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Characteristics of Body Shape of Female Athletes Based on Factor Analysis

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Abstract. We examined the body shape of female athletes in comparison with female adult non-athletes by factor analysis. The subjects were 433 adult non-athletes and 464 athletes participating in 11 different sporting events. The physique, skinfold thickness and body composition of each subject were measured. The values obtained from non-athletes were analyzed by factor analysis, and the body shape of the athletes was then analyzed according to these factors. Four main factors with which 80 percent of total variance could be explained were body fat (Factor 1), mass (Factor 2), leg length to height ratio (Factor 3) and length (Factor 4), and were extracted from the values from non-athletes. The body shape of the athletes could be classified into 4 categories by cluster analysis for factor score of sporting events: less body fat and slim type, average type like non-athletes, muscular and well-balanced type, and tall and well-developed mass. Compared with non-athletes, female athletes for all sporting events had less body fat. Moreover, the athletes had a body shape suitable for their sporting events; i. e., their mass, length of leg and height. *(Appl Human Sci, 14(1) : 55-61, 1995)*

Keywords: physique, body composition, body shape, female athlete, factor analysis

Introduction

It is of great significance to classify the body shape of athletes, because it provides useful information for judging their aptitude for their sporting events and assessing their training effects. Tsunawake et al. (1994a) analyzed the body shape of male athletes participating in 12 sporting events in comparison with male adult non-athletes. They revealed the body shape characteristics of each sporting event based on the factor scores which were calculated from the four factors obtained by factor analysis of 30 physical measurements such as physique, skinfold thickness and body composition. They also evaluated the similarity and relationship between sporting events by cluster analysis of the factor scores and demonstrated that the body shape of top-ranking athletes was suitable for the respective sporting events.

On the other hand, sex hormones enhance the accumulation of body fat in women after puberty (Wade & Gray, 1979). Therefore, there are great differences between the sexes in body fat and body composition at adolescence (Sato, 1975; Kitagawa et al., 1977), which will considerably affect the body shape. Since excessive body weight and body fat are disadvantageous in physical activities (Wilmore, 1983; Sparling & Cureton, 1983; Tsunawake et al., 1988, 1994b), it is very important for female athletes to have information regarding their body shape such as physique and body composition.

Most studies on the body shape of female athletes used individual physical measurements or the ratios between such variables (Shepherd, 1974; Novak, 1977; Thorland et al., 1981; Puhl, 1982; Wilmore, 1983; Fleck, 1983; Butts, 1985; Tsunawake, 1986; Tahara et al., 1993; Tsunawake et al., 1991, 1993a), and there have been no reports of studies in which multivariate analysis was performed. In this study, we examined the characteristics of the body shape of female athletes and the similarity between various sporting events using the physical model obtained by analyzing the physique, skinfold thickness and body composition of adult non-athletes (Tsunawake et al. 1994a).

Methods

A. Subjects, period and place of examination

The female non-athletes examined (as control) were 433 healthy female in their 20s or 30s (mean: 24.6 years). The study group consisted of 464 athletes of high school age (S) and adults(A) from 11 different sporting events: long-distance running (L), sprinting (Sp), throwing (T), volleyball (V), basketball (B), canoeing (C), swimming (Sw) and kendo (K). All subjects were representative players (or equivalent) from Nagasaki Prefecture par-

ticipating in the National Athletic Meet and other nationwide tournaments. Title holders of high school championships in volleyball, basketball and canoeing were also included among the subjects. They had 2 to 11 years of training experience and regularly trained for at least 2 hours/day. 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 and skinfold thickness

Twenty-one parameters were measured: height (Ht), weight, lower height, sitting height, body surface area, body volume, circumferences of 7 locations and skinfold thicknesses at 8 locations. Lower height was calculated by subtracting sitting height from height, and was used in place of lower limb length. Circumference and skinfold thickness 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.

