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Classification of Body Shape of Male Athletes by Factor Analysis

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The purpose of this study was to evaluate the body shape of athletes in comparison with adult non-athletes by factor analysis. The subjects were 210 male adult non-athletes and 485 male high school age and adult athletes participating in 13 different sporting events. Physique, skinfold thickness and body composition of each subject were measured. Measured values from adult non-athletes were analyzed by factor analysis, and body shape of the athletes was then analyzed according to these factors. The results are summarized as follows: 1. Four main factors, that is, body fat, mass, leg length to height ratio and length, which could explain 88.5 percent of total variance, were extracted from the measured values from adult non-athletes. 2. Similarity of body shape between sporting events was analyzed by cluster analysis. Body shape of the athletes could be classified into 3 categories: muscular and well-balanced type ; rich muscular and large-built type ; and rich muscular and long-torso type. Compared with adult non-athletes, male athletes had less body fat and greater mass except for long-distance runners. The present results suggested that the athletes had body shapes suitable to their sporting events. (Ann. Physiol. Anthrop. 13(6): 383-392, 1994)

Key words: Physique, Body composition, Body shape, Male athlete, Factor analysis

Physique, body shape and body construction of athletes significantly affect their sporting abilities and strategies of teams. Thus, it is well-known that top-ranking athletes have body shapes that are specific for their sporting events. Although there have been many reports on physique and body construction of athletes (Shephard, 1974 ; Pipes, 1977 ; Tanaka et al., 1977 ; Thorland et. al., 1981 ; Puhl, 1982 ; Wilmore, 1983 ; Fleck, 1983 ; Butts, 1985 ; Tahara et al., 1990 ; Tsunawake et al., 1989, 1993), only a few studies on body shape have been performed, including a report using Hearth-Carter Method (Hearth & Carter, 1966) (Thorland et al., 1981 ; Carter, 1984 ; Butts, 1985) and a report utilizing body indices calculated from physical measurements (Tanaka et al., 1977).

Recently, body shape has been discussed in anthropology (Fukushima, 1967 ; Kouchi, 1977) and clothing science (Masuda, 1965 ; Yamana et al. 1988) by multivariate analysis of physique data. In sports science, multivariate analysis is used for analyzing physical strength, motor ability (Matuura, 1973 ; Imanaka, 1979 ; Kin & Matsuura, 1985) and psychological factors (Nishida & Inomata, 1981). Using factor analysis, one of the analytical methods of multivariate analysis, complex relationships between many parameters can be represented by a small number of factors.

Therefore, evaluating body shape of athletes by factor axis scores would have merit for athletes as

well as their trainers. In this study, we conducted measurements of physique, skinfold thickness, and body composition of adult male non-athletes and male athletes. Data from the non-athletes were analyzed by factor analysis, and classifications and grouping of athletes from different sporting events were based on the physical model of non-athletes.

METHODS

A. Subjects, period and place of examination

Male non-athletes (as control) were 210 healthy male in their 20's or 30's (mean: 26.8). The study group consisted of 485 athletes of high school age (S) and adults (A) from 13 different sporting events: long-distance running (L), sprinting (Sp), soccer (So), volleyball (V), canoeing (Ca), weight lifting (W), swimming (Sw), cycling (Cy) and rugby (R). All adult weight lifting athletes belonged to the middleweight class, and high school athletes belonged to the lightweight or middleweight classes. All subjects were representative players (or equivalent) from Nagasaki Prefecture participating in the National Athletic Meet and other nationwide tournaments. Some Olympic tournament players were included among the adult canoeing and weight lifting athletes. Title holders of high school championships in soccer, canoeing and cycling were also included among the subjects. They had 2 to 15 years training experience and were regularly trained for at least 2 hours. We adopted abbreviations in this paper; for example L(S) represents a high school long-distance runner and L(A) adult long-distance runner. Determinations were performed in the physical education section of the Faculty of Liberal Arts of Nagasaki University between 1986 and 1993.

B. Parameters determined and methods

1. Physique, body surface area and body volume

Thirteen parameters were measured: height (Ht), weight, lower height, sitting height, circumferences of 7 locations, body surface area and body volume. Lower height was calculated by subtracting sitting height from height, and was used in place of lower limb length. Circumferences were measured according to Behnke & Wilmore (1974). Body surface area was calculated with the formula reported by Fujimoto et al. (1968). Body volume was determined by the underwater weighing method and this value was used as the denominator in the formula for calculating body density.

2. Body indices

Relative body weight, relative sitting height and relative lower height were utilized as body indices, which were calculated by dividing body weight, sitting height and lower height by height, respectively. These indices were compared to body shape to in order obtain balanced information.

3. Skinfold thickness

Skinfold thickness was determined using the Eiken skinfold caliper. Location and method of measurements were based on Behnke & Wilmore (1974). Eight locations were measured: 1) Triceps, 2) Scapula, 3) Abdomen, 4) Supra-iliac, 5) Chest, 6) Thigh, 7) Knee and 8) Midaxilla

4. Body composition

Percent fat (%Fat), body density, fat mass (Fat), lean body mass (LBM), Fat/Ht and LBM/Ht were included to the body composition indices. These values were determined by the underwater weighing method (Tsunawake et al., 1993), and %Fat was calculated from Brožek's estimated formula (Brožek et al., 1963).

