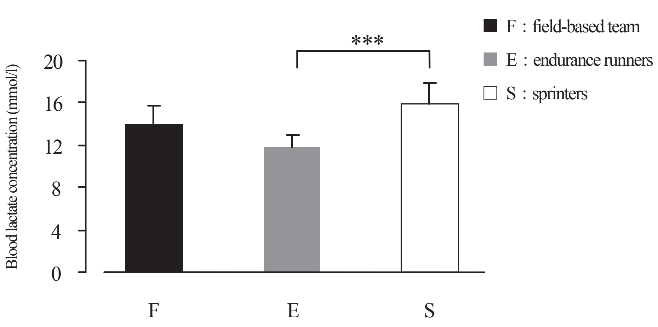


**Figure 5** Maximal (±SD) blood lactate concentration during the 40s anaerobic power test for F (■ n = 8), E (■ n = 8) and S (□ n = 8). ***Significantly different (P < 0.001).

**Table 2** Mean and peak power during the 40s anaerobic power test

| Groups | Mean power | | Peak power | |
|---|---|---|---|---|
| | (W) | (W/weight) | (W) | (W/weight) |
| F (n = 8) | 546 ± 46 * | 8.2 ± 0.4 * | 744 ± 68 * | 11.2 ± 0.6 * |
| E (n = 8) | 479 ± 24 | 7.9 ± 0.4 | 629 ± 31 | 10.4 ± 0.4 |
| S (n = 8) | 560 ± 57 ** | 8.7 ± 0.3 ** | 776 ± 121 ** | 12.0 ± 1.0 ** |

F : field-based team (soccer n = 4 , handball n = 4) , E : endurance runners , S : sprinters. Values are means ± SD.

Significantly different from E * ($P < 0.05$) ** ($P < 0.01$).

anaerobic power test for the subjects in this study were also similar with those of the top soccer (Miyagi et al., 1997b) and handball players (Rannou et al., 2001), which indicates that the field-based team sports players in this study demonstrated high anaerobic capacity. The field-based team sports players in this study repeated high-intensity exercise such as sprinting and jumping during games exceeding 60 minutes; therefore, both aerobic and anaerobic energy supply capacities were thought to have been improved through daily exercise.

Sprinters in this study yielded La max values after 40-second anaerobic power test similar to the top sprinters (Fukashiro et al., 1991; Gratas et al., 1994; Rannou et al., 2001), which indicates that the sprinters in this study had high anaerobic capacity. As in the above-mentioned daily exercise, because the sprinters in this study had sufficient rest between repeated sprints, their anaerobic energy supply capacities were improved through exercise.

Meanwhile, the endurance runners in this study showed slightly lower $\dot{V}O_2$max compared with top-level endurance runners (Yamaji, 1986; Billat et al., 2001; Lucia et al., 2006). The endurance runners in this study were all first-year university students, had belonged to sports clubs at their universities for only three months, and had athletic careers that were shorter than the other two groups; therefore, their aerobic energy supply capacity was thought to have been inferior to top-level athletes.

### 4.1.2. Setup of exercise form and intensity

The intermittent sprint exercise test applied in this study was developed by the author. For the purpose of discussion, the author assumed that this test allowed movement similar to that of field-based team sports players during games and showed differences in the physiological index among field-based team sports players, endurance runners and sprinters. Furthermore, in order to set the exercise form and intensity in the test, we considered the two items described below.

Firstly, we set the distance of sprints at 30m. Balsom et al. (1992) surveyed the changes in sprint time and physiological index during repeated sprints with a set rest time between sprints and varying sprint distances. As a result, sprints at 30 and 40m showed sprint time and physiological index changes during repeated sprints. However, at 15m there were no significant differences either in sprint time at 1$^{st}$ and 40$^{th}$ sprints, or physiological index before and after exercise. Meanwhile, field-based team sports players sprinted most often between 10 and 20m during games (Spencer et al., 2005). Therefore, sprint measurements in this study were set at 30m, which was close to the distance that field-based team sports players often sprint and a distance that would show changes in sprint time and physiological index.

Secondly, sprints were repeated every 40 seconds in a certain direction. Previous studies on the sprint time and physiological index during high-intensity intermittent sprint exercise used passive recovery as the protocol for measurement (Balsom et al., 1992; Bishop et al., 2004; Brown et al., 2007). However, field-based team sports players rarely stop moving completely during games. That is, players constantly change position in accordance with the movement of the ball and opponents. The protocol for the measurement of repeated sprints in this study was set at 40 seconds and the fixed direction of the sprints for active recovery was set at 1 to 2m/sec., which is the distance covered of the majority of field-based team sports players during games.

