Journal of
PHYSIOLOGICAL
ANTHROPOLOGY

Physique, Body Composition and Maximum Oxygen Consumption of Selected Soccer Players of Kunimi High School, Nagasaki, Japan

Yasuaki Tahara[1)], Kazuhiko Moji[2)], Noriaki Tsunawake[3)], Rika Fukuda[4)], Masao Nakayama[1)], Masaki Nakagaichi[5)], Tadatoshi Komine[6)], Yosuke Kusano[7)] and Kiyoshi Aoyagi[8)]

1) Department of School Health and Health Promotion, Faculty of Education, Nagasaki University
2) Institute of Tropical Medicine, Nagasaki University
3) Department of Nutrition and Health Sciences, Siebold University of Nagasaki
4) Department of Nutritional Health, Faculty of Wellness Studies, Kwassui Women's College
5) Research and Development Center for Higher Education, Nagasaki University
6) Kunimi High School, Nagasaki
7) Human Service and Community Development, Nagasaki Wesleyan University
8) Department of Public Health, Nagasaki University Graduate School of Biomedical Sciences

Abstract This study evaluates the physical and physiological ability of selected soccer players of Kunimi High School in Nagasaki Prefecture, Japan. The Kunimi team is famous for its intensive training, and had won the championship of the All Japan High School Soccer Tournament six times by 2003. We measured physique, body composition, and maximal oxygen uptake of 72 members aged between 16 and 18 years old between 1986 and 1994. They consisted of 66 outfield players (12 forward players, 23 midfielders, 31 defenders) and 6 goalkeepers. Body density was measured by the under-water weighing method, and Brozek's equation was applied to calculate percentage body fat (%Fat, %), fat-free mass (FFM, kg), FFM/height (FFM/Ht, $kg \cdot m^{-1}$), and FFM index (FFM/Ht^3, $kg \cdot m^{-3}$). The following results were obtained:

1. The average of 66 outfield players was 172.7 cm of height, 64.6 kg of weight, 54.0 cm of girth of thigh, and 90.0 cm of girth of hip, 9.3% of %Fat, 58.6 kg of FFM, 33.9 $kg \cdot m^{-1}$ of FFM/Ht and 113.8 $kg \cdot m^{-3}$ of FFM index. The mean vital capacity was 4.25 L and total lung capacity was 5.58 L. The mean maximal ventilation was 138.7 $L \cdot min^{-1}$, $\dot{V}O_2max$ was 3.95 $L \cdot min^{-1}$, and $\dot{V}O_2max/Wt$ was 61.4 $ml \cdot kg^{-1} \cdot min^{-1}$.
2. Goalkeepers were taller and heavier than outfielders, and had a smaller mean value of $\dot{V}O_2max/Wt$ than outfielders ($p<0.01$).
3. For 23 out of the 72 players measured twice with an interval of about one year, FFM increased and %Fat reduced significantly, while $\dot{V}_E max$, $\dot{V}O_2max$ and $\dot{V}O_2max/Wt$ did not change.

Kunimi players of the present study had as large a $\dot{V}O_2max/Wt$ as local players, and a similar or slightly smaller $\dot{V}O_2max/Wt$ than national-level players. They had similar %Fat and a similar $\dot{V}O_2max/Wt$ with professional soccer players in England (Davis et al., 1992) while they had much smaller physiques. *J Physiol Anthropol 25(4): 291–297, 2006* http://www.jstage.jst.go.jp/browse/jpa2
[DOI: 10.2114/jpa2.25.291]

Keywords: body composition, fat-free mass (FFM), maximum oxygen uptake ($\dot{V}O_2max$), soccer (football)

Introduction

Soccer games require comprehensive ability including physical, mental, and tactical abilities. (Bangsbo, 1994; Ekblom, 1986; Tumility, 1993). The physical abilities of players exert marked effects on the skill of the players and on the tactics of the team because soccer games demand repeated maximum exertion. Soccer players cover 8–12 km during a match, consisting of 24% walking, 36% jogging, 20% coursing, 11% sprinting, 7% moving backwards and 2% moving in possession of the ball (Reilly, 1996). Therefore, players must have physical abilities to make rapid and powerful movements. They must have aerobic and anaerobic capacities that make them competent in prolonged vigorous offensive and defensive maneuvers to win a match. To evaluate these physical and physiological abilities, parameters such as height (Ht), weight (Wt), the percentage of fat mass to Wt (%Fat), fat mass (FM), fat-free mass (FFM), FFM/Ht ($kg \cdot m^{-1}$), FFM index ($kg \cdot m^{-3}$) and maximum oxygen consumption ($\dot{V}O_2max$; $ml \cdot kg^{-1} \cdot min^{-1}$) are often used.