3. Body composition

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

C. Statistical analysis

The means and standard deviations of each parameter were calculated. The differences in mean values between the control and athlete group were analyzed by Student's unpaired t-test. The factors on body shape of control were extracted by the normal varimax rotation procedure to the factors obtained by principal factor analysis with an eigenvalue of more than 1.0. Calculation of individual factor scores and examination of similarity of each factor score of each event were reported previously (Tsunawake et al., 1994a). 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

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

No\Variable	N(A)	L(S)	L(A)	Sp(S)	Sp(A)	T(A)	V(S)	B(S)	B(A)	C(S)	Sw(S)	K(S)
Number	433	29	59	11	91	33	88	56	70	8	12	7
Age(years)	24.62±6.13	16.58±0.74	19.57±2.63	16.73±1.19	19.2±0.67	19.25±0.72	16.77±0.76	17.01±0.82	20.45±1.59	16.81±0.60	16.16±0.57	16.93±0.63
Physique												
1.Height(cm)	158.25±5.44	159.28±4.64	157.36±3.91	158.95±3.83	161.44±4.81	161.79±4.29	168.18±5.97	165.72±6.40	165.45±6.51	157.67±6.79	157.77±3.50	163.11±3.10
2.Weight(kg)	52.59±6.29	47.84±3.25	49.91±2.96	54.58±8.04	54.62±5.33	60.05±4.49	61.24±5.32	58.21±5.95	61.04±6.11	56.05±9.62	52.70±4.53	57.99±4.90
3.Sitting Height(cm)	85.77±2.94	85.49±2.92	84.39±1.96	85.60±2.30	86.21±2.40	86.97±1.97	89.25±2.58	88.56±3.40	88.09±3.03	86.20±2.97	83.13±2.58	87.92±2.86
4.Lower height(cm)	72.48±3.65	73.79±3.08	72.96±3.09	73.35±2.83	75.31±3.39	74.81±3.66	78.93±4.17	77.16±3.72	77.36±4.38	71.47±4.01	74.64±3.04	75.17±2.63
5.Chest girth(cm)	79.95±4.62	76.41±2.66	77.57±2.44	81.79±6.13	80.16±3.85	84.72±3.44	82.80±3.88	81.85±3.69	83.28±3.68	82.13±6.47	84.31±3.19	81.19±3.25
6.Abdominal girth(cm)	72.06±6.68	66.13±4.45	67.29±3.43	71.44±7.62	69.93±4.47	74.90±4.99	72.96±4.60	71.40±3.52	73.29±5.11	73.61±6.44	70.12±4.68	72.91±6.49
7.Upper arm girth(cm)	24.53±2.14	21.42±1.14	23.31±1.57	25.14±3.30	24.30±1.58	26.54±1.38	25.20±1.70	24.43±1.43	25.53±1.60	26.05±2.83	25.80±1.22	26.57±1.00
8.Thigh girth(cm)	51.97±3.67	51.02±7.74	50.65±2.46	52.82±4.15	53.32±2.78	55.30±3.46	55.72±3.13	53.99±2.63	55.53±2.90	54.20±5.17	51.32±2.06	55.97±3.48
9.Lower leg girth(cm)	34.44±2.33	33.87±1.34	34.57±1.32	35.65±2.10	35.61±1.74	36.57±1.95	36.38±1.92	36.18±2.02	36.84±1.64	34.95±2.49	33.86±1.20	35.97±2.28
10.Waist(cm)	64.00±5.05	60.68±3.07	61.56±2.44	64.62±5.10	63.50±3.28	67.54±3.87	67.84±3.83	65.56±3.15	68.13±3.84	65.59±5.56	63.79±3.52	65.61±3.98
11.Hip(cm)	88.42±4.41	84.58±3.51	85.87±2.08	89.85±5.60	89.26±3.62	91.37±3.69	92.09±3.26	90.97±4.49	92.89±3.92	90.17±6.82	86.45±3.81	90.86±2.27
12.Body surface area (m^2)	1.48±0.10	1.43±0.07	1.44±0.05	1.51±0.11	1.53±0.09	1.59±0.07	1.65±0.09	1.60±0.11	1.63±0.11	1.52±0.15	1.48±0.07	1.58±0.06
