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Body Composition and Physical Fitness of Female Volleyball and Basketball Players of the Japan Inter-high School Championship Teams

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Abstract This study evaluated the body composition (underwater weighing) and cardiorespiratory function ($\dot{V}O_2$max and O_2debt max measured by the treadmill exercise test) in 12 members of the women's volleyball team (mean age 17.4 years) and 11 members of the women's basketball team (mean age 17.6 years) that won the championship in the Japan Inter-high School Meeting. We also examined differences in the physical abilities between the members of the top teams of different events. The following results were obtained.

1. The mean values of the height and body weight were 168.7±5.89 cm and 59.7±5.73 kg in the volleyball players and 166.5±7.87 cm and 58.8±6.85 kg in the basketball players.
2. The mean %Fat was 18.4±3.29% in the volleyball players and 15.7±5.05% in the basketball players, and was similar to the reported values in elite adult players.
3. The mean $\dot{V}O_2$max was 2.78±0.32 L·min^{-1} (46.5±2.90 ml·kg^{-1}·min^{-1}) in the volleyball players and 3.32±0.31 L·min^{-1} (56.7±4.17 ml·kg^{-1}·min^{-1}) in the basketball players, and was similar to the reported values in elite adult players.
4. The mean O_2debt max was 6.18±1.15 L (103.2±12.40 ml·kg^{-1}) in the volleyball players and 7.92±1.80 L (134.3±23.24 ml·kg^{-1}) in the basketball players. These values were 2.6 times and 3.3 times as high as the average values in high school students in general.
5. No significant difference was observed in any measured item of the physique, skinfold thickness, or body composition between the volleyball players and basketball players.
6. The $\dot{V}O_2$max and O_2debt max were 22% and 28% higher in the basketball players than in the volleyball players.

From these results, the female volleyball players and basketball players evaluated in this study had the physical abilities needed to win the championship in the Japan Inter-high School Meets, i.e. a large FFM and excellent aerobic and anaerobic work capacities. Also, basketball appears to require higher aerobic and anaerobic work capacities than volleyball.
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Introduction

Ball games require comprehensive ability including physical, technical, mental, and tactical abilities. Among them, physical abilities of players exert marked effects on the skill of the players themselves and the tactics of the team, because ball games demand repeated maximum exertion such as dashing and jumping. Therefore, players must have the physical abilities to make rapid and powerful movements, and aerobic and anaerobic capacities that make them competent in prolonged vigorous offensive and defensive maneuvers. Such physical abilities are important for both volleyball and basketball players to win.

To evaluate these physical abilities, parameters of the body composition such as the percent body fat (%Fat) and fat-free mass (FFM), parameters of the aerobic work capacity such as the maximum oxygen uptake ($\dot{V}O_2$max), and parameters of the anaerobic work capacity such as the maximum oxygen debt (O_2debt max) are often used.

The body composition and $\dot{V}O_2$max of female volleyball players have been reported by Kovaleski et al. (1980), Puhl et al. (1982), and Filaire et al. (1998), and those of female basketball players by Sining (1973), Vaccaro et al. (1979), and

Sugahara et al. (1983). However, the subjects of these reports were general college students or non-student athletes, and there has been no report on comprehensive physical abilities including the O_2debt max.

In this study, therefore, to provide a reference for improving the competitive level of high school players and to clarify conditions to be top athletes, we evaluated characteristics of physical abilities of the members of the female volleyball and basketball teams that won the championship in the Japan Inter-high School Meeting. Characteristics of physical abilities needed for volleyball and basketball were also evaluated by comparing the data from the members of the two teams.

Methods

Subjects, time and place of evaluation

The subjects were 12 members of the female volleyball team that won the championship in the 1989 Japan Inter-high School Meeting (Group V) and 11 members of the female basketball team that won the championship in the 1991 Japan Inter-high School Meeting (Group B). As controls of physique, skinfold thickness, and body composition, 46 female high school students with no particular athletic background were examined (Group N). The measurements were performed in Group V in August, 1989 after the Japan Inter-high School Meeting, in Group B in January, 1992 after the National Tournament of Seeded High Schools, in which the team with the same members came in second, and in Group N in July, 1992 at the Physical Education Laboratory, Nagasaki University. The subjects were explained about the significance of the measurements and consented to the measurements through their coaches.