The body composition and $\dot{V}O_2max$ of soccer players have been reported by Raven et al. (1971), Novak et al. (1978), Kansal et al. (1980), Withers et al. (1977), and Davis et al.

(1992) for professional players or elite athletes. For Japanese players, the reported mean $\dot{V}O_2$max ranged from 54.0 (Ishizaki 1977 for a prefectural team) to 62.9 $ml \cdot kg^{-1} \cdot min^{-1}$ (Togari 1977 for an all-Japan youth team, as shown in Table 5). In the present study, we report the results of measurements of physical and physiological abilities of selected players of Kunimi High School of Nagasaki Prefecture in terms of their position, and compare them with other Japanese and international soccer players. We also report the changes of physical and physiological abilities in a year for some players. The team is famous for its intensive training, and had won the championship of the All Japan High School Soccer Tournament six times by 2003.

Subjects and Method

A total of 72 soccer players (mean age: 16.8±1.1 years, range: 16–18 years) were assessed for physique (Ht, Wt, girths of thigh and hip, sum of skinfold thickness of seven sites), body composition (%Fat, FFM, FFM/Ht, FFM index), and maximal oxygen uptake ($\dot{V}O_2$max) in April or May of nine years between 1986 and 1994. The subjects were selected male soccer players of Kunimi High School of Nagasaki Prefecture, Japan. The purpose of the physical assessment was to feed back the results to individual players and to the head coach in order to improve their training and the selection of players. The head coach of the team, one of the authors (TK) selected players to participate in the study. The subjects were mainly the regular members of each year. The players were told about the significance and procedure of the measurements, and those who were willing to find out their physical and physiological ability voluntarily participated in the study. The measurement of the first year for each player was used for this analysis, although 23 outfield players (hereafter referred as "outfielders") out of the 72 players participated in measurement for two years or more. The measurements were made for 66 outfielders (12 forward players, 23 midfielders, and 31 defenders) and 6 goalkeepers. These players had experience of 3–9 years.

Measurements of Physique and Skinfold Thickness

The height (Ht, cm), weight (Wt, kg), hip girth (cm), thigh girth (cm), and skinfold thickness of seven sites (mm, Behnke and Wilmore, 1974) were measured. The skinfold thickness was measured using Eiken-model skinfold calipers (calibrated with a unit of 10 g/mm^2). The sites of measurement were the triceps, sub-scapular, abdominal, supra-iliac, chest, thigh and mid-axillary on the right side. The first author (YT) measured everything by himself.

Body composition was determined by the underwater weighing method (Tahara et al., 2002). Players were instructed to sit in a chair hung with a load cell in a tank (120 cm in diameter and 160 cm in height) filled with warm water at 36–37°C. The heaviest weight in five times after maximum expiration was regarded as body weight in water (WW, kg). Residual lung volume (RV, L) was determined with a helium spirometer (Fukuda COMF-100) outside the tank. Body density (BD) was calculated with the following formula:

$$BD = Wt/((Wt - WW)/WTC - RV)$$ (where WTC is water density at the given temperature)

Percentage body fat was calculated from the formula reported by Brozek et al. (1963):

$$\%Fat = (4.570/BD - 4.142) \times 100$$

Fat mass is the product of Wt and %Fat, and FFM is obtained by subtracting FM from body weight.

$\dot{V}O_2$max ($L \cdot min^{-1}$ or $ml \cdot kg^{-1} \cdot min^{-1}$) was determined with reference to Kuroda's method (1973), i.e., gradually increasing the speed of a treadmill at an oblique angle of 5 degrees. After subjects had run at 160 $m \cdot min^{-1}$ for 3 min, the speed was increased by 20 $m \cdot min^{-1}$ every 2 min. They were instructed to run until exhaustion. The expired air was collected every 1 min with a Douglas bag, and the expiratory volume was determined with a continuous pneumotachograph (Fukuda CR150). The O_2 and CO_2 levels of the expired air collected in each sample bag were determined with an MINATO, AE-280 analyzer. For the determination of $\dot{V}O_2$max, the maximum of the results obtained every minute was adopted. Heart rate was monitored during the measurement of $\dot{V}O_2$max with a telemeter system (Nihon Kohden).