C. Statistical analysis

Means and standard deviations of each parameter were calculated. Differences in mean values between the control and athletes group were analyzed by Student's unpaired t-test. Extraction of factors on body shape of control and calculation of factor scores for each sporting event were carried out by the following steps (Matsuura, 1973; Nishida & Inomata, 1981; Yamanaka et al., 1991). Factors for control were obtained by the normal varimax rotation procedure to the factors obtained by principal factor analysis with an eigenvalue of more than 1.0. Individual factor scores were calculated using

factor score coefficients from control. To analyze similarity of body shape between sporting events, cluster analysis using the hierarchical group average method was conducted for dissimilarity ; that is, differences between each factor score of each event (Imanaka, 1979). For stability of interpretation, many cluster analyses using different methods were carried out to discuss clusters. These statistical analyses were carried out using the ANALYST statistical data processing package on a FACOM VP1200 computer at Nagasaki University Information Science Center.

RESULTS

1. Physique, body indices, skinfold thickness and body composition

Table 1 lists the mean and standard deviation values of control and athletes participating in 13 different sporting events. Results of significance tests of mean values between control and athletes and percent representation of ratio between the mean scores of control and scores of each event are shown in table 2. Physique, skinfold thickness of control, and body composition were thought to be typical of Japanese males (Tahara et al., 1994). There were some notable significant differences between control and athletes from each sporting event. All mass and girth items except for length of L(S) and L(A) were significantly lower than control. In contrast, length, mass, and girth items of R(A) were all significantly higher than those of control. With regard to skinfold thickness, all 8 measuring locations of L(S), L(A), Sp(S), So(S) and Ca(S) were significantly lower than control, whereas there was no significant difference in Ca(A) or R(A). %Fat was significantly lower in L(S), L(A), Sp(S), So(S), Ca(S), W(S), W(A), Sw(S), Cy(S) and R(S). LBM was significantly lower in L(S) and L(A), and significantly higher in So(S), Ca(A), W(A), R(S) and R(A).

2. Factorial structure of adult male non-athletes

Table 3 shows the factor loading matrix after the normal varimax rotation procedure. Four factors with which 88.5% of total variance on physique, body indices, skinfold thickness and body composition could be explained were extracted. Factor 1 showed high positive scores in %Fat, Fat, Fat/Ht and skinfold thickness, and showed high negative scores in body density. Thus, this factor could be interpreted as representing "Body fat". Factor 2 showed high positive scores in body weight, circumference such as thigh and hip girth, body surface area, body volume, weight/Ht, LBM and LBM/Ht, and thus, could be interpreted as a "Mass" factor. Factor 3 showed high positive scores in lower height and relative lower height, and showed a high negative score in relative sitting height. Thus, we interpreted this as "Leg length to height ratio" factor. Factor 4 showed high loading scores in height and sitting height. Thus, we interpreted it as a "Length" factor.

3. Body shape of athletes from each sporting event

Plots of factor scores in male athletes based on factor score coefficients (Table 3) are shown in Fig. 1. On the Factor 1 axis, all groups were located in the negative region. On the Factor 2 axis, L(S) and L(A) were located in the negative region, whereas other groups were located in the positive region. On the Factor 3 axis, 8 groups (V(S), Sp(S), Sw(S), So(S), L(S), Ca(S), L(A) and R(A)) were located in the positive region. On the Factor 4 axis, W(A), W(S), Sp(S) and Cy(S) were located in the negative region, whereas other groups were located in the positive region.

4. Similarity of body shape between sporting events

Fig. 2 shows a dendrogram of clustering of factor scores for male athletes. L(A) and Ca(S) had the shortest distance (0.119) i.e. showed the highest similarity. Next, Sw(S) and L(S) showed high similarity with L(A) and Ca(S), which constituted a cluster of well-balanced muscular body shape. Ca(A), R(S) and R(A) constituted another cluster of rich muscular large-built type. W(A) solely constituted an independent cluster of rich muscular and long-torso type.

Table 1 Test items, mean and standard deviation for male non-athletes and athletes.