Items of measurements

1. Physique and skinfold thickness

The height, body weight, chest girth, and skinfold thickness were measured. The skinfold thickness was measured using Eiken-model skinfold calipers (calibrated with a unit of $10\,g/mm^2$) according to Behnke & Wilmore (1974). It was measured by Y. T., one of the authors with experience in the measurement, to ensure the accuracy.

The sites of measurement were the triceps, sub-scapular, abdominal, supra-iliac, chest, thigh, knee, and mid-axillary regions on the right side. The various skinfold sites are defined as follows:

triceps, midway between the acromion and olecranon processes on the posterior aspect of the arm.
sub-scapular, inferior angle of the scapula at the axillary border.
abdominal, adjacent to the umbilicus.
supra-iliac, crest of the ilium at the mid-axillary.
chest, over the lateral border of the pectoralis major, just medial to the axilla.
thigh, anterior aspect of the thigh midway between the hip and knee joints.
knee, midpoint of the patella.
mid-axillary, on the mid-axillary line approximately at the level of the fifth rib.

2. Body composition

Body composition was determined by the underwater weighing method. The subject was instructed to sit in a chair hung with loadcel in a tank (120 cm in diameter and 160 cm in height) filled with warm water at 36–38°C. The heaviest weight after maximum expiration was regarded as body weight in water. The determination was performed five times. Residual lung volume (RV) was determined with a helium spirometer (Fukuda COMF-100) outside the tank. Body density (BD) was calculated with the following formula: BD=WA/((WA−WW)/WTC−RV).

Percent fat was calculated from the formula reported by Brozek et al. (1963), as follows: %fat=(1.570/BD−4.142)×100. FM is the product of body weight and %fat, and FFM is obtained by subtracting FM from body weight.

3. $\dot{V}O_2$max

$\dot{V}O_2$ max was determined with reference to Kuroda's method (1973), i.e., gradually increasing the speed of a treadmill at an oblique angle of 5°. After subjects had run at $120\,m\cdot min^{-1}$, for 3 minutes, the speed was increased by $20\,m\cdot min^{-1}$ every 2 minutes. They were instructed to run until exhaustion. The expired air was collected every one minute 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 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 determined with a telemeter system (Nihon Kohden).

4. O_2debt max

O_2debt max was determined with reference to Kurora's method (1973) in a manner similar to that for $\dot{V}O_2$max; a treadmill was set at an oblique angle of 5°, and after the subject's running capacity had been determined, she was instructed to run at $230–250\,m\cdot min^{-1}$ so that exhaustion would occur within about 60–70 seconds. Immediately after running until exhaustion, the subject rested in the sitting position, and the expired air was collected in a Douglas bag for 40 minutes during recovery. The metabolism in excess of that at rest was used for the determination of O_2debt max. With regard to metabolism at rest, the subject was instructed to rest in the sitting position for 30 minutes after entering the experimental room, the expired air was measured for 10 minutes, and then O_2 and CO_2 levels were determined by an analysis similar to that for $\dot{V}O_2$max.

Statistics

The mean and standard deviation of each item of measurement were calculated in each group, and the differences in the mean values among Group N, Group V, and Group B were examined by non-paired Student t-test. P values of <0.05 were regarded as significant.

Table 1 Physical characteristics of female volleyball and basketball championship team players in the Japan Inter-high School Meeting.