The mean and standard deviation (SD) of each item of measurement were calculated for all the players, outfielders and goalkeepers, and for forward players, midfielders and defenders among outfielders. Firstly, the differences in the mean values between the outfielders and the goalkeepers were examined by non-paired student's t-test. Then, the difference within the outfielders was examined by ANOVA. In the case of a significant difference by ANOVA, post hoc multiple comparison among forward players, midfielders and defenders was made by using Fisher's least-significant-difference test. The difference in measurements for 23 outfielders who participated in the measurement twice was tested by paired t-test. P values of less than 0.05 were regarded as significant.

Results

Table 1 shows the mean and standard deviation of physique and body composition by position. Outfielders (O) on average were 172.7 cm of height, 64.6 kg of weight, 54.0 cm of thigh girth, and 90.0 cm of hip girth, 9.3% of %Fat, 58.6 kg of FFM, 33.9 kg/m of FFM/Ht and 113.8 kg/m^3 of FFM-index. Goalkeepers on average were 177.8 cm of height, 71.4 kg of weight, 56.3 cm of thigh girth, and 94.2 cm of hip girth, 13.7% of %Fat, 61.6 kg of FFM, 34.7 g/m of FFM/Ht and 109.9 kg/m^3 of FFM-index. Goalkeepers were bigger than outfielders in terms of Ht, Wt, thigh girth, hip girth and %Fat. Among

Table 1 Physical characteristics and body composition in KUNIMI S. H. S. soccer players (means and standerd deviation)

		Height (m)	Weight (kg)	Thigh girt (cm)	Hip girth (cm)	Skinfold 3 (mm)	% Fat (%)	FFM 4 (kg)	FFM/Ht.5 ($kg \cdot m^{-1}$)	FFM index 6 ($kg \cdot Em^{-3}$)
Forwards (F)	M	172.8	65.8	55.0	91.7	58.6	10.9	58.6	33.9	113.8
(n=12)	SD	5.2	5.5	2.3	3.4	16.6	2.9	4.9	2.5	10
Midfielders (M)	M	171.2	62.8	53.8	88.7	58.3	9.5	56.8	33.2	113.3
(n=23)	SD	5.3	5.2	2.4	3.2	14.8	2.5	4.5	2.1	8.8
Defenders (D)	M	173.8	65.5	53.8	90.2	55.3	8.5	59.9	34.5	114.3
(n=31)	SD	5.2	4.8	2.2	3.2	12.4	2.4	4.3	2	8.7
Outfielders (O)	M	172.7	64.6	54.0	90.0	57.0	9.3	58.6	33.9	113.8
(n=66)	SD	5.3	5.1	2.3	3.3	13.9	2.6	4.6	2.2	8.8
	Max.	185.7	77.8	60.9	98.5	101.5	15.0	69.0	39.0	136.7
	Min.	161.1	55.8	49.8	83	37.5	1.7	50.5	30.0	98.1
Goalkeepers (G)	M	177.8	71.4	56.3	94.2	67.1	13.7	61.6	34.7	109.9
(n=6)	SD	3.9	3.5	2.4	2.4	14.5	4.1	2.9	1.9	9.4
All	M	173.2	65.2	54.2	90.3	57.8	9.6	58.8	34.0	113.5
(n=72)	SD	5.4	5.3	2.2	3.5	14.2	3.0	4.6	2.2	8.9
	Max.	185.7	77.8	61.1	98.5	101.5	19.2	69.0	39.0	136.7
	Min.	161.1	55.8	49.8	83	37.5	1.7	50.5	30.0	93.1
Difference (1)		G>O	G>O	G>O	G>O	n.s.	G>O	n.s.	n.s.	n.s.
Difference (2)		n.s.	n.s.	n.s.	F>M	n.s.	F>D	M<D	n.s.	n.s.

1. Difference (1) Comparison between outfielders (O) and goalkeepers (G)
2. Difference (2) Comparison among forward (F), midfilders (M) and defenders (D) Significant For example "G>O" indicates the value of goalkepers is significantlylarger than that of outfilders ($p<0.05$, ns : non-significant.
3. Skinfold : sum of seven skinfolds (tricept, abdomen, scapula, supra-illiac, crest, thigh and mid-axilla)
4. FFM: fat-free mass
5. FFM/Ht: FFM (kg)/Ht (m)
6. FFM index: FFM (kg)/Ht $(m)^3$

outfielders, hip girth, %Fat, and FFM varied significantly. Defenders had heavier FFM than midfielders. Forward players had larger hip girth than midfielders, and larger %Fat than defenders.