No \ Variable	N (A)	L (S)	L (A)	Sp (S)	So (S)	V (S)	Ca (S)	Ca (A)	W (S)	W (A)	Sw (S)	Cy (S)	R (S)	R (A)
Number	210	25	116	11	126	10	72	4	20	3	13	54	15	16
Age (years)	26.8 ± 6.9	15.9 ± 3.4	22.9 ± 3.5	17.9 ± 3.0	17.2 ± 1.0	16.5 ± 0.5	17.1 ± 1.1	24.3 ± 0.9	17.1 ± 0.6	25.3 ± 2.0	16.6 ± 0.8	16.9 ± 0.9	17.0 ± 0.5	22.9 ± 2.5
Physique														
1. Height (cm)	169.7 ± 5.5	170.3 ± 4.4	169.8 ± 3.7	171.0 ± 4.0	172.8 ± 5.2	175.9 ± 8.2	170.3 ± 4.6	174.9 ± 3.9	166.7 ± 5.3	165.0 ± 4.1	171.9 ± 2.9	168.6 ± 4.3	173.7 ± 5.5	175.4 ± 5.4
2. Weight (kg)	65.1 ± 10.4	55.9 ± 5.3	57.5 ± 4.3	58.7 ± 4.2	64.8 ± 5.1	66.7 ± 8.5	60.3 ± 6.2	74.7 ± 2.1	62.5 ± 7.9	69.7 ± 6.5	61.5 ± 5.2	62.4 ± 6.6	70.6 ± 5.0	79.7 ± 10.8
3. Sitting height (cm)	91.2 ± 3.0	90.5 ± 2.9	90.7 ± 2.1	89.8 ± 3.1	91.7 ± 3.0	92.6 ± 3.7	91.2 ± 2.6	94.9 ± 1.8	89.8 ± 2.9	90.4 ± 1.8	91.0 ± 2.1	90.8 ± 2.5	93.5 ± 2.6	94.1 ± 2.5
4. Lower height (cm)	78.5 ± 4.1	79.7 ± 3.0	79.2 ± 3.1	81.2 ± 2.7	81.1 ± 3.3	83.3 ± 5.1	79.2 ± 3.2	80.0 ± 2.6	76.9 ± 3.4	74.6 ± 2.3	80.9 ± 1.8	77.8 ± 3.1	80.2 ± 4.4	81.3 ± 3.8
5. Chest girth (cm)	89.2 ± 6.8	83.6 ± 3.8	85.4 ± 3.0	86.2 ± 4.0	88.3 ± 3.6	86.7 ± 4.0	88.4 ± 4.9	101.6 ± 4.0	89.0 ± 4.4	96.4 ± 4.3	89.0 ± 4.0	87.3 ± 4.6	92.9 ± 3.1	98.6 ± 5.8
6. Abdominal girth (cm)	76.4 ± 8.6	68.4 ± 3.4	69.1 ± 3.2	68.7 ± 4.6	72.6 ± 3.2	73.0 ± 4.4	70.5 ± 3.5	78.8 ± 0.4	70.9 ± 5.3	75.2 ± 3.3	70.1 ± 4.1	72.9 ± 5.1	75.7 ± 3.5	82.1 ± 6.4
7. Upper arm girth (cm)	27.9 ± 3.2	23.6 ± 1.5	24.0 ± 1.3	24.7 ± 1.1	26.3 ± 1.4	26.2 ± 1.1	27.2 ± 2.5	31.5 ± 1.2	27.6 ± 2.0	30.1 ± 0.5	26.6 ± 1.3	27.1 ± 2.0	29.5 ± 2.1	31.7 ± 2.1
8. Thigh girth (cm)	52.7 ± 4.4	48.9 ± 2.6	49.9 ± 2.2	50.8 ± 1.7	53.9 ± 2.8	53.4 ± 3.0	50.5 ± 3.6	56.8 ± 0.8	54.4 ± 3.5	58.3 ± 2.3	50.3 ± 1.9	54.6 ± 3.1	57.3 ± 3.3	60.7 ± 4.8
9. Lower leg girth (cm)	36.8 ± 3.1	35.1 ± 2.2	35.7 ± 1.8	36.0 ± 1.6	37.5 ± 1.8	38.1 ± 2.4	34.7 ± 2.3	37.3 ± 0.7	35.3 ± 2.4	37.0 ± 2.5	35.7 ± 1.5	36.4 ± 2.2	38.2 ± 2.0	40.2 ± 3.0