	Volleyball (V)	Basketball (B)	Non-athletes (N)	Significance level (V VS. N)	(B VS. N)	(V VS. B)
Number	12	11	46			
Age (years)	17.4 ± 0.73	17.6 ± 0.88	17.7 ± 0.40	ns	ns	ns
Height (cm)	168.7 ± 5.89	166.5 ± 7.87	157.7 ± 5.11	***	***	ns
Weight (kg)	59.7 ± 5.73	58.8 ± 6.85	50.7 ± 6.42	***	***	ns
Chest girth (cm)	82.8 ± 4.34	83.9 ± 3.25	71.9 ± 5.84	***	***	ns
Abdominal girth (cm)	73.7 ± 4.43	72.1 ± 2.98	77.7 ± 5.41	*	**	ns
Upper arm girth (cm)	25.2 ± 2.04	24.5 ± 1.22	24.5 ± 1.97	ns	ns	ns
Thigh girth (cm)	53.9 ± 3.69	53.9 ± 2.44	52.3 ± 3.24	ns	ns	ns
Lower leg girth (cm)	35.5 ± 1.95	35.7 ± 1.63	34.9 ± 3.91	ns	ns	ns
Waist (cm)	67.3 ± 4.04	64.8 ± 3.35	63.1 ± 4.41	**	ns	ns
Hip (cm)	90.9 ± 3.29	91.1 ± 4.35	87.6 ± 4.25	*	*	ns
Skinfold thickness						
Triceps (mm)	16.3 ± 3.58	14.7 ± 4.03	17.9 ± 3.54	ns	*	ns
Sub-scapular (mm)	12.1 ± 4.10	11.6 ± 3.75	14.2 ± 3.46	ns	*	ns
Abdominal (mm)	14.5 ± 3.83	14.2 ± 3.75	20.7 ± 4.79	***	***	ns
Supra-iliac (mm)	13.3 ± 4.21	10.9 ± 4.23	18.3 ± 5.57	**	***	ns
Chest (mm)	10.9 ± 2.17	11.3 ± 3.79	12.4 ± 3.19	ns	ns	ns
Thigh (mm)	23.4 ± 2.76	21.7 ± 5.50	29.1 ± 4.55	***	***	ns
Knee (mm)	12.9 ± 3.96	11.0 ± 2.79	14.5 ± 3.63	ns	**	ns
Mid-axillary (mm)	11.2 ± 3.60	9.3 ± 3.44	11.5 ± 3.41	ns	ns	ns
Body composition						
Body density (BD) ($g \cdot ml^{-1}$)	1.0564 ± 0.0080	1.0632 ± 0.0124	1.0440 ± 0.0092	***	***	ns
Percent body fat (%Fat) (%)	18.4 ± 3.29	15.7 ± 5.05	23.8 ± 3.03	***	***	ns
Fat mass (FM) (kg)	11.0 ± 2.46	9.4 ± 3.57	12.2 ± 2.59	ns	***	ns
FM/Ht ($kg \cdot m^{-1}$)	6.5 ± 1.40	5.6 ± 2.05	7.7 ± 1.55	*	***	ns
Fat-free mass (FFM) (kg)	48.6 ± 4.53	49.4 ± 5.08	38.7 ± 4.41	***	***	ns
FFM/Ht ($kg \cdot m^{-1}$)	28.8 ± 2.42	29.6 ± 1.77	24.9 ± 3.39	***	***	ns

* $p<0.05$, ** $p<0.01$, *** $p<0.001$, ns: not significant

Results

Physical abilities of female volleyball and basketball players

1. Physique and skinfold thickness

Table 1 shows the data of the physique, skinfold thickness, and body composition as the means and standard deviations and the results of statistical analysis of the differences in the mean values among Groups V, B, and N. In Group N, the height was comparable to, but the weight was about 2 kg smaller than, the averages of the Japanese at the age 17 (Japanese Ministry of Education, 1992).

Concerning the physique, the height, weight, and chest girth were significantly greater, but the abdominal birth was significantly smaller, in Groups V and B than in Group N ($p<0.05$–0.001). The skinfold thickness was significantly smaller in the abdominal, supra-iliac, and thigh regions in Group V, and in the triceps, sub-scapular, abdominal, supra-iliac, thigh, and knee regions in Group B, than in Group N ($p<0.05$–0.001).

2. Body composition

%Fat and FFM were 18.4% and 48.6 kg in Group V and 15.7% and 49.4 kg in Group B. %Fat was significantly smaller, and FFM was significantly greater, in Groups V and B than in Group N (23.8%, 38.7 kg). The FM/Ht and FFM/Ht values of the volleyball and basketball players relative to the mean values of Group N (=100) are plotted in Figure 1. Most of both the volleyball and basketball players were plotted in the second quadrant.

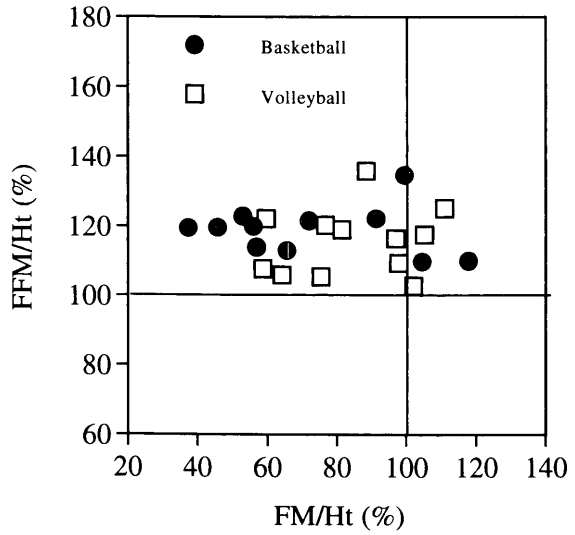

Fig. 1 Percentage of FM/Ht and FFM/Ht of female volleyball and basketball players compared to those of the non-athletes (N;100%).