Table 2 shows the mean and standard deviation of VC, TLC, $\dot{V}_E$max, $\dot{V}O_2$max, and $\dot{V}O_2$max/Wt. Outfielders had a larger value of $\dot{V}O_2$max/Wt than goalkeepers (61.4 vs. 54.2 $ml \cdot kg^{-1} \cdot min^{-1}$, $p<0.01$). There was no significant variation among outfielders, although defenders and midfielders had a slightly higher mean $\dot{V}O_2$max/Wt than forward players.

Tables 3 and 4 show the mean values of measurements of the first year and the second year for 23 outfielders who were measured twice with an interval of about one year. Body height (Ht), Wt, FFM, FFM/Ht, and FFM index increased significantly in one year. FFM increased by 1.8 kg on average. In contrast, mean %Fat decreased significantly from 9.2% to 7.9%. There were no significant changes in the girths of thigh and hip or the sum of seven skinfold thicknesses. VC and TLC increased significantly in one year, while $\dot{V}_E$max, $\dot{V}O_2$max and $\dot{V}O_2$max/Wt did not change significantly during this period.

Table 5 compares the age, Ht, Wt, %Fat, $\dot{V}O_2$max and $\dot{V}O_2$max/Wt of the present study with those of previous studies of Japanese non-athletes, rugby players and distance runners of a similar age. The table also compares the results of the present study with those of soccer players inside and outside Japan since the 1970s. The Kunimi players of the present study were taller and heavier than the Japanese non-athletes of 17.0–17.9 years old of the Nagasaki Body Composition Study (Tahara et al., 2002). They had smaller %Fat (9.6%) than the non-athletes (15.0%). For $\dot{V}O_2$max and $\dot{V}O_2$max/Wt, the Kunimi players of the present study had much larger capacity than the Japanese standard for non-athletes of 17.0 years old (158% of $\dot{V}O_2$max and 142% of $\dot{V}O_2$max/Wt).

Compared with other athletes of high schools in Nagasaki (Tahara et al., 1995), the soccer players of the present study had similar Ht, lighter Wt by 5.4 kg, larger %Fat by 0.5 points, and larger $\dot{V}O_2$max/Wt by 2.2 $ml \cdot kg^{-1} \cdot min^{-1}$ than rugby players, and had taller Ht by 3.1 cm, heavier Wt by 9.4 kg, larger %Fat by 0.6 points, and smaller $\dot{V}O_2$max/Wt by 6.0 $ml \cdot kg^{-1} \cdot min^{-1}$ than distance runners.

In comparison with other Japanese soccer players, the subjects of the present study had similar physiques. They had a higher $\dot{V}O_2$max and higher $\dot{V}O_2$max/Wt than the local team of Tochigi Prefecture (Ishizaki, 1977), and had a similar or slightly smaller $\dot{V}O_2$max and $\dot{V}O_2$max/Wt with the top-level Japanese national-level players of the previous studies. No data on %Fat were available for Japanese soccer players.

The mean values of Ht, Wt, %Fat, $\dot{V}O_2$max and $\dot{V}O_2$max/Wt of soccer players from various countries ranged widely reflecting the variety of the subjects. Japanese soccer players were shorter in height and lighter in weight than Western players. Professional soccer players reported by Bangsbo (1994) had an average height of 181 cm, and those reported by Reilly (1996) had average height values between 174.6 and 180.4 cm. Weight also differs considerably. Davis et al. (1992) reported a mean Wt of 77.1 kg for outfielders and of 86.1 kg

Table 2 Physiological characteristics in KUNIMI S. H. S. soccer players (means and standerd deviation)

		VC 3 (L)	TLC 4 (L)	$\dot{V}_E$max (L)	$\dot{V}O_2$max ($L \cdot min^{-1}$)	$\dot{V}O_2$max/Wt. ($L \cdot kg^{-1} \cdot min^{-1}$)
Forwards (F)	M	4.19	5.37	142.7	3.87	59.1
(n=12)	SD	0.37	0.56	15.8	0.19	5.1
Midfielders (M)	M	4.19	5.48	140.0	3.91	62.3
(n=23)	SD	0.47	0.58	17.7	0.42	4.9
Defender (D)	M	4.32	5.74	136.3	4.02	61.6
(n=31)	SD	0.43	0.56	16.3	0.40	5.7
Outfield players (O)	M	4.25	5.58	138.7	3.95	61.4
(n=66)	SD	0.43	0.58	16.7	0.38	5.3
	Max.	5.29	6.83	181.7	5.12	72.8
	Min.	3.39	4.4	94.6	3.17	50.3
Goalkeepers (G)	M	4.30	5.53	143.2	3.87	54.2
(n=6)	SD	0.32	0.29	10.3	0.39	4.5
All (A)	M	4.26	5.58	139.1	3.95	60.8
(n=72)	SD	0.42	0.56	16.2	0.38	5.6
	Max.	5.29	6.83	181.7	5.12	72.8
	Min.	3.39	4.40	94.6	3.17	46.5
Difference (1)		n.s.	n.s.	n.s.	n.s.	O>G
Difference (2)		n.s.	n.s.	n.s.	n.s.	n.s.

