

## Changes in Body Shape of Young Individuals from the Aspect of Adult Physique Model by Factor Analysis

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**Abstract.** The purpose of this study was to clarify characteristics of age-related changes in body shape in adolescence, in 11- to 19-year-old boys and girls, by using previously reported physique models of adult men and women as the scale. The scale consisted of four factors obtained by factor analysis using 30 items as variables, such as the values measured for the physique, skinfold thickness and body composition. The four factors were Factor 1: body fat, Factor 2: mass, Factor 3: leg length to height ratio, and Factor 4: length, and were interpreted in the men and women in a similar manner. The subjects were 307 boys and 368 girls; all were healthy. Thirty items were measured and included the values measured for the physique, skinfold thickness and body composition, as in the men and women. Factor scores in the subjects were standardized by mean and standard deviation for each item in the adult subjects, and calculated for individuals by using the coefficient of factor score in the adult subjects. The body shapes of the boys and girls were investigated from the factor score by age calculated for each factor. The following results were obtained: 1. Factor 1 tended to gradually decrease and reached the adult level at 15 years of age in the boys. But it tended to gradually increase and reached the adult level at 15 years of age in the girls; 2. Factor 2 rapidly increased with age in the first half of the teen years in the boys and girls, and it reached the adult level at 18 years of age in the girls, whereas this factor did not reach the adult level even at 19 years of age in the boys; 3. with regard to Factor 3, leg length tended to be temporarily somewhat long at 13-15 years of age in the boys, whereas the girls showed changes at approximately the level of the adult subjects; 4. Factor 4 rapidly increased with age in the first half of the teen years in the boys and girls, and reached approximately the adult level at 17 and 15 years of age in the boys and girls, respectively. These results suggest that, the physique in adolescence is almost equivalent to that of adults and that body shape is essentially fully formed in the early

20s in boys and by about 18 years in girls through rapid growth in both mass and length during the first half of the teen years.

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**Keywords:** physique, body composition, body shape, young individual, factor analysis

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### Introduction

It is important to clarify the processes of age-related changes in the physique and body shape of humans for evaluation of growth and nutritional status. Adolescence, in particular, is a stage of physical maturation in which people become adults via secondary sex characteristic development, and this stage is thus significant.

The physique and the body shape of humans have been studied from the values measured for physique and body indices (Tanaka et al., 1977; Hoshi, 1984; Komiya, 1988; Saeki et al., 1990; Tahara et al., 1990, 1992, 1993a, 1993b), by the somatotype method (Thorland et al., 1981; Carter, 1984; Butts, 1985; Pářizková & Carter, 1976), and by multivariate analysis (Masuda, 1965; Fukushima, 1967; Kawabe et al., 1980; Kato, 1984; Tsunawake et al., 1994, 1995). Among these methods, multivariate analysis facilitates the expression of statistical data consisting of many items measured approximately, with a small number of factors (Osawa, 1992). Therefore, the factors obtained from many values measured for physique and body indices are considered to be an efficient and comprehensive scale for clarifying and classifying characteristics of the body shape (Masuda, 1965; Fukushima, 1967). However, many past reports on multivariate analysis have dealt with the physique values measured as variables. Thus, body shape has been adequately assessed by taking into consideration body composition and body volume. In studies on the body shape of young

individuals by Kawabe et al. (1980) and Kato (1984), factors obtained from the young subjects were used as the scale, and the body shape of young individuals was not assessed on the basis of that in adults.

We have previously clarified characteristics of athletes' body shapes from the physique model, in the general population of adult men and women, by factor analysis, i.e., using a multivariate analytical method (Tsunawake et al., 1994, 1995). The variables used in this study were 30 items, and included the values measured for the physique, skinfold thickness, body composition, body surface area and body volume. The scale for the adult body shape obtained consisted of four factors, which were interpreted in the same manner in men and women. The factors were as follows: Factor 1: body fat, Factor 2: mass, Factor 3: leg length to height ratio, and Factor 4: length. The purpose of the present study was to clarify the characteristics of age-related changes in body shape, in 11- to 19-year-old boys and girls by using these four factors of the body shapes of adult men and women.