13.Body volume(l)	50.40±6.34	44.90±3.22	47.08±3.01	51.62±7.81	51.62±5.22	57.07±4.50	58.11±5.27	55.08±5.96	57.64±6.02	53.51±9.13	50.26±4.58	55.31±4.81
Body index												
14.Weight/Ht(kg/m)	33.21±3.58	30.02±1.61	31.72±1.72	34.31±4.69	33.80±2.74	37.11±2.53	36.42±2.88	35.08±2.66	36.84±2.74	35.40±4.91	33.39±2.57	35.56±3.10
15.Sitting Height/Ht(cm/m)	54.22±1.24	53.67±1.20	53.65±1.12	53.87±1.12	53.39±1.07	53.78±1.28	53.09±1.11	53.45±0.96	53.26±1.20	54.69±0.73	52.70±1.42	53.91±1.38
16.Lower Height/Ht(cm/m)	45.78±1.24	46.33±1.20	46.35±1.12	46.13±1.12	46.61±1.07	46.22±1.28	46.91±1.11	46.55±0.96	46.74±1.20	45.31±0.73	47.30±1.42	46.09±1.38
Skinfold thickness												
17.Triceps(mm)	16.83±4.91	11.74±3.50	13.46±3.75	15.45±5.47	14.17±3.37	17.33±3.75	16.47±3.96	14.71±3.64	15.89±4.22	17.13±4.16	14.63±3.34	17.57±2.35
18.Scapula(mm)	16.47±5.70	9.81±3.13	11.03±2.79	11.86±3.88	12.32±3.04	15.88±4.14	12.48±3.57	11.32±3.40	14.01±4.53	16.25±3.67	12.63±4.03	16.00±5.07
19.Abdomen(mm)	20.17±5.95	11.52±4.01	13.36±4.29	16.05±7.22	14.99±4.31	18.58±5.77	15.36±4.74	14.13±4.21	16.72±5.14	17.00±3.85	16.58±4.88	17.57±4.63
20.Supla-iliac(mm)	18.21±6.35	9.78±3.81	11.82±3.97	15.41±5.44	13.02±4.30	16.94±4.23	13.16±4.58	12.00±3.95	15.11±5.81	17.38±5.37	17.29±6.39	18.14±5.31
21.Chest(mm)	13.48±4.90	7.95±2.68	9.28±3.43	10.41±3.50	10.10±3.24	13.09±3.58	11.01±3.32	9.49±3.26	10.89±3.90	12.63±3.47	11.63±2.13	12.00±4.40
22.Thigh(mm)	25.04±5.61	17.52±4.55	22.04±4.78	23.36±6.12	21.87±5.03	25.82±3.79	23.42±5.34	20.92±4.09	23.24±4.53	26.56±6.60	23.25±4.09	30.21±4.91
23.Knee(mm)	14.48±4.69	9.83±3.76	12.75±3.97	13.50±4.52	13.18±3.54	14.73±3.84	15.12±5.04	12.65±2.95	14.44±3.79	16.31±4.36	12.25±4.43	15.71±3.09
24.Midaxilla(mm)	13.14±4.96	7.45±2.27	8.24±2.57	10.73±4.00	9.79±2.82	12.33±3.72	10.55±3.19	9.73±3.33	10.31±3.98	11.56±4.09	11.08±3.57	12.00±2.08
Body composition												
25.%Fat(%)	23.47±5.18	15.58±3.79	16.92±3.91	17.77±3.46	17.60±3.53	19.99±4.70	19.56±3.66	17.96±5.03	18.78±4.46	22.18±5.09	21.43±4.05	21.62±1.66
26.Body density(g/ml)	1.0443±0.0124	1.0634±0.0094	1.0601±0.0097	1.0580±0.0085	1.0584±0.0087	1.0526±0.0114	1.0536±0.0089	1.0576±0.0123	1.0555±0.0108	1.0473±0.0121	1.0491±0.0097	1.0486±0.0040
27.Fat(kg)	12.49±3.74	7.48±2.07	8.48±2.18	9.83±2.83	9.68±2.43	12.06±3.23	12.05±2.84	10.59±3.58	11.52±3.42	12.40±3.23	11.38±2.81	12.58±1.86
28.Fat/Ht(kg/m)	7.89±2.34	4.70±1.28	5.40±1.38	6.18±1.72	5.99±1.48	7.45±1.95	7.17±1.69	6.37±2.10	6.96±2.02	7.85±1.97	7.22±1.81	7.72±1.19
29.LBM(kg)	40.11±4.24	40.26±2.77	41.41±2.45	44.75±5.91	44.94±4.06	47.99±3.79	49.16±3.96	47.62±4.32	49.30±4.75	43.64±8.27	41.32±3.13	45.41±3.32
30.LBM/Ht(kg/m)	25.32±2.29	25.29±1.35	26.33±1.39	28.13±3.40	27.81±1.98	29.66±2.27	29.22±2.04	28.70±1.82	29.79±1.97	27.56±4.35	26.17±1.55	27.84±2.05