1. Difference (1) Comparison between outfielders (O) and goalkeepers (G)
2. Difference (2) Comparison among forward (F) , midfilders (M) and defenders (D)

Significant For example "G>O" indicates the value of goalkepers is significantlylarger than that of outfilders ($p<0.05$, ns: non-significant.)

3. VC : vital capacity
4. TLC : total lung capacity

Table 3 Changes of physical characteristics and body composition in KUNIMI S. H. S. soccer players (outfield players, n=23)

		Height (m)	Weight (kg)	Thigh girth (cm)	Hip girth (cm)	Skinfold 2 (mm)	% Fat (%)	FFM 3 (kg)	FFM/Ht 4 ($kg \cdot m^{-1}$)	FFM index 5 ($kg \cdot m^{-3}$)
1st.	M	171.2	64.0	53.8	89.4	55.7	9.2	58.0	33.9	115.9
	SD	4.3	4.4	2.4	3.2	13.2	3.0	3.8	2.1	9.5
2nd.	M	171.7*	65.0*	54.2	89.8	55.5	7.9*	59.8*	34.8*	118.3*
	SD	4.3	4.1	1.9	3.9	12.3	2.8	4.0	2.2	9.3

1. *: significant ($p<0.05$); 1st. vs 2nd.
2. Skinfold 2 : sum of sevsen skinfolds (tricept, abdomen, scapula, supra-illiac, crest, thigh and mid-axilla)
3. FFM: fat-free mass
4. FFM/Ht: FFF (kg)/Ht (m)
5. FFM index: FFM (kg)/Ht $(m)^3$

Table 4 Changes of physiological characteristics in KUNIMI S. H. S. soccer players (outfielders, n=23)

		VC 2 (L)	TLC 3 (L)	$\dot{V}_E$max (L)	$\dot{V}O_2$max ($L \cdot min^{-1}$)	$\dot{V}O_2$max/Wt. ($L \cdot kg^{-1} \cdot min^{-1}$)
1st.	M	4.23	5.49	137.9	3.96	62.2
	SD	0.44	0.59	15.2	0.34	6.0
2nd.	M	4.37*	5.71*	140.8	4.02	62.3
	SD	0.47	0.58	13.9	0.31	5.0

1. *: significant ($p<0.05$); 1st. vs 2nd.
2. VC: vital capacity
3. TLC: total lung capacity

for goalkeepers, while that of the present study was 64.6 kg and 71.4 kg, respectively. For aerobic capacity, the French national team (Joussellin et al., 1984) showed as high as 63.9 $ml \cdot kg^{-1} \cdot min^{-1}$of $\dot{V}O_2$max/Wt. Figure 1 compares the $\dot{V}O_2$max/Wt of the present study with that of professional players of England reported by Davis et al. (1992) by position. The $\dot{V}O_2$max/Wt of England was estimated from the results of a 20-meter shuttle run test (Leger and Lambert, 1982). The Kunimi players of the present study showed the similar $\dot{V}O_2$max/Wt with the professional players of England, while the English players were much heavier than the Kunimi players (86.1 kg vs. 65.2 kg).