10. Waist (cm)	74.9 ± 8.3	67.2 ± 3.5	67.8 ± 3.4	67.9 ± 2.8	71.6 ± 3.1	71.2 ± 4.6	69.1 ± 3.0	81.0 ± 5.2	69.7 ± 5.3	75.0 ± 2.9	69.2 ± 4.0	70.6 ± 5.0	74.4 ± 3.3	82.3 ± 6.8
11. Hip (cm)	91.1 ± 5.8	85.6 ± 3.4	85.5 ± 2.7	87.1 ± 3.0	90.1 ± 3.4	91.4 ± 4.8	87.6 ± 4.0	92.5 ± 1.3	87.6 ± 4.8	92.7 ± 2.4	87.7 ± 3.1	88.7 ± 4.5	92.9 ± 3.6	96.1 ± 5.4
12. Body surface area (m^2)	1.70 ± 0.14	1.60 ± 0.09	1.61 ± 0.07	1.64 ± 0.07	1.72 ± 0.09	1.77 ± 0.15	1.65 ± 0.09	1.85 ± 0.05	1.65 ± 0.12	1.72 ± 0.10	1.68 ± 0.08	1.67 ± 0.09	1.80 ± 0.07	1.91 ± 0.14
13. Body volume (l)	61.3 ± 10.5	52.0 ± 5.1	53.2 ± 4.1	54.2 ± 4.0	60.0 ± 4.9	62.3 ± 8.3	55.9 ± 6.0	69.4 ± 2.4	58.3 ± 7.7	64.4 ± 5.9	57.1 ± 5.1	58.1 ± 6.5	65.4 ± 5.0	74.7 ± 10.8
Body index														
14. Weight / Ht (kg/m)	38.3 ± 5.7	32.8 ± 2.7	33.8 ± 2.2	34.3 ± 1.9	37.5 ± 2.5	37.8 ± 3.3	35.4 ± 3.3	42.7 ± 0.5	37.4 ± 3.9	42.2 ± 3.0	35.8 ± 2.7	37.0 ± 3.6	40.7 ± 3.0	45.4 ± 5.3
15. Sitting height / Ht (cm/m)	53.8 ± 1.4	53.2 ± 1.1	53.4 ± 1.1	52.5 ± 1.2	53.1 ± 1.0	52.7 ± 1.1	53.5 ± 1.1	54.3 ± 0.7	53.9 ± 1.1	54.8 ± 0.3	52.9 ± 0.8	53.9 ± 1.1	53.9 ± 1.4	53.7 ± 1.1
16. Lower height / Ht (cm/m)	46.2 ± 1.4	46.8 ± 1.1	46.6 ± 1.1	47.5 ± 1.2	46.9 ± 1.0	47.3 ± 1.1	46.7 ± 1.1	45.8 ± 0.7	46.1 ± 1.1	45.2 ± 0.3	47.1 ± 0.8	46.1 ± 1.1	46.1 ± 1.4	46.3 ± 1.1
Skinfold thickness														
17. Triceps (mm)	10.4 ± 5.0	6.4 ± 2.0	5.7 ± 1.6	6.9 ± 2.7	8.3 ± 2.2	9.9 ± 2.8	7.5 ± 3.1	7.4 ± 1.3	9.9 ± 3.6	4.5 ± 0.5	6.2 ± 2.2	9.6 ± 3.6	10.6 ± 5.4	9.3 ± 3.7
18. Scapula (mm)	13.5 ± 6.3	7.0 ± 1.2	7.3 ± 1.4	7.5 ± 1.6	8.2 ± 1.5	9.2 ± 1.4	8.2 ± 2.6	10.6 ± 1.7	10.0 ± 3.7	6.3 ± 0.3	7.7 ± 2.2	9.8 ± 3.4	10.5 ± 4.3	14.6 ± 6.4
19. Abdomen (mm)	16.9 ± 8.8	6.6 ± 1.9	6.8 ± 2.4	6.8 ± 1.8	8.4 ± 2.6	9.4 ± 1.7	8.1 ± 3.7	13.1 ± 3.2	10.7 ± 6.8	8.0 ± 2.3	7.1 ± 2.7	12.5 ± 5.7	10.8 ± 6.0	16.7 ± 6.0