The intermittent sprint exercise test employed in this study does not completely simulate the movements of field-based team sports players during games; however, the exercise form and intensity set for the test were considered sufficient for clarification of the physical characteristics of field-based team sports players.

#### 4.1.3. Setup of expired gas sampling intervals

In the preliminary experiment, we had two subjects undergo intermittent sprint exercise test and videotaped their exercise. Using video, we calculated the time required from the time the subjects ran through 30m to the time they turned around to return back to the start line. Both subjects turned around at approximately eight to nine seconds after they started running to return back to the start line. Therefore, this study considered the movements from the time the subjects ran through 30m to the time they turned about to return back to the start line as a sequence of movements of the sprint, and measured setting the sampling interval of expired gas at 10 seconds.

However, the time between the completion of a sprint and turn around varies depending on the athlete. Therefore, there is a need to classify the sprint and active recovery times more accurately using a shorter sampling interval and videotapes of the exercise.

### 4.2. Intermittent sprint exercise test

#### 4.2.1. Sprint time

Mean sprint times for each set of the F group between 0 and 15m, and between 0 and 30m were significantly faster than the E group; however, there were no significant differences compared with the S group (**Figure 1-A, Figure 1-C**). Meanwhile, mean sprint times in the 1st and 2nd sets between 15 and 30m were significantly slower than the S group (**Figure 1-B**). While the mean sprint times for the S group between 0 and 30m became slower as the subjects went through the sets, the F group became faster as the subjects went through the sets.

Spencer et al. (2005) reported that the average individual sprint time for players in field-based team sports during games was two to three seconds, which is equivalent to a distance of 10 to 20m. According to Cometti et al. (2001), the individual sprint time for soccer players belonging to the 1st and 2nd professional soccer leagues from start to 10m was significantly faster than for amateur players; however, there were no significant differences in sprint time from start to 30m. Therefore, Cometti et al. concluded that sprint time for short distances, such as 10m, was a determining factor in victory. Granados et al. (2007) compared the sprint times for 5 and 15m between top handball players in Spain, including those who had competed in the Olympics, and amateur players who belong to the country's 2nd league. All of the professional and amateur players had been playing handball for the same amount of time. Top professional handball players were significantly faster in 5 and 15m sprints than the amateur players were. Granados et al. concluded that sprinting speed was an important physical fitness factor for handball players hoping to compete at higher levels.

Meanwhile, according to Ae et al. (1994), it was approximately 50 to 70m after the start when all players reached maximum speed during the final 100m race at the top world level. According to Matsuo et al. (2008), the top five male athletes who ran the final 100m race at the IAAF World Championships in Athletics held in Osaka in 2007 reached maximum speed at approximately 60 to 70m. Running speed from the start to 10m was approximately 45% of the maximum running speed of 5.20m/sec. (5.05 – 5.31m/sec.) on average. This suggested that sprinters did not reach maximum running speed at 20m, but at and after the midpoint of the race, which is one of the characteristics of the sprinters.

The above indicates that field-based team sports players are characterized by excellent acceleration over short distances, such as 15m, and by the ability to maintain sprint time during repeated sprints.

#### 4.2.2. Oxygen uptake and blood lactate concentration

Hamilton et al. (1991) reported that endurance runners exhibited superior oxygen uptake and excellence in maintaining power exertion than ball sports players during intermittent exercise. In addition, Balsom et al. (1994) asked male university students in physical education departments to perform high-intensity intermittent exercise in environments equivalent to those at 3000m above sea level (526mmHg) and 0m above sea level (760mmHg) in an artificial climate chamber to measure and compare oxygen uptake, blood lactate concentration, and power exertion. At conditions equivalent to 3000m above sea level, oxygen uptake during the high-intensity intermittent exercise was lower, which increased the blood lactate concentration and significantly reduced power exertion.

Therefore, we concluded that it was important to take up as much oxygen as possible during repeated sprints to reduce the energy supply from the lactacid energy supply system and to maintain the sprint time, and thus focused on the relationship between oxygen uptake in the interval phase and La peak after each set during repeated sprints. Mean oxygen uptake values in each set in the interval phase of each group showed no significant differences (**Figure 2-A**). The mean La peak values after each set of the F group were significantly lower than the S group; however, there were no significant differences in mean La peak values after each set of the F group and the E group (**Figure 3**).