Table 5 Comparison of physique, body composition, and aerobic capacity between the present study and previous studies and non-athletes

Study	Sports event	Position	N	Age (yrs)	Height (cm)	Weight (kg)	%Fat (%)	$\dot{V}O_2$max ($L \cdot min^{-1}$)	$\dot{V}O_2$max/Wt ($ml \cdot kg^{-1} \cdot min^{-1}$)	Team
Present study	Soccer	All	72	16.8 (16–18)	173.2	65.2	9.6¶	3.98	60.8 (T)	Kunimi High School
Present study	Soccer	Outfielder	66	16–18	172.7	64.6	9.3¶	3.95	61.4 (T)	Kunimi High School
Present study	Soccer	Goalkeeper	6	16–18	177.8	71.4	13.7¶	3.87	54.2 (T)	Kunimi High School
Tokyo Metroplitan Univ. ('00)	Non-athlete	—	86	17.0	—	—	—	2.52	42.9 (T)	Non-athletes
Tahara and Moji ('02)	Non-athlete	—	29	17.5	169.8	60.7	15.0¶	—	—	Non-athletes
Tahara and Tunawake ('95)	Distance runner	—	30	16.7	170.1	55.8	9.0¶	3.71	66.8 (T)	High schools in Nagasaki
Tahara and Tunawake ('95)	Rugby player	—	15	17.0	173.7	70.6	9.1¶	4.11	58.6 (T)	High schools in Nagasaki
Ishizaki ('77)	Soccer	All	40	17.9	170.2	64.7	—	3.47	54.0 (B)	Tochigi Prefecture team.
Matsumoto et al. ('77)	Soccer	All	11	—	170.8	64.0	—	—	61.6 (T)	College players
Togari et al. ('79)	Soccer	All	22	—	175.2	65.3	—	4.06	62.9 (T)	Japan youth team
Ohashi et al. ('90)	Soccer	Outfielder	37	16–18	—	—	—	4.18	62.2 (T)	Japan youth team
Togari et al. ('79)	Soccer	All	14	—	175.1	67.4	—	3.91	59.0 (T)	Japan representatives
Raven et al. ('71)	Soccer	All	18	25.6 (19–32)	176.3	75.7	9.6§	—	58.4 (T)	Professional players (USA)
Withers et al. ('77)	Soccer	All	5	28.1 (20–47)	178.1	75.2	15.7¶	4.67	62.0 (T)	Australian representatives
Novak et al. ('78)	Soccer	All	9	24.8	174.1	71.8	6.2	3.81	53.2 (B)	Olympians (Morocco)
Kansal et al. ('80)	Soccer	All	29	16–18	—	57.6	12.1¶	2.55	44.2 (B)	Junior national player (India)
Joussellin et al.('84)	Soccer	All	8	22.2	—	—	—	4.46	63.9 (T)	French national teams
Ramadan et al. ('87)	Soccer	All	18	—	—	—	8.9§	—	51.9 (B)	Kuwaiti World Cup players
Reilly ('96, report in the literature)	Soccer	All	—	—	174.6–180.0	69.4–77.0	—	—	55–70	Varius country teams
Bangsbo ('94)	Soccer	All	65	18–36	181 (167–193)	77.1 (59.5–97.0)	—	—	53–72	Danish top league players
Bangsbo ('94)	Soccer	Midfilder	21	—	—	—	—	—	62.4 (T)	Danish top league players
Bangsbo ('94)	Soccer	All	5	16	—	—	—	—	59.5 (T)	Danish players (16 years old)
Davis ('92)	Soccer	Outfielder	122	26.7	—	77.1	10.5§	—	60.4 (S)	Professional players (UK)
Davis ('92)	Soccer	Goalkeeper	13	23.8	—	86.1	13.3§	—	56.4 (S)	Professional players (UK)

T ($\dot{V}O_2$max) ; treadmill test
B ($\dot{V}O_2$max) ; bicycle ergometer test
S ($\dot{V}O_2$max) ; 20 m shuttle run test (Leger and Lambert, 1982)
§;(%Fat) ; skinfold method
¶ (%Fat) ; under-water weighing method
—; no data

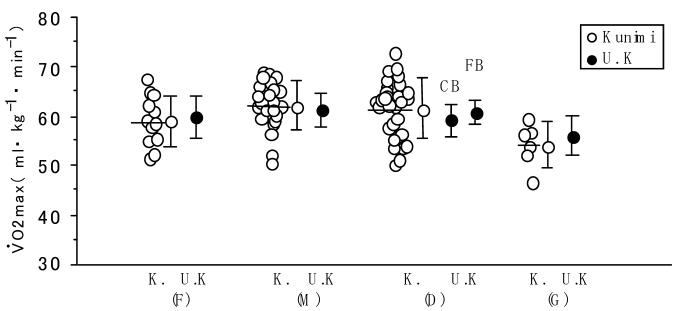

Fig. 1 Comparisons of $\dot{V}O_2$max/Wt ($ml \cdot kg^{-1} \cdot min^{-1}$) of the present study with that of professional players of England reported by Davis et al. (1992) by position. Each open circle shows the value of each player in the present study. The horizontal line and vertical line show the mean $\dot{V}O_2$max /Wt and its standard deviation for each group, respectively.
K: Kunimi High School Players (present study), U.K: Professional players of England
F: Forward, M: Midfielders, D: Defender, CB: Centre backs, FB: Full backs, G: Goalkeepers
$\dot{V}O_2$max: Kumini :Treadmill running, UK: 20 m shuttle run test (Leger and Lambert, 1982)