20. Supra-iliac (mm)	15.8 ± 8.0	6.9 ± 1.9	6.3 ± 2.8	7.5 ± 1.7	9.4 ± 3.5	10.6 ± 4.2	8.8 ± 4.2	13.8 ± 2.5	10.7 ± 6.5	6.3 ± 2.4	9.0 ± 4.2	12.6 ± 6.2	10.8 ± 5.2	16.9 ± 6.7
21. Chest (mm)	9.9 ± 5.2	4.8 ± 1.4	4.6 ± 1.2	5.1 ± 0.9	5.7 ± 1.7	6.8 ± 2.2	5.5 ± 1.9	6.5 ± 4.1	7.4 ± 4.0	4.5 ± 1.0	4.9 ± 1.8	7.5 ± 3.6	6.6 ± 3.0	9.6 ± 4.1
22. Thigh (mm)	14.2 ± 6.3	8.3 ± 2.7	6.9 ± 2.5	7.9 ± 2.5	10.1 ± 3.1	13.5 ± 3.5	10.2 ± 3.8	12.8 ± 1.0	11.0 ± 3.7	6.7 ± 0.3	8.8 ± 2.8	12.2 ± 4.5	11.7 ± 4.4	13.5 ± 4.6
23. Knee (mm)	8.5 ± 3.5	6.0 ± 1.2	5.0 ± 1.3	6.3 ± 1.3	7.4 ± 1.9	9.8 ± 3.2	6.8 ± 2.2	6.3 ± 0.3	8.2 ± 3.2	5.3 ± 1.0	6.2 ± 1.6	8.0 ± 2.7	9.2 ± 3.2	9.1 ± 3.1
24. Midaxilla (mm)	11.1 ± 5.8	5.1 ± 1.4	5.6 ± 1.7	5.6 ± 1.4	6.2 ± 1.6	6.9 ± 1.1	6.4 ± 2.1	9.9 ± 2.8	8.3 ± 3.3	6.8 ± 0.6	5.6 ± 1.9	8.2 ± 4.0	8.0 ± 4.4	12.2 ± 5.6
Body composition														
25. %Fat (%)	15.8 ± 6.3	9.7 ± 2.2	8.7 ± 2.8	7.2 ± 3.4	9.0 ± 3.1	12.0 ± 4.5	9.5 ± 3.7	10.0 ± 3.9	11.5 ± 4.8	7.9 ± 1.1	10.1 ± 3.1	11.7 ± 4.1	9.1 ± 5.5	13.8 ± 4.4
26. Body density (g/ml)	1.063 ± 0.015	1.078 ± 0.006	1.081 ± 0.007	1.085 ± 0.009	1.080 ± 0.008	1.072 ± 0.011	1.079 ± 0.009	1.077 ± 0.010	1.074 ± 0.012	1.083 ± 0.003	1.077 ± 0.008	1.073 ± 0.010	1.080 ± 0.014	1.068 ± 0.011
27. Fat (kg)	10.7 ± 5.9	5.5 ± 1.5	5.0 ± 1.8	4.3 ± 2.2	5.9 ± 2.2	8.1 ± 3.7	5.9 ± 2.8	7.5 ± 3.0	7.4 ± 3.6	5.5 ± 0.6	6.3 ± 2.2	7.4 ± 3.2	6.5 ± 4.1	11.3 ± 2.0
28. Fat / Ht (kg/m)	6.3 ± 3.4	3.2 ± 0.8	3.0 ± 1.0	2.5 ± 1.2	3.4 ± 1.3	4.6 ± 2.0	3.4 ± 1.6	4.3 ± 1.7	4.4 ± 2.1	3.3 ± 0.4	3.7 ± 1.3	4.4 ± 1.9	3.8 ± 2.5	6.4 ± 2.7
29. LBM (kg)	54.4 ± 6.7	50.6 ± 4.5	52.4 ± 3.9	54.5 ± 3.9	59.0 ± 4.5	58.6 ± 6.7	54.5 ± 4.7	67.3 ± 2.2	55.1 ± 6.0	64.2 ± 6.5	55.2 ± 4.0	54.9 ± 4.9	64.1 ± 5.0	68.4 ± 6.6
30. LBM / Ht (kg/m)	32.0 ± 3.5	29.7 ± 2.3	30.8 ± 2.0	31.8 ± 2.0	34.1 ± 2.1	33.2 ± 2.6	32.0 ± 2.4	38.5 ± 1.2	33.0 ± 2.9	38.9 ± 3.0	32.1 ± 2.0	32.6 ± 2.6	36.9 ± 2.3	38.9 ± 3.0