## Methods

### A. Subjects, time and place of measurements

The subjects consisted of 307 and 368 healthy 11- to 19-year-old boys and girls, respectively, who were living in Nagasaki City and the neighboring areas. To determine the average body shape of adolescent males and females, this study included subjects of the same generation, who were within  $\pm 20\%$  of the standard body weight by height as a body mass index (BMI: Compiled under the supervision of the Health Promotion and Nutrition Section, Health Service Bureau, the Japanese Ministry of Health and Welfare). Prior to the measurements, the purpose of the measurements and methods were explained to the subjects, and informed consent was obtained from them. The adult men and women used as the basis of the physique model in this study were 210 men (mean age, 26.8 years) and 433 women (mean age, 24.6 years), all of whom were healthy (Tsunawake et al., 1994, 1995).

### B. Time and place of determinations

Determinations were performed during summer vacation, mainly in the Physical Education Department of the Faculty of Liberal Arts of Nagasaki University, between 1987 and 1992.

### C. Items determined and methods

#### 1. Physique and skinfold thickness

Twenty parameters were measured: height (Ht), body weight, sitting height, lower height, body volume, circumferences at 7 locations, and skinfold thicknesses at 8 locations. Lower height was calculated by subtract-

ing sitting height from standing height, and was used in place of lower limb length. Circumference and skinfold thickness were measured according to Behnke & Wilmore (1974). Body volume was determined by the underwater weighing method, and this value was used as the denominator in the formula for calculating body density (Tsunawake et al., 1993a, b).

#### 2. Body indices and body surface area

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. Body surface area was calculated using the formula reported by Fujimoto et al. (1968).

#### 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 the formula reported by Brožek et al. (1963).

### D. Statistical analysis

The means and standard deviations of each item were determined for each age distribution of the young subjects. The differences in mean values between the values in the adult subjects and those at each age distribution were analyzed by Student's unpaired t-test. The factor score in the young subjects was calculated for individuals from the following formulae (1) and (2) by using the means, standard deviations and coefficient of factor score for each item in the adult subjects, which had been previously reported (Tsunawake et al., 1994, 1995). The means and standard deviations for each age distribution were calculated:

$$Z_{ik} = (X_{ik} - \bar{X}_i) / \sigma_i \quad (1)$$

$i = 1, 2, 3, \dots, m$

$k = 1, 2, 3, \dots, n$

$Z_{ik}$  ; standard score of variable  $ik$  in young subjects

$X_{ik}$  ; variable  $ik$  in young subjects

$\bar{X}_i$  ; mean of variable  $i$  in adult subjects

$\sigma_i$  ; standard deviation of variable  $i$  in adult subjects

$$Y_{rk} = \sum_{i=1}^m W_{ir} Z_{ik} \quad (2)$$

$r = 1, 2, 3, \dots, p$

$k = 1, 2, 3, \dots, n$

$Y_{rk}$  ; factor score in young subjects

$W_{ir}$  ; coefficient of factor score of variable  $ir$  in adult subjects

Factor scores were analyzed by analysis of variance of the effects of the age factor by other factors and by sex. A FACOM VP1200 computer at Nagasaki University Information Science Center was used, and the data were

processed with a statistical analysis package, ANA-  
LYST.

## Results

### 1. Physique, body index, skinfold thickness and body composition

Tables 1 and 2 show the means and standard deviations by items at each age distribution of the boys and girls, and the previously reported values of adult subjects (Tsunawake et al., 1994, 1995). Tables 3 and 4 show the results of analysis of significant differences between the means in adult and young subjects at each age distribution and the percentages (%) of values in the young subjects at each age distribution to those in the adult subjects. Fig. 1 shows the percentages of Ht, body weight and weight/Ht ratio in young subjects, at each age distribution, to those in adult subjects for determination of the growth status of parameters such as Ht, weight, and the degree of physical maturity. These 11- to 19-year-old subjects showed marked development in the first half of the teen years, and the degree of change in growth in the boys was higher than that in the girls. With regard to the percentages of the values in young subjects to those in adult subjects, body weight, circumferences such as chest and abdominal girths, and skinfold thickness around the abdominal region were significantly lower before 19 years of age in the boys. In the

girls, on the other hand, almost all items such as the physique, circumferences, skinfold thickness, and body composition were significantly lower before age 15, whereas the differences between these values and those in adult subjects were reduced at age 16. Relatively short stature, lower height among the body indices, was significantly higher at ages 12-15 and 13-14 years in the boys and girls, respectively, as compared to that in adult subjects.