N; Non-athlete, L; Long-distance running, Sp; Sprinting, T; Throwing, V; Volleyball, B; Basketball, C; Canoeing, Sw; Swimming, K; Kendo
(S); High school student, (A); Adult and college student
(Mean±SD)

of the factor for control and athletes participating in 11 different sporting events. The significance of the mean values between control and athletes and percent representation of ratio between the mean scores of control and scores for each event are shown in Table 2. Athletes of T(A), V(S), B(S) and B(A) showed better physique compared with control. With regard to skinfold thickness, L(S), L(A), Sp(A), V(S), B(S) and B(A) had significantly lower values than the control. %Fat was significantly lower in L(S), L(A), Sp(S), Sp(A), V(S), B(S) and B(A). LBM was significantly higher in L(A), Sp(S), Sp(A), T(A), V(S), B(S), B(A), C(S) and K(S).

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 80% 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. Factor 2 showed high positive scores in LBM, LBM/Ht,body weight, weight/Ht, body surface area, body volume and circumference such as lower leg and hip girths. Factor 3 showed high positive scores in lower height and relative lower height, and showed a high negative score in relative sitting height. Factor 4 showed high loading scores in height and sitting height.

3. Body shape of athletes for each sporting event

Fig. 1 shows the plots of factor scores in female athletes based on factor score coefficients (Table 3) . On the Factor 1 axis, all groups were located in the negative region. On the Factor 2 axis, L(S) was located in the negative region, whereas the other groups were located in the positive region. On the Factor 3 axis, C(S) was located in the negative region, whereas other groups were located in the positive region. On the Factor 4 axis, V(S), B(S), B(A) and K(S) were located in the positive region, whereas other groups were located in the negative region.

4. Similarity of body shape between sporting events

Fig. 2 shows a dendrogram of clustering of factor scores for male athletes. According to formation of cluster, sporting events could be classified into 4 categories: 1) L(S) and L(A), 2) Sw(S), 3) Sp(S), Sp(A), T(A), K(A) and C(S), and 4) V(S), B(A) and B(S)

Discussion

The physique and body composition of the control obtained in this study were similar to those in healthy, adolescent, mature Japanese women (Sato, 1975; Kitagawa, et al., 1977, 1993; Tahara et al., 1994). The factors obtained by factor analysis of 30 physical measurements in the control group were considered to be "body fat" as the first factor, "mass" as the second, "leg length to height ratio" as the third and "length" as the fourth. These four factors were the same as those obtained from healthy, mature men reported by Tsunawake et al.