N; Non-athlete, L; Long-distance running, Sp; Sprinting, So; Soccer, V; Volleyball, Ca; Canoeing, W; Weight lifting, Sw; Swimming, Cy; Cycling, R; Rugby.

(S); High school student, (A); Adult and college student

(Mean ± SD)

Table 2 Ratio of athletes to non-athletes and significant difference between male non-athletes and athletes.

No \ Variable	L (S)	L (A)	Sp (S)	So (S)	V (S)	Ca (S)	Ca (A)	W (S)	W (A)	Sw (S)	Cy (S)	R (S)	R (A)
	%	%	%	%	%	%	%	%	%	%	%	%	%
1. Height	100.3	100.1	100.8	101.9 ***	103.7 ***	100.4	103.1	98.3 *	97.3	101.3	99.4	102.4 **	103.4 ***
2. Weight	85.9 ***	88.3 ***	90.2 *	99.6	102.5	92.6 ***	114.8	96.0	107.1	94.4	95.8	108.5 *	122.4 ***
3. Sitting height	99.3	99.4	98.5	100.6	101.6	100.0	104.0 *	98.5	99.1	99.7	99.6	102.5 **	103.2 ***
4. Lower height	101.6	100.9	103.4 *	103.3 ***	106.1 ***	100.9	102.0	98.0	95.1	103.1 *	99.1	102.2	103.6 **
5. Chest girth	93.8 ***	95.7 ***	96.6	99.0	97.2	99.2	113.9 ***	99.8	108.1	99.8	97.9	104.2 *	110.6 ***
6. Abdominal girth	89.5 ***	90.4 ***	89.9 **	94.9 ***	95.5	92.3 ***	103.0	92.7 **	98.4	91.7 **	95.3 **	99.1	107.4 **
7. Upper arm girth	84.5 ***	86.0 ***	88.6 **	94.4 ***	93.8	97.4	112.9 *	98.8	107.8	95.2	97.3	105.5	113.7 ***
8. Thigh girth	92.8 ***	94.8 ***	96.4	102.4 **	101.5	96.0 ***	107.8	103.3	110.8 *	95.5	103.7 **	108.9 ***	115.2 ***
9. Lower leg girth	95.2 ***	96.9 ***	97.8	101.9 *	103.4	94.2 ***	101.2	95.7 *	100.4	97.0	98.7	103.6	109.2 ***
10. Waist	89.7 ***	90.6 ***	90.7 **	95.6 ***	95.0	92.3 ***	108.1	93.0 **	100.2	92.4 *	94.3 ***	99.3	109.8 ***
11. Hip	93.9 ***	93.9 ***	95.6 *	98.9	100.4	96.1 ***	101.6	96.2 *	101.8	96.3 *	97.4 **	102.0	105.5 **
12. Body surface area	93.8 ***	94.8 ***	96.2	101.2	103.7	97.1 **	108.7 *	97.2	101.2	98.5	97.9	105.5 *	112.0 ***
13. Body volume	84.8 ***	86.7 ***	88.3 *	97.9	101.5	91.2 ***	113.1	94.97	105.0	93.1	94.8 *	106.7	121.8 ***
14. Weight / Ht	85.7 ***	88.2 ***	89.5 *	97.8	98.7	92.3 ***	111.5	97.6	110.1	93.3	96.4	106.2	118.3 ***
15. Sitting height / Ht	98.9 *	99.3 *	97.7 **	98.7 ***	98.0 *	99.5	100.9	100.2	101.9	98.4 *	100.2	100.2	99.8
16. Lower height / Ht	101.3 *	100.8 *	102.7 **	101.5 ***	102.3 *	101.0 *	98.9	99.7	97.8	101.8 *	99.7	99.8	100.2
17. Triceps	61.8 ***	55.2 ***	66.0 *	80.1 ***	95.3	72.5 ***	71.0	94.8	43.3 *	59.6 **	92.5	102.0	89.3
18. Scapula	51.7 ***	54.1 ***	55.7 **	60.8 ***	68.3 *	61.0 ***	78.9	74.0 *	47.0	57.4 **	72.9 ***	78.2	108.6
19. Abdomen	38.9 ***	39.9 ***	40.0 ***	49.6 ***	55.2 **	48.0 ***	77.5	63.0 **	47.2	41.8 ***	73.5 ***	63.6 **	98.6
20. Supra-iliac	43.5 ***	39.8 ***	47.1 ***	59.4 ***	66.6 *	55.3 ***	86.9	67.6 **	40.0 *	57.1 **	79.5 **	68.0 *	107.0
21. Chest	48.9 ***	46.7 ***	51.9 **	57.9 ***	68.2	55.8 ***	65.7	75.0 *	45.5	49.0 ***	75.7 **	66.7 *	97.3
22. Thigh	58.3 ***	48.5 ***	55.7 **	71.0 ***	95.1	72.0 ***	89.8	77.2 *	47.0 *	61.8 **	85.7 *	82.6	94.9
23. Knee	70.5 ***	58.9 ***	74.5 *	87.7 **	115.5	79.6 ***	73.7	96.7	62.8	72.5 *	94.7	108.1	107.2
24. Midaxilla	45.7 ***	50.0 ***	50.7 **	55.4 ***	61.6 *	57.9 ***	88.9	74.4 *	61.4	50.6 ***	74.1 ***	71.7 *	109.9
25. %Fat	61.3 ***	55.0 ***	45.5 ***	56.9 ***	75.8	60.1 ***	63.1	73.0 **	50.2 *	64.0 **	74.2 ***	57.5 ***	87.0
26. Body density	101.4 ***	101.7 ***	102.0 ***	101.6 ***	100.9	101.5 ***	101.4	101.0 **	101.8 *	101.3 **	100.9 ***	101.6 ***	100.5
27. Fat	51.3 ***	47.1 ***	39.9 ***	55.0 ***	76.3	54.8 ***	70.2	69.1 *	51.5	59.0 **	69.7 ***	60.9 **	106.1
28. Fat / Ht	51.0 ***	47.1 ***	39.4 ***	54.0 ***	73.1	54.7 ***	68.1	70.2 *	53.0	58.3 **	70.3 ***	60.4 **	102.2
29. LBM	92.9 **	96.3 **	100.1	108.3 ***	107.6	100.1	123.6 ***	101.3	118.0 *	101.4	100.9	117.8 ***	125.6 ***
30. LBM / Ht	92.6 ***	96.3 ***	99.4	106.4 ***	103.7	99.7 *	120.0 ***	103.0	121.3 ***	100.1	101.6	115.1 ***	121.5 ***

N; Non-athlete, L; Long-distance running, Sp; Sprinting, So; Soccer, V; Volleyball, Ca; Canoeing, W; Weight lifting, Sw; Swimming, Cy; Cycling, R; Rugby.

(S); High school student, (A); Adult and college student.

*P<0.05, **P<0.01, ***P<0.001

Table 3 Rotated factor pattem matrix and factor score coefficient of 30 variabtes on male non-athletes.