### 2. Factor score in the young subjects on the basis of factor score in standard adult models

The means and standard deviations of factor scores by age for each factor are shown in Fig. 2, together with the results of analysis of variance among factor scores by age. Factor 1, which tended to decrease gradually from 1.0 at the age of 11 years, reached the adult level at the age of 15 years in the boys, and the factor that tended to increase gradually from  $-0.8$  at the age of 11 years reached the adult level at 15 years of age in the girls. Factor 2 was highly negative,  $-3.4$  at 11 years in the boys and  $-2.4$  at 11 years in the girls, but the value rapidly increased with age in the first half of the teen years in both boys and girls. Factor 2 did not reach the adult level even at 19 years in the boys, whereas it reached the adult level at almost 18 years of age in the girls. Factor 3 was temporarily high,  $0.6-0.8$ , at 13-15 years in the boys, whereas the girls showed changes in factor 3 within almost the adult level from the age of 11

**Table 1** Test items, mean and standard deviation for boys and adult men.

No/Age group	11	12	13	14	15	16	17	18	19	Adult <sup>a</sup>
Range in years	11.00–11.99	12.00–12.99	13.00–13.99	14.00–14.99	15.00–15.99	16.00–16.99	17.00–17.99	18.00–18.99	19.00–19.99	18.6–39.8
Years	(11.71±0.22)	(12.35±0.26)	(13.50±0.27)	(14.44±0.27)	(15.43±0.23)	(16.45±0.30)	(17.52±0.36)	(18.44±0.36)	(19.46±0.31)	(26.79±6.92)
Number	21	47	48	35	41	37	28	20	30	210
<b>Physique</b>										
1.Height(cm)	144.40±6.49	148.83±6.24	158.98±6.86	164.12±6.82	167.46±5.56	167.47±5.98	169.71±4.03	169.94±5.65	168.48±5.02	169.66±5.48
2.Weight(kg)	36.43±5.87	39.24±6.05	46.41±7.19	50.26±7.45	55.33±8.35	56.25±8.30	59.82±8.31	59.89±6.52	61.10±8.07	65.11±10.43
3.Sitting height(cm)	76.95±3.53	78.55±3.29	83.47±4.03	86.01±4.01	88.47±3.19	89.38±3.41	90.22±2.79	91.04±2.64	90.15±2.83	91.18±2.99
4.Lower height(cm)	67.45±3.61	70.28±3.65	75.51±3.73	78.11±4.05	79.00±3.66	78.09±3.88	79.49±2.62	78.90±3.80	78.33±3.30	78.48±4.11
5.Chest girth(cm)	67.85±5.22	70.04±4.69	74.54±5.21	77.87±4.97	81.48±5.84	82.33±5.90	83.53±4.60	84.87±4.61	85.37±5.10	89.19±6.75
6.Abdominal girth(cm)	59.92±5.66	61.60±5.23	64.11±3.96	65.80±4.18	68.11±6.39	68.94±6.23	71.27±6.15	70.91±5.58	71.27±5.40	76.45±8.56
7.Upper arm girth(cm)	20.45±2.55	20.73±2.04	22.12±2.06	22.56±2.16	24.61±2.57	25.56±2.41	26.48±2.47	25.69±1.86	26.71±2.13	27.91±3.16
8.Thigh girth(cm)	42.13±4.09	43.27±3.48	45.83±3.42	46.43±3.27	48.77±4.51	49.59±4.77	51.04±4.26	50.85±3.81	51.11±3.71	52.66±4.36
9.Lower leg girth(cm)	29.67±2.42	31.05±4.21	33.07±3.05	33.01±2.21	34.35±2.56	34.60±2.37	35.82±3.07	35.61±1.96	36.62±4.18	36.84±3.12