Table 2 $\dot{V}O_2$max and O_2debt max of female volleyball and basketball championship team players in the Japan Inter-high School Meeting.

	Volleyball (V)	Basketball (B)	Significance level (V VS.B)
Number	12	11	
$\dot{V}O_2$ max			
HRmax (beats·min^{-1})	186.1±9.20	187.5±6.33	ns
$\dot{V}$Emax (l·min^{-1})	101.2±13.97	117.5±9.22	**
$\dot{V}O_2$max (l·min^{-1})	2.78±0.32	3.32±0.31	***
$\dot{V}O_2$max (ml·kg^{-1}·min^{-1})	46.6±2.90	56.7±4.17	***
O_2debt max			
O_2debt max (l)	6.18±1.15	7.92±1.80	*
O_2debt max (ml·kg^{-1})	103.2±12.40	134.3±23.24	***

* $p<0.05$, ** $p<0.01$, *** $p<0.001$, ns: not significant

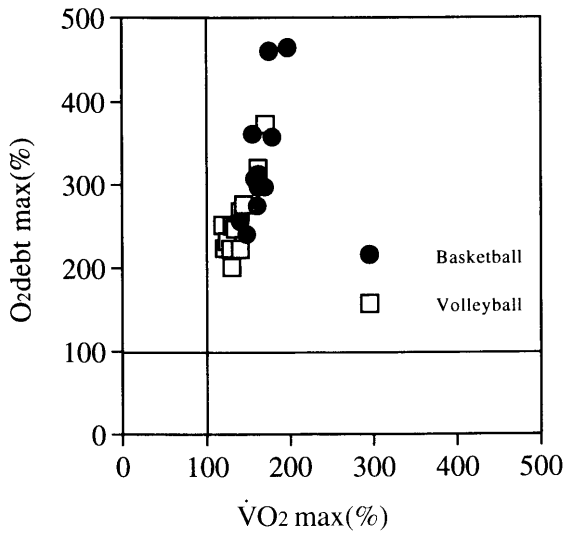

Fig. 2 Percentages of $\dot{V}O_2$max and O_2debt max of female volleyball and basketball players compared to those of the non-athletes. The value of the non-athletes (=100) was the average of Japanese at the same age (Tokyo Metropolitan Univ. Physical Education Laboratory, ed., 1989).

3. $\dot{V}O_2$max and O_2debt max

Table 2 shows the means and standard deviations of $\dot{V}O_2$max and O_2debt max. $\dot{V}O_2$max and O_2debt max were 2.78 L·min^{-1} (46.6 ml·kg^{-1}·min^{-1}) and 6.18 L (103.2 ml·kg^{-1}), respectively, in Group V and 3.32 L·min^{-1} (56.7 ml·kg^{-1}·min^{-1}) and 7.92 L (134.3 ml·kg^{-1}), respectively, in Group B. In Figure 2, the values of $\dot{V}O_2$max and O_2debt max in the volleyball and basketball players relative to those in the average Japanese at the same age ($\dot{V}O_2$max, 2.02 L·min^{-1}; O_2debt max, 2.4 L: Tokyo Metropolitan Univ. Physical Education Laboratory, ed., 1989) are plotted. All volleyball and basketball players were distributed in the first quadrant.

Differences in physical abilities between volleyball players and basketball players

No significant difference was observed in the physique, skinfold thickness, or body composition between Group V and Group B (Table 1). However, $\dot{V}O_2$max and O_2debt max were significantly greater in both the absolute and relative values in Group B than in Group V ($p<0.05$–0.001) (Table 2).

Discussion

1. Physique and skinfold thickness

In volleyball, teams compete by manipulating skills of spiking and blocking high above the head. In basketball, players try to carry the ball by dribbling and passing among a group of teammates and opponents and score goals in a hoop located above the head. Since both games require handling the ball above the head, height is considered to be the most important physical attribute. This is suggested by the fact that the mean heights of volleyball and basketball players rank among the highest in the Japanese National Teams of various events (Amemiya, 1990). Group V and Group B, who were Japan Inter-high School champions, showed markedly greater height, fat-free mass, and girths than Group N consisting of non-athletic average high school students. The height was 170 cm or greater in 7 of Group V and 2 of Group B; the 2 basketball players were at 182.9 cm and 179.3 cm tall. Some authors have suggested the height as an important condition of sports talent in such events that require height (Toyoda, 1989), and the presence of tall players is an indispensable element in success as a team.