Discussion

Physique and body composition are important factors for sports games. Kitagawa et al. (1974) and Wilmore (1983) indicated that body composition affects physical strength and skill in various sports. It is an important aspect of fitness for soccer as superfluous adipose tissue acts as dead weight in activities where body mass must be lifted repeatedly against gravity (Reilly, 1996). In the present study we confirmed a large difference of body size between goalkeepers and outfielders. Goalkeepers were taller, as a taller player is advantageous in defending the goal. As Ht correlates with Wt in general, goalkeepers were heavier than outfielders. On the other hand, FFM did not differ between the two groups. In addition to their heavier weight, presumably because endurance is less important for goalkeepers, $\dot{V}O_2$max/Wt was smaller for goalkeepers than outfielders.

Although Reilly (1996) mentioned that the lack of height might not be in itself a bar to success in soccer, and that it might determine the choice of playing position, it is obviously a disadvantage. To compensate for a smaller physique, it is required for Japanese players to have high-level skills and physical fitness. To reduce %Fat is one thing and to acquire high aerobic and anaerobic capacities is another. The %Fat of the Kunimi players of the present study was similar to that of English players; 9.3% vs. 10.5% for outfielders, and 13.7% vs. 13.3% for goalkeepers. The $\dot{V}O_2$max represents an integrated physiological function, and values for $\dot{V}O_2$max/Wt above 60 $ml \cdot kg^{-1} \cdot min^{-1}$ would seem desirable for outfielders (Bangsbo, 1994). Enhanced aerobic endurance in players improves soccer performance by increasing the distance covered, enhancing work intensity, and increasing the number of sprints and improvements with the ball during a match (Helgerud et al., 2001). The outfielders of the present study had similar aerobic power to the England players, although there was considerable variation ranging between 50.3 and 72.8 $ml \cdot kg^{-1} \cdot min^{-1}$. Some of the Kunimi players reached 60 $ml \cdot kg^{-1} \cdot min^{-1}$ through hard training (Table 5). Although there was no significant increase of $\dot{V}O_2$max/Wt after one year of training, there is a possibility that players increased their ability to play with a high % of $\dot{V}O_2$max. But we cannot say more here as we did not measure the lactate threshold in this study. The Kunimi team did endurance training including a 10 km time-trial, 1000 m interval training 5 times twice a week, and covered 140 matches per year. The physical abilities of the players of this team would be a factor for their winning championships. This kind of training, in turn, would create a large FFM index and small FM.

It is generally difficult for a team to maintain top competitiveness for a long period. A good understanding of the importance of physical abilities and a good understanding of the physical ability of individual players by a head coach are important factors for keeping a team strong. Such knowledge makes a large difference in how to train players and how to use each player with different characteristics in a match, as the Kunimi team has successfully done.

Acknowledgments This study owes much to the cooperation of the Kunimi soccer team. We are grateful to the players and staff of the team who cooperated and/or participated in this study. We are also grateful to our colleagues who participated in measurements. This study was carried out with financial support from Nagasaki Prefecture and the KTN Sports Foundation. We are thankful to the Committee of Sports Medicine and Science of Nagasaki, which made this study possible.

References

Bangsbo J (1994) The physiology of soccer. Acta Physiologica Scandinavica 151 Supplementum 619: 1–155

Behnke AR , Wilmore JH (1974) Evaluation and regulation of body build and composition. Pretice-Hall Inc., Englewood Cliffs, 38–52

Brozek J, Grande F, Anderson JT, Keys A (1963) Densitometric analysis of body composition; Revision of some quantitative assumptions. Ann NY Acad Sci 110: 113–140

Davis JA, Brewer J, Atkin D (1992) Pre-season physiological characteristics of English first and second division soccer players. J Sports Science 10: 541–547

Ekblom B (1986) Applied physiology of soccer. Sport Med 3: 50–60

Helgerud J, Engen LC, Wisloff U, Hoff J (2001) Aerobic endurance training improves soccer performance. Med Sci Sports Exerc 33: 1925–1931