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

No\Variable	L(S)	L(A)	Sp(S)	Sp(A)	T(A)	V(S)	B(S)	B(A)	Ca(S)	Sw(S)	K(S)
Number	29	59	11	91	33	88	56	70	8	12	7
1.Height(cm)	100.7	99.4	100.4	102.0***	102.2***	106.3***	104.7***	104.5***	99.6	99.7	103.1*
2.Weight(kg)	91.0***	94.9**	103.8	103.9**	114.2***	116.4***	110.7***	116.1***	106.6	100.2	110.3*
3.Sitting Height(cm)	99.7	98.4***	99.8	100.5	101.4*	104.1***	103.3***	102.7***	100.5	96.9**	102.5
4.Lower height(cm)	101.8	100.7	101.2	103.9***	103.2***	108.9***	106.5***	106.7***	98.6	103.0*	103.7
5.Chest girth(cm)	95.6***	97.0***	102.3	100.3	106.0***	103.6***	102.4**	104.2***	102.7	105.5**	101.6
6.Abdominal girth(cm)	91.8***	93.4***	99.1	97.0**	103.9*	101.2	99.1	101.7	102.2	97.3	101.2
7.Upper arm girth(cm)	87.3***	95.0***	102.5	99.1	108.2***	102.7**	99.6	104.1***	106.2*	105.2*	108.3*
8.Thigh girth(cm)	98.2	97.5**	101.6	102.6**	106.4***	107.2***	103.9***	106.9***	104.3	98.7	107.7**
9.Lower leg girth(cm)	98.3	100.4	103.5	103.4***	106.2***	105.6***	105.1***	107.0***	101.5	98.3	104.4
10.Waist(cm)	94.8***	96.2***	101.0	99.2	105.5***	106.0***	102.4*	106.5***	102.5	99.7	102.5
11.Hip(cm)	95.7***	97.1***	101.6	101.0	103.3***	104.2***	102.9***	105.1***	102.0	97.8	102.8
12.Body surface area(m^2)	96.6**	97.3**	102.0	103.4***	107.4***	111.5***	108.1***	110.1***	102.7	100.0	106.8**
13.Body volume(l)	89.1***	93.4***	102.4	102.4	113.2***	115.3***	109.3***	114.4***	106.2	99.7	109.7*
14.Weight/Ht(kg/m)	90.4***	95.5**	103.3	101.8	111.7***	109.7***	105.6***	110.9***	106.6	100.5	107.1
15.Sitting Height/Ht(cm/m)	99.0*	98.9***	99.4	98.5***	99.2	97.9***	98.6***	98.2***	100.9	97.2***	99.4
16.Lower Height/Ht(cm/m)	101.2*	101.2***	100.8	101.8***	101.0	102.5***	101.7***	102.1***	99.0	103.3***	100.7
17.Triceps(mm)	69.8***	80.0***	91.8	84.2***	103.0	97.9	87.4**	94.4	101.8	86.9	104.4
18.Scapula(mm)	59.6***	67.0***	72.0**	74.8***	96.4	75.8***	68.7***	85.1***	98.7	76.7*	97.1
19.Abdomen(mm)	57.1***	66.2***	79.6*	74.3***	92.1	76.2***	70.1***	82.9***	84.3	82.2*	87.1
20.Supla-iliac(mm)	53.7***	64.9***	84.6	71.5***	93.0	72.3***	65.9***	83.0***	95.4	94.9	99.6
21.Chest(mm)	59.0***	68.8***	77.2*	74.9***	97.1	81.7***	70.4***	80.8***	93.7	86.3	89.0
22.Thigh(mm)	70.0***	88.0***	93.3	87.3***	103.1	93.5*	83.5***	92.8*	106.1	92.9	120.6*
23.Knee(mm)	67.9***	88.1**	93.2	91.0*	101.7	104.4	87.4**	99.7	112.6	84.6	108.5
24.Midaxilla(mm)	56.7***	62.7***	81.7	74.5***	93.8	80.3***	74.0***	78.5***	88.0	84.3	91.3
25.%Fat(%)	66.4***	72.1***	75.7***	75.0***	85.2***	83.3***	76.5***	80.0***	94.5	91.3	92.1
26.Body density(g/ml)	101.8***	101.5***	101.3***	101.3***	100.8***	100.9***	101.3***	101.1***	100.3	100.5	100.4
27.Fat(kg)	59.9***	67.9***	78.7*	77.5***	96.6	96.5	84.8***	82.2*	99.3	91.1	100.7
28.Fat/Ht(kg/m)	59.6***	68.4***	78.3*	75.9***	94.4	90.9**	80.7***	88.2**	99.5	91.5	97.8
29.LBM(kg)	100.4	103.2*	111.6***	112.0***	119.6***	122.6***	118.7***	122.9***	108.8*	103.0	113.2**
30.LBM/Ht(kg/m)	99.9	104.0**	111.1***	109.8***	117.1***	115.4***	113.3***	117.7***	108.8**	103.4	110.0**