The skinfold thickness, which can be measured most readily from outside among various body tissues, is often examined for evaluation of the nutritional state and physical changes associated with training. In Groups V and B, the values of skinfold thickness in the abdominal, supra-iliac, and thigh regions were 60–80% of those in Group N, indicating less subcutaneous fat deposits in the abdominal region to the legs compared with other regions. The values of skinfold thickness in the volleyball and basketball players in this study were comparable to those in 7th graders (Tsunawake et al., 1995b), and such low values are considered to have been maintained through training over many years (Ikegami et al., 1979; Ishigure et al., 1980).

Despite differences in the event characteristics between Group V and Group B, no significant difference was observed in the values of girth or skinfold thickness as well as the height and body weight between the two groups.

2. Body composition

Kitagawa et al. (1974) and Wilmore (1993) indicated that the body composition greatly affects the energy-related physical strength and skill in various sports. %Fat has been determined by the underwater weighing method at 19.5% in college students by Kovaleski et al. (1980), 17.9% in college students by Puhl et al. (1982), 18.0% in players of company-owned teams by Ikegawa et al. (1988), and 19.6% in high school students by Tsunawake et al. (1995a) among volleyball players and at 20.8% in college students by Sinning et al. (1973) and 18.8% in players of company-owned teams and 18.0% in high school students by Tsunawake et al. (1995a)

among basketball players. Although the value in Group V was generally in agreement with these reported values, those in Group B (15.7%) was the lowest among the reported values. A difference of 2.7% was observed between Group V and Group B, but it was not significant. This difference may be related to the difference in the distance of running during the game between the net-type and goal-type games and the presence or absence of intense body contact. From these results, the optimal %Fat in female volleyball or basketball players is estimated to be 16–20%.

FFM is the body weight minus the fat mass. Forbes & Lewis (1956) reported that skeletal muscles account for 48.2–54.4% of FFM, which suggests that FFM is a parameter that reflects the muscle mass. The value of FFM is largely dependent on the physique including the height and body weight. For this reason, we calculated FFM per 1 m of the height to evaluate the muscle mass relative to the skeleton, which is the framework of the body. FFM/Ht was 28.8 and 29.6 $kg \cdot m^{-1}$ in Groups V and B, respectively, and these values were close to 31.4 $kg \cdot m^{-1}$ in players of company-owned teams (Ikegawa et al.; 1988), 28.7 $kg \cdot m^{-1}$ in college students (Kovaleski et al.; 1980), and 29.2 $kg \cdot m^{-1}$ in high school students (Tsunawake et al.; 1995a) concerning volleyball players and to 29.8 $kg \cdot m^{-1}$ in players of company-owned teams and 28.7 $kg \cdot m^{-1}$ in high school students (Tsunawake et al.; 1995a) concerning basketball players. FFM/Ht was not different between Groups V and B.

The subjects of this study in both Group V and Group B had an experience in the game of 3–7 years. Their low FM and large FFM and FFM/Ht, acquired and retained through deliberate training over a long period, are considered to be factors of their high level of fitness and performance. However, FM/Ht and FFM/Ht were not uniform among the athletes. As shown in Table 1, both the volleyball and basketball players showed considerable individual variations compared with the mean value of general students. Such differences may be based on the play style and position, and how to make effective use of players with different characteristics is an important problem for the team.

3. $\dot{V}O_2$max and O_2debt max

$\dot{V}O_2$max in volleyball players or basketball players is not markedly high according to the inter-event comparison among the French National Teams by Joussellin et al. (1984) and the reviews of reports concerning various events by Butts (1985) and Yamaji (1985). The reported values of $\dot{V}O_2$max per kg of body weight were 41–56 $ml \cdot kg^{-1} \cdot min^{-1}$ in volleyball and 45–57 $ml \cdot kg^{-1} \cdot min^{-1}$ in basketball, and these values appear to be the levels required to players of top teams (Table 3). Its values in Group V and Group B fell in these ranges, so that both teams are considered to have possessed a sufficient aerobic work capacity. Particularly, the value in Group B, which was near the maximum level, may have been a result of endurance training that included a 5,000-m time-trial and 400-m interval training implemented twice a week (Yamasaki, 2000).