Ishizaki T (1977) Physical fitness of senior high school football players delegated for the national athletic meets from Tochigi prefecture. Bull Faculty of General Education, Utsunomiya Univ 10: 109–116

Joussellin E, Handschuh R, Barrault D, Rieu M (1984) Maximal aerobic power of French top level competitors. J Sports Med 24: 175–182

Kansal DK, Verma SK, Sidhu LS (1980) Intrasportive difference in Maximum oxygen uptake and body composition of Indian players in hockey and foot ball. J Sports Med 20: 309–316

Kitagawa K, Ikuta K, Hara Y, Hirota K (1974) Investigation of lean body mass as a limiting factor of maximum oxygen uptake. Jpn J Phys Fitness Sports Med 23: 96–100 [*In Japanese*]

Kuroda Y, Ito S, Tsukagoshi K, Amemiya T, Suzuki Y (1973) Maximum oxygen uptake and maximum oxygen debt of the elite Japanese athletes part 2. Sport Scientific Research Reports JASA 1973: 1–27 [*In Japanese*]

Leger LA, Lambert J (1982) A maximal multistage 20-mshuttle run test to predict $\dot{V}O_2$max. Eur J Appl Physiol 49: 1–12

Matsumoto M, Komiya Y, Kubota Y, Iwamura E (1977) A study of the game analysis of soccer with special reference

to work intensity during the game. Bull Faculty of Education, Fukushima Univ 29: 55–65 [*In Japanese*]

Novak LM, Bestit C, Mellerowicz H, Woodward WA (1978) Maximal oxygen consumption, body composition and anthropometry of selected Olympic male athletes. J Sports Med 18: 139–151

Ohashi J, Hyodo K, Togari H, Maruyama T (1990) Maximal oxygen uptake of elite soccer players in Japan. Bull Faculty of General Education (*Taiikugaku Kennkyou*), Tokyo Univ 24: 65–71 [*In Japanese*]

Ramadan J, Byrd R (1987) Physical characteristics of elite soccer players. J Sports Med 27: 424–428

Raven PB, Gettman LR, Pollock ML, Cooper KH (1971) A physiological evaluation of professional soccer players. Br J Sports Med 10: 209–216

Reilly T (ed.) (1996) Science and Soccer. E & FN SPON, An Imprint of Chapman & Hall, London, 25–64

Tahara Y, Tsunawake N, Yukawa K, Nishiyama K, Senjyu H, Urata H, Katuno K, Fukuyama Y, Mori S, Michimuko R, Nishizawa S, Katayose M, Uekata M, Miyahara K, Yamanaka R (1995) Physique, body composition, cardiorespiratory function (maximal oxygen uptake, maximal oxygen debt) and anaerobic power on elite male and female athletes. Bull Faculty Liberal Arts (Natural Science, Special issue) 33: 309–339 [*In Japanese*]

Tahara Y, Moji K, Aoyagi K, Nishizawa S, Yukawa K, Tsunawake N, Muraki S, Mascie-Taylor CGN (2002) Age-related pattern of body density and body composition in Japanese males and females, 11 and 18 years of age. Am J Hum Biol 14: 327–337

Tokyo Metropolitan University Physical Education Laboratory (ed.) (1989) Physical fitness standard value of Japanese. 4th ed., Fumaido, Tokyo, 236–245 [*In Japanese*]

Togari H, Asami T, Adachi N, Yamamoto K, Sugiyama S, Ohashi J (1979) A Study on Physical Fitness of the Top Soccer Players in Japan. Bull Faculty of General Education (*Taiikugaku Kennkyou*), Tokyo Univ 13: 33–42 [*In Japanese*]

Tumility D (1993) Physiological characteristics of elite soccer players. J Sports Med 16: 80–96

Wilmore JH (1983) Body composition in sport and exercise: directions for future research. Med Sci Sports Exerc 15: 21–31

Withers RT, Roberts RGD, Davies GJ (1977) The maximum aerobic power, anaerobic power and body composition of South Australian male representatives in athletics, basketball, field hockey and soccer. J Sports Med 17: 391–400

Received: October 14, 2005
Accepted: March 29, 2006
Correspondence to: Yasuaki Tahara, Faculty of Education, Nagasaki University, 1–14 Bunnkyo-machi, Nagasaki 852–8521, Japan
Phone: +81–95–819–2354
Fax: +81–95–819–2354
e-mail: y-tahara@nagasaki-u.ac.jp