10.Waist(cm)	58.48±4.90	59.89±4.52	62.31±3.83	63.50±4.08	66.19±5.79	67.66±5.55	69.56±5.32	70.93±5.39	69.74±4.89	74.91±8.32
11.Hip(cm)	72.62±5.03	74.17±5.16	79.64±4.80	82.17±4.32	85.55±5.33	87.36±5.52	89.25±5.46	89.61±3.67	88.95±4.50	91.07±5.77
12.Body surface area(m <sup>2</sup> )	1.18±0.11	1.25±0.11	1.40±0.13	1.49±0.13	1.57±0.13	1.58±0.13	1.64±0.11	1.64±0.10	1.65±0.12	1.70±0.14
13.Body volume(l)	34.63±5.78	37.17±5.89	43.60±6.67	46.90±6.91	51.95±8.17	52.85±8.28	56.22±8.39	56.21±6.63	57.36±7.96	61.34±10.51
<b>Body index</b>										
14.Weight/Ht(kg/m)	25.15±3.33	26.29±3.29	29.08±3.44	30.54±3.51	32.98±4.47	33.55±4.45	35.23±4.62	35.25±3.76	36.21±4.13	38.33±5.70
15.Sitting height/Ht(cm/m)	53.30±1.03	52.79±1.06	52.50±1.12	52.41±1.32	52.83±1.21	53.38±1.28	53.16±1.07	53.58±1.00	53.52±1.08	53.76±1.41
16.Lower height/Ht(cm/m)	46.70±1.03	47.21±1.06	47.50±1.12	47.59±1.32	47.17±1.21	46.62±1.28	46.84±1.07	46.41±1.00	46.48±1.06	46.24±1.41
<b>Skinfold thickness</b>										
17.Triceps(mm)	11.12±4.10	9.93±4.30	8.96±3.01	7.71±2.39	9.70±4.03	11.33±5.78	11.14±5.20	9.25±3.12	10.58±4.62	10.39±5.03
18.Scapula(mm)	7.76±3.22	7.52±4.09	7.43±2.50	7.36±2.25	9.62±4.91	10.52±4.16	11.45±5.12	10.85±3.43	11.68±4.60	13.47±6.33
19.Abdomen(mm)	9.24±5.47	8.74±5.30	8.32±3.26	7.44±2.82	10.55±6.06	12.93±7.31	13.96±9.05	12.22±5.20	13.17±5.62	16.93±8.78
20.Supra-iliac(mm)	9.79±5.71	9.05±5.48	7.45±3.37	6.91±2.38	10.37±6.24	13.07±7.18	15.80±8.68	11.95±4.67	12.73±4.65	15.83±7.97
21.Chest(mm)	7.86±3.93	7.07±4.13	6.29±2.29	5.76±2.17	7.46±4.24	8.46±4.36	8.77±4.94	7.67±2.97	8.68±4.13	9.90±5.19
22.Thigh(mm)	15.67±3.89	14.45±4.62	12.91±3.74	11.46±3.07	13.20±4.95	15.12±6.32	16.20±5.90	13.30±4.45	14.78±5.87	14.19±6.35
23.Knee(mm)	9.26±3.92	8.72±3.99	8.65±2.75	7.49±1.76	8.22±3.16	9.43±3.57	9.11±3.02	8.42±2.57	8.30±2.67	8.48±3.55
24.Midaxilla(mm)	6.31±2.46	6.73±4.28	6.06±2.62	6.04±1.90	8.04±4.62	8.38±3.75	9.33±4.02	8.85±3.59	8.88±3.54	11.12±5.78
<b>Body composition</b>										
25.%Fat(%)	19.84±6.11	18.50±6.06	15.28±4.86	12.30±3.94	14.55±5.22	14.67±6.51	14.76±5.57	14.39±6.36	14.49±4.83	15.80±6.27
26.Body density(g/ml)	1.0530±0.0047	1.0563±0.0147	1.0642±0.0121	1.0716±0.0098	1.0660±0.0128	1.0658±0.0162	1.0655±0.0137	1.0665±0.0158	1.0661±0.0119	1.0630±0.0153
27.Fat(kg)	7.38±2.92	7.34±3.08	7.02±2.28	6.16±2.05	8.22±3.94	8.54±4.55	9.13±4.62	8.83±4.57	9.03±3.98	10.67±5.86
28.Fat/Ht(kg/m)	5.09±2.00	4.94±2.08	4.42±1.43	3.76±1.28	4.90±2.34	5.12±2.74	5.38±2.72	5.22±2.76	5.34±2.20	6.28±3.42
29.LBM(kg)	29.05±4.41	31.90±5.01	39.40±6.89	44.10±7.04	47.11±6.44	47.70±5.85	50.69±5.22	51.06±4.78	52.07±5.96	54.43±6.67
30.LBM/Ht(kg/m)	20.05±2.35	21.35±2.53	24.66±3.40	26.78±3.33	28.08±3.32	28.43±2.77	29.85±2.74	30.03±2.43	30.87±2.99	32.05±3.48