The ergometer or the treadmill is generally used as the loading instrument for the measurement of $\dot{V}O_2$max. Withers et al. (1981) reported that $\dot{V}O_2$max was 10.4% higher on the treadmill than on the ergometer in long-distance runners. Since both volleyball and basketball are ground games, there is the possibility of variation in the results of evaluation depending on the loading equipment, and clarification of which loading equipment was used may be needed for the comparison of $\dot{V}O_2$max.

According to the reports to date, $\dot{V}O_2$max is higher in basketball players than in volleyball players (Joussellin et al., 1984; Butts, 1985; Yamaji, 1985). In our study, also, $\dot{V}O_2$max/Wt was 10.1 $ml \cdot kg^{-1} \cdot min^{-1}$ (about 22%) higher in Group B than in Group V. The value in Group B was comparable to those in middle-distance track runners (Kuroda

Table 3. Various reported of %Fat, $\dot{V}O_2$max and O_2debt max on elite female volleyball and basketball players.

Study	n	Age (yrs.)	%Fat (%)	$\dot{V}O_2$max ($l \cdot min^{-1}$)	$\dot{V}O_2$max ($ml \cdot kg^{-1} \cdot min^{-1}$)	O_2debt max (l)	O_2debt max ($ml \cdot kg^{-1}$)	Work method	Teams
Volleyball									
Present study	12	17.4	18.4 a	2.78	46.6	6.18	103.2	T	Japan Inter-high School Chanpion Team
Toyoda H et al. (1975)	6			2.99	46.3			T	Japan League Team
Kovaleski JE et al. (1980)	10	20.5	19.5 a	3.34	55.5			T	Varsity players (U.S.)
Spence DW et al. (1980)	6	21.6		3.04	41.7			T	Pan-Anerivan Team (U.S.)
Pull J et al. (1982)	14	21.6	17.9 a	3.57	50.6			T	University World Games Team (U.S.)
Joussellin R et al. (1984)	27			3.53	52.7			E	National Team (France)
Filaire et al. (1998)	7	24.6	20.2	3.08	44.5			E	National players (France)
Basketball									
Present study	11	17.6	15.7 a	3.32	56.7	7.92	134.3	T	Japan Inter-high School Chanpiom Team
Sining WE (1973)	14	19	20.8 a	2.69	43.0			E	College players (U.S.)
Vaccaro P et al. (1979)	15	19.4	20.8 b	3.39	49.6			T	University players (U.S.)
Sugahara et al. (1983)	6	22.0	15.8 b	3.2	52.2			T	Japan Industrial League Team
Joussellin R et al. (1984)	13			4.00	57.2			E	National Team (France)

%Fat method=a: underwater weighing method, b: skinfold thickness method
Work method ($\dot{V}O_2$max and O_2debt max)=T: treadmill test, E: bicycle ergometer test

et al., 1973; Joussellin et al., 1984; Butts, 1985; Yamaji, 1985), indicating the high aerobic work capacity required for basketball players.

Both volleyball and basketball have been reported to also require a high anaerobic work capacity (Nakamura, 1987). The absolute values of O_2dept max in Group V and Group B were about 2.6 times and 3.3 times as high as the average of the Japanese (Tokyo Metropolitan Univ. Physical Education Laboratory, ed., 1989). Of the exercise performed in basketball, 90% has been suggested to be anaerobic (Cardinal, 1994). However, there have been few reports on O_2dept max, which was used in this study as an index of the anaerobic work capacity, in female volleyball or basketball players, probably because the measurement takes a long time and, hence, involves considerable discomfort of the subjects. Although O_2dept max was about 28% higher in Group B than in Group V, the values of both groups were comparable to those in short-distance track runners (Kuroda et al., 1973). These results suggest that the players of both teams possessed a high anaerobic work capacity, which won them a championship through a stiff competition.

It is generally difficult for a team to maintain top competitiveness in national meeting. Players must acquire high aerobic and anaerobic capacities to be competitive. However, as shown in Table 2, the players of both events showed considerable individual variations compared with the averages of Japanese of the same age level. These individual variations may be due to genetic factors (Yamaji, 2001) and differences in the activity level among positions (Vaccaro P et al, 1980; Bale P, 1991).

The excellent physical abilities of the players of these teams are a factor in their winning championships in the Japan Inter-high School Meeting. Also, it was speculated to be due partly to good understanding of physical abilities of individual players by the coaches and excellent tactics based on efficient use of each player.

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