N; Non-athlete, L; Long-distance running, Sp; Sprinting, T; Throwing, V; Volleyball, B; Basketball, C; Canoeing, Sw; Swimming, K; Kendo
(S); High school student, (A); Adult and college student
*P<0.05, **P<0.01, ***P<0.001

Table 3 Loaded factor pattern matrix and factor score coefficient of 30 variables on female 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	-0.136	0.309	0.386	0.848	0.982	0.006	-0.066	0.052	0.368
2.Weight	0.479	0.817	0.063	0.307	0.995	-0.001	0.094	0.017	0.035
3.Sitting height	-0.086	0.347	-0.276	0.883	0.983	-0.002	-0.084	-0.190	0.455
4.Lower height	-0.133	0.181	0.797	0.552	0.990	0.010	-0.031	0.232	0.181
5.Chest girth	0.548	0.614	-0.060	0.110	0.693	0.017	0.071	-0.009	-0.019
6.Abdominal girth	0.648	0.412	-0.109	0.091	0.611	0.054	0.010	-0.027	0.023
7.Upper arm girth	0.562	0.619	-0.121	-0.062	0.717	0.007	0.103	-0.012	-0.110
8.Thigh girth	0.509	0.664	0.017	0.097	0.710	0.006	0.092	0.020	-0.047
9.Lower leg girth	0.301	0.737	-0.013	0.027	0.635	-0.039	0.149	0.015	-0.112
10.Waist	0.590	0.604	-0.075	0.090	0.726	0.023	0.067	-0.012	-0.024
11.Hip	0.514	0.675	-0.005	0.251	0.782	0.015	0.063	-0.004	0.041
12.Body sruface area	0.329	0.751	0.189	0.539	0.998	0.001	0.051	0.033	0.156
13.Body volume	0.548	0.773	0.062	0.299	0.992	0.014	0.076	0.018	0.043
14.Weight/Ht	0.572	0.808	-0.059	0.069	0.987	-0.004	0.126	0.000	-0.080
15.Sitting height/Ht	0.079	0.060	-0.993	0.048	0.998	-0.011	-0.026	-0.364	0.128
16.Lower height/Ht	-0.080	-0.060	0.993	-0.048	0.998	0.011	0.026	0.364	-0.128
17.Triceps	0.750	0.296	-0.066	-0.105	0.666	0.071	0.008	0.009	-0.063
18.Scapula	0.774	0.290	-0.125	-0.154	0.723	0.071	0.013	-0.007	-0.082
19.Abdomen	0.771	0.174	-0.070	-0.030	0.631	0.093	-0.041	-0.003	0.006
20.Supla-iliac	0.751	0.208	0.000	-0.027	0.609	0.088	-0.028	0.022	-0.009
21.Chest	0.711	0.172	-0.045	-0.093	0.545	0.081	-0.021	0.011	-0.036
22.Thigh	0.592	0.214	-0.107	-0.015	0.408	0.062	-0.013	-0.021	-0.001
23.Knee	0.447	0.250	-0.022	-0.166	0.290	0.027	0.045	0.024	-0.113
24.Midaxilla	0.724	0.262	-0.106	-0.057	0.608	0.073	-0.008	-0.012	-0.027
25.%Fat	0.962	-0.061	0.016	0.068	0.934	0.157	-0.141	0.016	0.111
26.Body density	-0.961	0.064	-0.016	-0.068	0.932	-0.157	0.141	-0.016	-0.112
27.Fat	0.912	0.302	0.041	0.177	0.956	0.115	-0.063	0.020	0.095
28.Fat/Ht	0.935	0.268	-0.010	0.078	0.952	0.115	-0.056	0.012	0.052
29.LBM	-0.095	0.944	0.058	0.299	0.993	-0.104	0.195	0.008	-0.032
30.LBM/Ht	-0.060	0.992	-0.083	0.027	0.995	-0.124	0.255	-0.012	-0.178
Amount of contribution	10.488	7.968	2.977	2.605	20.452				
Degree of contribution(%)[1]	34.961	26.560	9.925	8.685	80.131				
Degree of contribution(%)[2]	34.961	61.521	71.446	80.131					