(Mean±SD), a:Data of Tsunawake et al.(1994)

**Table 2** Test items, mean and standard deviation for girls and adult women.

No/Age group	11	12	13	14	15	16	17	18	19	Adult*
Range in years	11.00–11.99	12.00–12.99	13.00–13.99	14.00–14.99	15.00–15.99	16.00–16.99	17.00–17.99	18.00–18.99	19.00–19.99	18.2–39.9
Years	(11.51±0.30)	(12.45±0.29)	(13.43±0.30)	(14.36±0.31)	(15.46±0.31)	(16.34±0.30)	(17.48±0.29)	(18.51±0.28)	(19.48±0.26)	(24.62±6.13)
Number	43	40	36	44	56	29	43	33	44	433
<b>Physique</b>										
1.Height(cm)	145.78±7.29	150.18±5.75	155.05±4.51	156.23±5.29	157.21±5.24	158.44±6.13	157.21±4.97	157.82±5.72	158.81±5.48	158.25±5.44
2.Weight(kg)	36.50±6.25	41.78±6.16	44.83±6.80	47.59±4.17	48.87±5.79	51.29±6.45	50.28±6.57	52.85±6.62	51.36±5.75	52.59±6.29
3.Sitting height(cm)	78.48±3.90	80.92±3.37	83.32±3.00	84.05±2.28	84.98±2.86	85.98±3.47	85.69±2.87	84.94±2.45	85.34±2.93	85.77±2.94
4.Lower height(cm)	67.30±4.04	69.25±3.27	71.73±2.97	72.17±3.99	72.24±3.68	72.47±3.39	71.52±3.20	72.88±4.14	73.47±3.38	72.48±3.65
5.Chest girth(cm)	68.70±4.86	73.34±5.30	75.57±4.91	77.71±3.85	78.48±4.71	80.34±4.12	79.08±4.68	80.61±4.26	78.44±3.99	79.95±4.62
6.Abdominal girth(cm)	58.56±5.01	62.48±6.42	64.52±6.24	67.47±5.16	68.99±5.96	70.96±5.80	72.22±7.10	70.60±6.14	68.48±6.33	72.06±6.68
7.Upper arm girth(cm)	20.95±1.80	22.62±3.18	22.60±2.11	23.30±1.81	23.95±2.35	24.57±2.34	24.30±2.11	24.69±2.06	24.15±2.27	24.53±2.14
8.Thigh girth(cm)	43.02±3.90	46.38±4.25	47.61±4.06	49.89±2.88	50.73±3.68	52.09±3.44	51.72±3.37	52.38±3.37	51.25±3.65	51.97±3.67
9.Lower leg girth(cm)	29.57±2.17	31.53±2.40	32.69±2.41	33.46±1.82	33.54±2.06	34.82±3.79	33.90±2.01	35.06±2.80	33.90±2.03	34.44±2.33
10.Waist(cm)	55.83±3.75	58.67±4.58	59.29±4.66	61.09±2.80	61.15±4.10	62.80±4.30	62.97±4.95	64.40±4.35	61.52±3.73	64.00±5.05
11.Hip(cm)	74.56±5.46	79.98±5.36	82.29±5.30	83.87±4.22	85.55±4.22	87.04±3.88	87.42±4.00	89.03±4.56	88.18±3.73	88.42±4.41
12.Body surface area(m <sup>2</sup> )	1.19±0.13	1.29±0.11	1.36±0.11	1.41±0.07	1.43±0.10	1.46±0.11	1.45±0.11	1.48±0.11	1.47±0.09	1.48±0.10
13.Body volume(l)	34.71±6.10	39.82±6.21	42.56±6.78	45.36±4.17	46.73±5.79	49.25±6.63	48.29±6.65	50.69±6.57	48.71±5.20	50.40±6.34
<b>Body index</b>										