Oxygen uptake in the interval phase of this study was considered equal to oxygen uptake during alactacid $O_2$ debt and active recovery classified by Margaria et al. (1933). According to Piiper et al. (1970), alactacid $O_2$ debt is associated with the amount of PCr resynthesis. In other words, if the oxygen uptake is high in alactacid $O_2$ debt, it is possible to resynthesize PCr used during exercise and reduce the energy from the lactacid energy supply system. However, in this study, we were unable to clearly classify oxygen uptake during alactacid $O_2$ debt and active recovery. Therefore, based on the La peak after each set, it was thought that the S group showed lower oxygen uptake in alactacid $O_2$ debt than the F and E groups, and insufficiency in resynthesis of PCr. The S group could not sufficiently resynthesize PCr in the interval phase, which resulted in an increase of the contribution from the lactacid energy supply system during repeated sprints. Meanwhile, the F and E groups sufficiently resynthesize PCr in the interval phase, with less involvement of lactacid energy supply system compared with the S group.

Hirvonen et al. (1987) reported that the faster a sprinter is able to run, the more efficient the supply of energy from the alactacid energy supply system. Since it is important for sprinters to use explosive energy, it is assumed that they train for this. Therefore, during repeated sprints at the short intervals in this study, energy from the lactacid energy supply system may have increased, which resulted in a slowing of sprint times.

Meanwhile, Mohr et al. (2003) reported no differences in total distance covered during games by level of soccer player; however, higher-level soccer players achieved a 58% greater total sprint distance (30km/h or faster) than players at lower levels. They pointed out that the ability to repeat high-intensity exercise such as the sprints was an important factor in play at higher levels.

This suggested that the F group in this study could resynthesize PCr in the interval phase and reduce energy from the lactacid energy supply system to the same degree as the E group.

## 5. Conclusion

This study was carried out to clarify the physical characteristics of field-based team sports players during repeated sprints from the viewpoint of the energy supply system. Although there remain issues related to the physical fitness level of subjects to be addressed, we clarified the factors as listed below.

(1) The mean sprint times in each set between 0 and 15m, and 0 and 30m for field-based team sports players were faster than endurance runners, but did not show a difference from sprinters.

(2) The mean sprint times in each set between 15 and 30m for field-based team sports players were slower than sprinters.

(3) While the mean sprint times in each set between 0 and 30m for field-based team sports players became faster as they went through sets, the mean sprint times in each set between 0 and 30m for sprinters became slower.

(4) The mean oxygen uptake values during interval phase revealed no differences among different types of athletes.

(5) The mean La peak values after each set of field-based team sports players were lower than sprinters, which did not change even after they went through the sets as endurance runners.

The results described above suggest that field-based team sports players accelerate more quickly over short distances, such as 15m, and have a superior ability to repeat sprints without lowering sprint times due to lower lactacid energy supply system involvement. It was also suggested that an understanding of the physical characteristics clarified by this study would be beneficial in improving the performance of field-based team sports players.

**References**

Ae, M., Suzuki, M., Miyanishi, T., Okada, H., Hirano, T. (1994). Analysis of racing patterns in 100m sprint of world's best top sprinters. World-class athlete technology. (pp.14-28). Tokyo : Baseball Magazine sha. (in Japanese)

Balsom, PD., Seger, JY., Sjodin, B., Ekblom, B. (1992). Physiological responses to maximal intensity intermittent exercise. Eur J Appl Physiol, 65 : 144-149

Balsom, PD., Gaitanos, GC., Ekblom, B., Sjodin, B. (1994).

Reduced oxygen availability during high intensity intermittent exercise impairs performance. Acta Physiol Scand , 152 : 279-285

Bangsbo, J. (1994). The physiology of soccer ; with special reference to intense intermittent exercise. Acta Physiol Scand Suppl , 619 : 1-155

Billat, VL., Demarle, A., Slawinski, J., Paiva, M., Koralsztein, JP. (2001). Physical and training characteristics of top-class marathon runners. Med Sci Sports Exerc , 33 : 2089-2097

Bishop, D., Edge, J., Goodman, C. (2004). Muscle buffer capacity and aerobic fitness are associated with repeated-sprint ability in women. Eur J Appl Physiol , 92 : 540-547

Brown, IP., Hughes, GM., Tong, JR. (2007). Relationship between $\dot{V}O_2max$ and repeated sprint ability using non-motorised treadmill ergometry. J Sports Med Phys Fitness , 47 : 186-190

Chaouachi, A., Brughelli, M., Levin, G., Boudhina, N., Cronin, J., Chamari, K. (2009). Anthropometric, physiological and performance characteristics of elite team-handball players. J Sports Sci , 27 : 151-157

Cometti, G., Maffuletti, NA., Pousson, M., Chatard, JC., Maffulli, N. (2001). Isokinetic strength and anaerobic power of elite, subelite and amateur French Soccer Players. Int J Sports Med , 22 : 45-51

Fukashiro, S., Wakayama, A., Harada, Y. (1991). Phyaical fitness and performance in top athletes. Journal of Health Physical Education and Recreation , 41 : 262-268. (in Japanese)