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

(1994a). Therefore, the same indices can be used to evaluate the body shape of both men and women.

Long-term training reduces the skinfold thickness and %Fat (Ikegami et al., 1979; Isigure et al., 1980; Wilmore, 1983). This study revealed that "body fat" of the female athletes of the 11 sporting events was negative, and that the amount of their body fat was smaller than that in the control (Fig 1). This tendency was particularly pronounced in L(S), L(A), Sp(S), B(S), B(A) and V(S), all scoring values around −1. Body fat increases rapidly in women after puberty (Forbes & Hursh, 1963) and %Fat in adult women is about 1.7 to 2.2 times higher than that in men (Sato, 1975; Kitagawa et al., 1977). Even among long-distance runners, this difference in %Fat between women and men remains unchanged showing a 1.8-fold difference (Tsunawake et al.1994b). Since Fat is a negative factor for physical activities (Wilmore, 1983; Sparling & Cureton, 1983; Tsunawake, 1988; Tsunawake et al., 1994b), Factor 1 will be an index more important in evaluating the body shape in female athletes than in male athletes.

The score of Factor 2 was positive in the 10 sporting events except L(S). In particular, B(A), V(S) and T(A) gave high scores around 2, which suggests that the requirement of "mass" is high in these sporting events. The factor loading values of LBM and LBM/Ht in Factor 2 were higher than those of body weight and chest girth etc. as shown in Table 3, indicating their greater influence. LBM, which is often used as an index of muscle volume (Forbes & Lewis, 1956), is reported to be positively correlated with physical strength and sporting results (Kitagawa et al., 1974, 1977; Tsunawake et al., 1993a, 1993b, 1994b). Since continuous physical exercise such as weight training increases LBM and body weight (Ikegami et al., 1979, Boileau et al., 1973; Wilmore, 1974), the athletes examined in this study may have the "mass" corresponding to the LBM suitable for their specialized sporting events. However, in this study, the "mass" in L(S) was similar to that in the control group. Considering the fact that the difference in body weight between athletes and control (−4.75 kg) is similar to that in Fat (−5.01 kg), it is an important training rule for long-distance runners to maintain the "mass" with a large contribution from LBM.

The scores of Factor 3 show that the athletes of most sporting events have a tendency to have long legs, while the athletes of C(S) alone tend to have a long sitting height. Similar results have been reported by Tsunawake et al. (1994a) for male athletes of canoeing. They also reported that the athletes of bicycling, which requires a sitting position as in canoeing, and weightlifting, in which athletes compete in the weight they can lift, have a tendency to have a long sitting height. Further studies will be necessary to elucidate if there are similar tendencies with other sporting events that have characteristics common to these. Four sporting events showed