14.Weight/Ht(kg/m)	24.92±3.20	27.76±3.56	28.86±3.84	30.46±2.43	31.05±3.22	32.32±3.43	31.92±3.58	33.44±3.55	32.31±3.20	33.21±3.58
15.Sitting height/Ht(cm/m)	53.85±1.12	53.89±1.11	53.75±1.26	53.83±1.26	54.07±1.31	54.27±0.98	54.51±1.14	53.85±1.24	53.74±1.04	54.22±1.24
16.Lower height/Ht(cm/m)	46.15±1.12	46.11±1.11	46.25±1.26	46.17±1.26	45.93±1.31	45.73±0.98	45.49±1.14	46.15±1.24	46.26±1.04	45.78±1.24
<b>Skinfold thickness</b>										
17.Triceps(mm)	11.48±3.57	13.17±4.50	13.44±5.58	15.60±4.63	16.38±4.06	18.05±4.10	18.36±4.94	17.85±4.04	16.44±3.78	16.83±4.91
18.Scapula(mm)	8.48±2.78	10.67±4.43	11.36±5.65	12.92±4.37	14.11±4.79	14.79±4.44	14.91±5.21	15.59±4.88	15.39±3.86	16.47±5.70
19.Ahdomen(mm)	10.80±4.35	13.06±4.64	12.81±4.75	16.26±5.55	18.68±6.07	20.86±4.87	21.21±5.73	20.86±5.03	20.18±4.25	20.17±5.95
20.Supra-iliac(mm)	10.04±3.61	12.81±5.33	12.39±5.50	15.60±5.19	16.65±6.37	18.40±6.11	18.66±6.25	19.85±5.70	18.94±5.01	18.21±6.35
21.Chest(mm)	8.33±3.63	9.40±4.04	11.21±5.10	11.56±3.87	12.06±3.78	12.69±3.89	12.78±4.14	12.70±3.91	14.06±3.72	13.48±4.90
22.Thigh(mm)	18.51±4.81	20.31±5.31	21.07±6.66	23.39±5.62	26.26±5.60	28.00±5.75	29.20±5.17	27.98±5.37	23.38±7.67	25.04±5.61
23.Knee(mm)	10.90±3.14	12.16±3.81	11.56±4.75	14.44±4.79	13.95±3.63	15.10±4.04	14.63±4.02	15.47±4.03	17.20±6.07	14.48±4.69
24.Midaxilla(mm)	7.52±2.99	9.44±4.58	10.76±5.34	11.19±3.75	11.53±4.12	11.48±4.41	12.19±4.81	13.48±4.46	12.60±3.38	13.14±4.96
<b>Body composition</b>										
25.%Fat(%)	20.12±5.20	20.89±5.79	19.28±5.08	21.25±5.20	22.48±5.39	24.25±5.48	24.28±4.38	23.85±4.40	22.49±4.29	23.47±5.18
26.Body density(g/ml)	1.0523±0.0126	1.0505±0.0139	1.0544±0.0123	1.0496±0.0125	1.0466±0.0130	1.0424±0.0130	1.0423±0.0104	1.0433±0.0105	1.0466±0.0123	1.0443±0.0124
27.Fat(kg)	7.44±2.57	8.92±3.49	8.83±3.37	10.17±2.94	11.13±3.34	12.65±4.17	12.39±3.55	12.72±3.28	11.98±2.92	12.49±3.74
28.Fat/Ht(kg/m)	5.07±1.63	5.92±2.25	5.68±2.12	6.52±1.89	7.07±2.10	7.97±2.53	7.86±2.14	8.05±2.03	7.54±1.86	7.89±2.34
29.LBM(kg)	29.06±4.67	32.86±3.94	36.00±4.53	37.42±3.51	37.74±4.10	38.64±3.73	37.89±3.87	40.14±4.57	39.38±3.36	40.11±4.24
30.LBM/Ht(kg/m)	19.85±2.37	21.85±2.16	23.18±2.42	23.94±1.97	23.98±2.19	24.36±1.81	24.07±2.00	25.40±2.34	24.81±1.70	25.32±2.29