Granados, C., Izquierdo, M., Ibanez, J., Bonnabau, H., Gorostiaga, ME. (2007). Differences in Physical Fitness and Throwing Velocity Among Elite and Amateur Female Handball Players. Int J Sports Med , 28 : 860-867

Gratas-Delamarche, A., Cam, LeR., Delamarche, P., Monnier, P., Koubi, H. (1994). Lactate and catecholamine responses in male and female sprinters during a Wingate test. Eur J Appl Physiol , 68 : 362-366

Hamilton, AL., Nevill, ME., Brooks, S., Williams, C. (1991). Physiological responses to maximal intermittent exercise : Differences between endurance-trained runners and game players. J Sports Sci , 9 : 371-382

Hirvonen, J., Rehunen, S., Rusko, H., Harkonen, M. (1987). Breakdown of high-energy phosphate compounds and lactate accumulation during short supramaximal exercise. Eur J Appl Physiol , 56 : 253-259

Loftin, M., Anderson, P., Lytton, L., Pittman, P., Warren, B. (1996). Heart rate response during handball singles match-play and selected physical fitness components of experienced male handball players. J Sports Med Phys Fitness , 36 : 95-99

Lucia, A., Esteve, J., Olivan, J., Gomez, F., Sanjuan, AF., Santiago, C., Perze, M., Chamorro, C. (2006). Physiological characteristics of the best Eritrean runners – exceptional running economy. Appl Physiol Nutr Metab , 31 : 530-540

Margaria, R., Edward, HT., Dill, BD. (1933). The possible mechanisms of contracting and paying the oxygen debt and role of lactic acid in muscular contraction. Am J Physiol , 106 : 689-715

Matsuo, A., Hirokawa, R., Yanagiya, T., Tsuchie, H., Sugita, M. (2008). Speed change in man and woman 100m race. Jpn Biomech Sports Excerc , 12 : 74-83. (in Japanese)

McInnes, SE., Carlson, JS., Jones, CJ., McKenna, MJ. (1995). The physiological load imposed on basketball players during competition. J Sports Sci , 13 : 387-397

Ministry of education, culuture, sports, science and technology. (2009). Ministry’s curriculum guidelines. (pp.90-97). Kyoto : Higashiyama-shobou. (in Japanese)

Miyagi, O., Susa, T., Kitagawa, K. (1997a). Physiological and movement characteristics during a game of soccer players. Descente sports science , 18 : 231-238. (in Japanese with English abstract))

Miyagi, O., Yamamura, C., Tsukanaka, A., Koiso, H., Shimazaki, T., Ishiko, T., Kitagawa, K. (1997b). Effects of the anaerobic and aerobic trainings on blood lactic acid and the form of locomotion activity during the game in soccer players. Jpn Biomech Sports Excerc , 1 : 15-23. (in Japanese with English abstract)

Miyashita, M. (1986). Physical fitness diagnostic system for athlete and public. (pp.77-80). Tokyo : Sony enterprise. (in Japanese)

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

Reilly, T., Bngsbo, J., Franks, A. (2000). Anthropometric and physiological predispositions for elite soccer. J Sports Sci , 181 : 669-683

Piiper, J., Spiller, P. (1970). Repayment of $O_2$ debt and resynthesis of high-energy phosphates in gastrocnemius muscle of the dog. J Appl Physiol , 28 : 657-662

Rannou, F., Prioux, J., Zouhal, H., Gratas-delamarche, Delamarche, P. (2001). Physiological profile of handball players. J Sports Med Phys Fitness , 41 : 349-353

Sakai, K., Sheahan, J., Takamatsu, K. (1999). The relationship between high power output during intermittent exercise and three energy delivery systems. Jan J Phys Sports Med , 48 : 453-466. (in Japanese with English abstract)

Sibila, M., Vuleta, D., Pori, P. (2004). Position-related differences in volume and intensity of large-scale cyclic movements of male players in handball. Kinesiology , 36 : 58-68.

Spencer, M., Bishop, D., Dawson, B., Goodman, C. (2005). Physiological and Metabolic Responses of Repeated-Sprint Activities. Sports Med , 35 : 1025-1044

Yamaji, K. (1986). International comparison of maximum oxygen uptake in elite athletes. Journal of Health Physical Education and Recreation , 36 : 371-376. (in Japanese)

Yamaji, K. (2001). Sciences of maximum oxygen uptake. (pp.15-18). Tokyo : Kyourin-shoin. (in Japanese)

Yamamoto, M. (1994). Capture of exercise with dual nature of anaerobics and aerobics. Jpn J Sports Sci , 13-5 , : 607-615. (in Japanese)

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