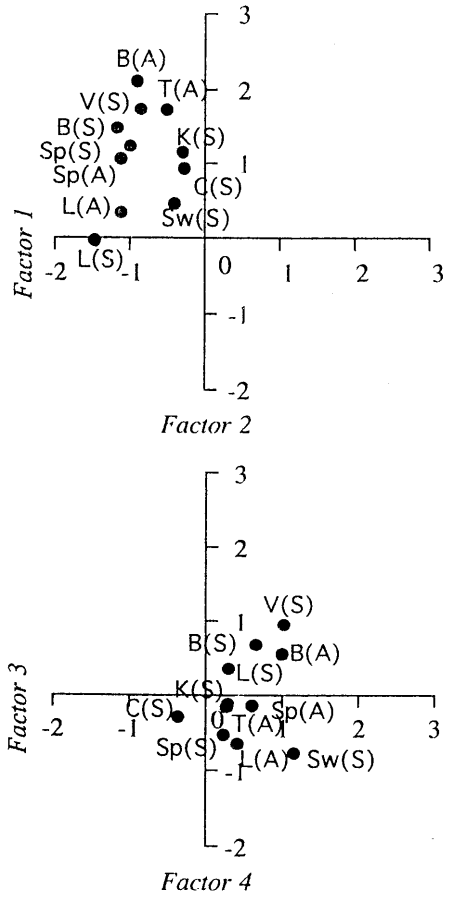

Fig.1 Plots of factor scores in female athletes.
L; Long-distance running, Sp; Sprinting, T; Throwing, V; Volleyball, B; Basketball, C; Canoeing, Sw; Swimming, K; Kendo
(S); High school student, (A); Adult and college student

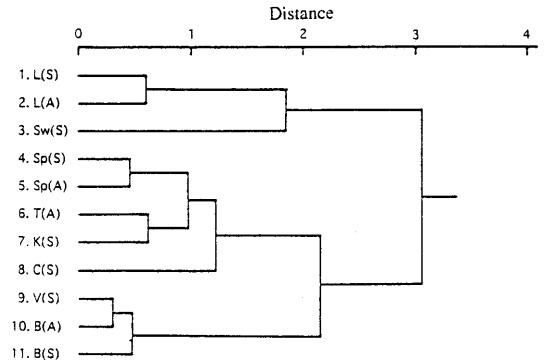

Fig.2 Dendrogram of clustering of factor scores for female athletes.
Method=Group average, Definition=Squered educlidean distance
L; Long-distance running, Sw; Swimming, Sp; Sprinting, T; Throwing, K; Kendo, C; Canoeing, V; Volleyball, B; Basketball
(S); High school student, (A); Adult and college student

positive values to Factor 4 , and six showed negative values. This factor, i.e. "length" seems to correlate with the rules and the characteristics of the techniques of individual sporting events. Athletes of volleyball and basketball, which showed high scores in Factor 4, are among the tallest of all athletes (Butts, 1985; Wilmore, 1983; Puhl et al., 1982), indicating that the requirement of a large "length " value is very high in these sporting events. On the other hand, sprinters, long-distance runners and swimmers with average "length " scores can do well in their respective sporting events (Åstrand & Rodahl, 1986; Tsunawake et al., 1991).

The sporting events examined in this study can be classified into 4 groups according to the similarity and correlation between them (Fig 2). These groups can be interpreted, according to the process of cluster formation, as 1) slim body shape with poor body fat (L(S) and L(A)), 2) standard body shape (Sw(S)), 3) well-balanced muscular body shape (Sp(S), Sp(A), T(A), K(S) and C(S)) and 4) tall body shape with rich "mass" (V(S), B(A) and B(S)). Group 3), well-balanced muscular body shape, consists of 3 small clusters, showing a tendency to become subdivided by the influence of Factor 2. Athletes of throwing events need to be large-built, a requirement due to the characteristic sporting techniques (Åstrand & Rodahl, 1986; Tsunawake et al., 1991). However, we failed to detect such a tendency with T(A), presumably because most of the T(A) examined in this study were local-class athletes with a small-build for athletes of throwing events, their height being only 102.2% of control. As these examples illustrate, our method of evaluating the body shape, which uses four factors based on the body model of adult non-athletes, explainsthe body shape characteristics of various sporting events in more concrete terms than the classification by somatotype (Thorland et al., 1981; Carter, 1984; Butts , 1985) or the evaluation by the body index (Tanaka et al., 1977).

In conclusion, female athletes of all the sporting events examined were found to have less body fat than female adult non-athletes. Although there were some characteristic differences in "mass", leg length and height between sporting disciplines, the findings suggested that the athletes had a body shape suitable for their sporting events.

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