	Factor loading					Factor score coefficient			
	Factor 1	Factor 2	Factor 3	Factor 4	Communality	Factor 1	Factor 2	Factor 3	Factor 4
1. Height	-0.011	0.268	0.504	0.816	0.991	0.008	-0.076	0.110	0.416
2. Weight	0.544	0.797	0.065	0.242	0.992	-0.015	0.094	0.010	0.027
3. Sitting height	0.039	0.293	-0.297	0.901	0.988	-0.007	-0.078	-0.157	0.515
4. Lower height	-0.044	0.143	0.888	0.431	0.998	0.016	-0.044	0.261	0.180
5. Chest girth	0.529	0.758	-0.051	0.113	0.869	-0.021	0.110	-0.020	-0.038
6. Abdominal girth	0.720	0.620	-0.006	0.101	0.914	0.034	0.044	0.003	-0.016
7. Upper arm girth	0.454	0.645	-0.029	0.025	0.623	-0.019	0.105	-0.008	-0.076
8. Thigh girth	0.551	0.753	-0.088	0.099	0.888	-0.018	0.108	-0.031	-0.042
9. Lower leg girth	0.364	0.632	0.011	0.009	0.532	-0.032	0.117	0.004	-0.090
10. Waist	0.669	0.642	-0.047	0.087	0.869	0.020	0.061	-0.011	-0.028
11. Hip	0.577	0.717	0.039	0.216	0.895	0.001	0.072	0.005	0.028
12. Body surface area	0.453	0.753	0.195	0.432	0.997	-0.011	0.060	0.039	0.138
13. Body volume	0.600	0.757	0.056	0.233	0.989	0.000	0.076	0.010	0.031
14. Weight / Ht	0.586	0.797	-0.042	0.081	0.988	-0.018	0.118	-0.014	-0.063
15. Sitting height / Ht	0.068	0.033	-0.990	0.120	0.999	-0.018	-0.006	-0.330	0.131
16. Lower height / Ht	-0.068	-0.033	0.990	-0.120	0.999	0.018	0.006	0.330	-0.131
17. Triceps	0.809	0.352	0.015	0.034	0.780	0.087	-0.031	0.022	-0.007
18. Scapula	0.816	0.436	-0.070	-0.067	0.865	0.069	0.010	-0.001	-0.077
19. Abdomen	0.830	0.308	-0.030	0.003	0.785	0.095	-0.041	0.010	-0.014
20. Supra-iliac	0.762	0.420	-0.067	0.005	0.762	0.065	0.001	-0.006	-0.033
21.Chest	0.870	0.309	-0.046	-0.010	0.855	0.101	-0.044	0.007	-0.020
22.Thigh	0.827	0.258	-0.028	-0.012	0.752	0.102	-0.051	0.012	-0.015
23. Knee	0.673	0.368	-0.021	-0.059	0.593	0.057	0.010	0.011	-0.070
24. Midaxilla	0.813	0.412	-0.020	-0.026	0.832	0.075	-0.004	0.013	-0.052
25. %Fat	0.969	0.045	-0.044	0.093	0.952	0.162	-0.150	0.008	0.094
26. Body density	-0.969	-0.040	0.044	-0.095	0.951	-0.163	0.151	-0.008	-0.095
27. Fat	0.909	0.332	-0.020	0.131	0.954	0.111	-0.068	0.007	0.062
28. Fat / Ht	0.916	0.318	-0.054	0.082	0.950	0.111	-0.064	0.000	0.037
29. LBM	0.051	0.953	0.118	0.263	0.994	-0.120	0.207	0.008	-0.013
30. LBM / Ht	0.060	0.995	-0.015	0.052	0.996	-0.138	0.256	-0.023	-0.139
Amount of contribution	12.133	9.023	3.188	2.209	26.553				
Degree of contribution (%) [1]	40.443	30.075	10.627	7.365	88.509				
Degree of contribution (%) [2]	45.693	33.980	12.006	8.321	100.000				

1) Degree of contribution to total variance, 2) Degree of contribution to total communality.

DISCUSSION

Thorlant et al. (1981), Carter (1984) and Butts (1985) classified body shape of Olympic tournament and top-ranked athletes using the Heath-Carter method (Hearth & Carter, 1966) which is a modification of the classification method described by Sheldon (1940) considering embryological factors. They reported that almost all athletes from different sporting events belonged to the mesomorphy type in which bone and muscle are markedly developed. Tanaka et al. (1977) reported that many body indices of judo, distance throw, and rugby players were significantly higher than those of non-athletes. In our present study, body shape for each sporting event could be characterized more definitively than in those previous studies since evaluations were made according to 4 factors based on the physical model of non-athletes ; content of body fat could be evaluated by Factor 1, body size by Factor 2, leg to height ratio by the Factor 3 and height by Factor 4.

Skinfold thickness and %Fat are decreased and LBM is increased by long-term training (Ikegami et al., 1979 ; Isigure et al., 1980 ; Wilmore, 1983). We also clarified that the %Fat of each athlete was low, about 46 to 87 percent of that in control. As shown in Fig. 1, on the Factor 1 axis, athletes from all

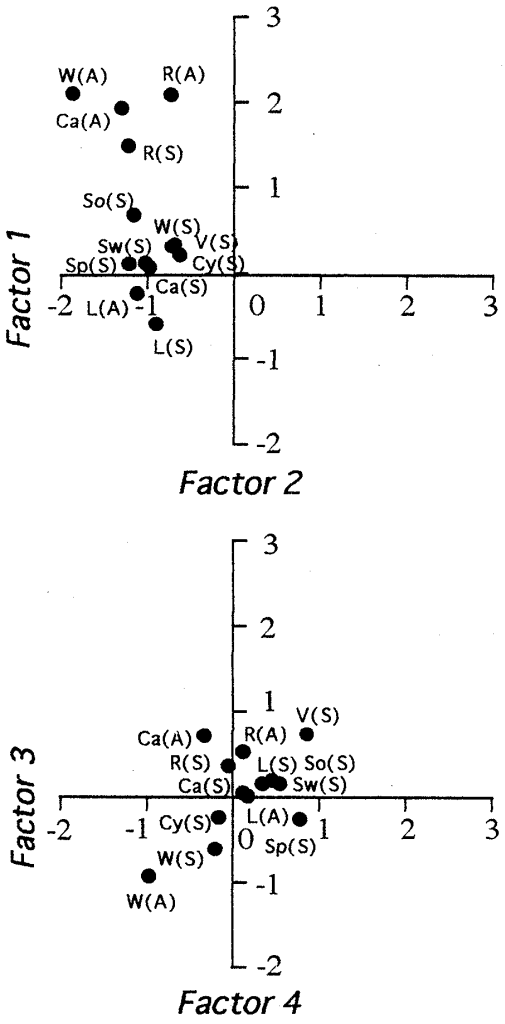

Fig. 1 Plots of factor scores in male athletes.
L ; Long-distanse running, Sp ; Sprinting, So ; Soccer, V ; Volleyball, Ca ; Canoeing, W ; Weight lifting, Sw ; Swimming, Cy ; Cycling, R ; Rugby (S) ; High school student, (A) ; Adult and college student

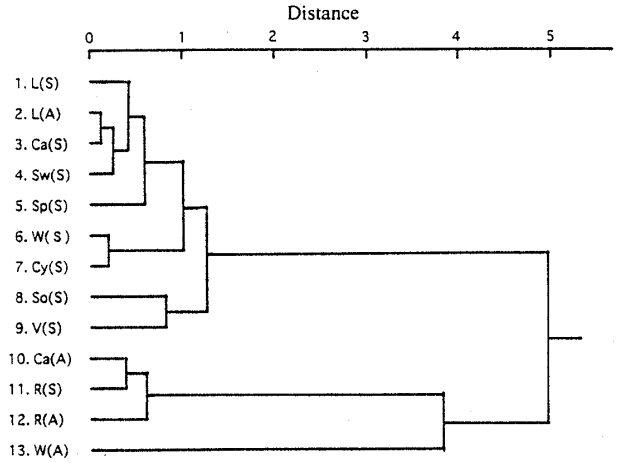

Fig. 2 Dendrogram of clustering of factor scores for male athletes.
L ; Long-distanse running, Sp ; Sprinting, So ; Soccer, V ; Volleyball, Ca ; Canoeing, W ; Weight lifting, Sw ; Swimming, Cy ; Cycling, R ; Rugby (S) ; High school student, (A) ; Adult and college student

sporting events had negative scores, which showed that they had less body fat than control. W(A) had higher negative scores (−1.9) comparing with those of other athletes (about −1.0). Excessive Fat acts as a negative factor in physical activities (Kitagawa et al., 1974 ; Tsunawake et al., 1994). Furthermore, the contribution of Factor 1 to the total variance was about 40 %. Thus, Factor 1 might be the most important information for determining physical condition. The loading score for factor 2 load of LBM (0.963) was higher than those of body weight (0.797) and circumferences (0.62 to 0.76). The factor scores of W(A), R(S), Ca(A), R(A) etc. were high (1.5 to 2.1). Thus, sporting events requiring higher power demand were supposed to require large body shape with high LBM. LBM has often been utilized as an index representing muscular volume (Forbes & Lewis, 1956), and there have been some reports showing strong relationships between LBM and aerobic and anaerobic work capacities (Kitagawa et al., 1974 ; Tahara et al., 1990 ; Tsunawake et al., 1993, 1994). High school and adult long-distance runners had negative scores in this factor, and had slim body shapes. Although even in the long-distance runners where excessive body weight and Fat react as negative factors, LBM must be necessary for physical resources to exert competitive performance (Tsunawake et al., 1994). In Factor 3, athletes from many events showed long leg tendencies. However, the factor score of W(A) was −0.9 showing a marked long-torso tendency. W(S) also had negative value. These results suggested that there might be some relationship between Factor 3 and characteristics required for these events. Further analysis of body weight and competitive performance would be required. In Factor 4, V(S) and Ca(A) had high positive scores, while W(A)

and W(S) had negative scores as in Factor 3. Height of athletes is closely related with rules and characteristics of the event involved. In volleyball, as well as basketball, height is an advantage in relation to the rules and techniques of the game. Thus, volleyball athletes have the highest Factor 4 scores (Puhl et al., 1982 ; Wilmore, 1983 ; Butts, 1985). Åtrand & Rodahl (1986) reported that when physical strength factors were interpreted by a physiological dimension as a scale for height, speed was proportional to raising the scale to the 0th power, and power was proportional to the square of the scale. That is, in sporting events requiring speed such as sprinting and long-distance running, height of the athletes had less or no effect on competitive performance, however, in distance throwing requiring power, height is advantageous. This might be important when determining suitability for sporting events.

In some sporting events, many factors tended to be located in the same quadrant. We analyzed the similarity and relationship between each sporting event using cluster analysis, and they could be categorized into 3 clusters as shown in Fig. 2. They were clustered mainly according to Factors 2 and 3. Thus, these groups could be characterized as 1) well-balanced muscular body type, 2) full muscular large-built type and 3) rich muscular and long-torso type. Furthermore, the well-balanced muscular body type could be classified into three sub-clusters : slim body-shaped type (L(S), L(A), Ca(S), Sw(S) and Sp(S)), average-shaped type (W(S) and Cy(S)) and sturdy built type (So(S) and V(S)). High school athletes and adult athletes participating in canoeing and weight lifting were clustered into different categories. This might be due to the fact that the adults in these events were top-class athletes and that there were significant differences in training experience between high school and adult subjects. In conclusion, male athletes had less body fat and greater body mass except for long-distance runners when compared with male adult non-athletes. There were some characteristic differences in leg to height ratio and length between sporting disciplines. The results suggested that athletes had body shapes suitable to their sporting events.

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