(Mean±SD), a:Data of Tsunawake et al.(1995)

**Table 3** Percentage of boys to adult men and significant difference between boys and adult men.

No/Age group	11	12	13	14	15	16	17	18	19
	%	%	%	%	%	%	%	%	%
1.Height(cm)	85.11***	87.7***	93.7***	96.7***	98.7*	98.7*	100.0	100.2	99.3
2.Weight(kg)	55.9***	60.3***	71.3***	77.2***	85.0***	86.4***	91.9*	92.0*	93.9*
3.Sitting height(cm)	84.4***	86.1***	9.15***	94.3***	97.0***	98.0**	98.9	99.8	98.9
4.Lower height(cm)	85.9***	89.6***	96.2***	99.5	100.7	99.5	101.3	100.5	99.8
5.Chest girth(cm)	76.1***	78.5***	83.6***	87.3***	91.4***	92.3***	93.7***	95.2**	95.7**
6.Abdominal girth(cm)	78.4***	80.6***	83.9***	86.1***	89.1***	90.2***	93.2**	92.8**	93.2**
7.Upper arm girth(cm)	73.3***	74.3***	79.3***	80.8***	88.2***	91.6***	94.9*	92.1***	95.7**
8.Thigh girth(cm)	80.0***	82.2***	87.0***	88.2***	92.6***	94.2***	96.9	96.6	97.1
9.Lower leg girth(cm)	80.5***	84.3***	89.8***	89.6***	93.2***	93.9***	97.2	96.7	99.4
10.Waist(cm)	78.1***	79.9***	83.2***	84.8***	88.4***	90.3***	92.9***	94.7***	93.1***
11.Hip(cm)	79.7***	81.4***	87.4***	90.2***	93.9***	95.9***	98.0	98.4	97.7
12.Body surface area(m <sup>2</sup> )	69.4***	73.3***	82.5***	87.3***	92.2***	93.0***	96.4*	96.5*	96.9
13.Body volume(l)	56.5***	60.6***	71.1***	76.5***	84.7***	86.2***	91.6*	91.6**	93.5*
14.Weight/Ht(kg/m)	65.6***	68.6***	75.9***	79.7***	86.0***	87.5***	91.9**	92.0**	94.5*
15.Sitting height/Ht(cm/m)	99.1	98.2***	97.7***	97.5***	98.3***	99.3	98.9**	99.7	99.5
16.Lower height/Ht(cm/m)	101.0	102.1***	102.7***	102.9***	102.0***	100.8	101.3**	100.4	100.5
17.Triceps(mm)	107.0	95.6	86.2*	74.2***	93.4	109.0	107.2	89.0	101.8
18.Scapula(mm)	57.6***	55.8***	55.2***	54.6***	71.4***	78.1***	85.0	80.6**	86.7
19.Ahdomen(mm)	54.6***	51.6***	49.1***	43.9***	62.3***	76.4**	82.4	72.2***	77.8**
20.Supra-iliac(mm)	61.8***	57.2**	47.1***	43.6***	65.5***	82.6	99.8	75.5**	80.4**
21.Chest(mm)	79.4	71.4***	63.6***	58.2***	75.4**	85.5	88.6	77.5**	87.7
22.Thigh(mm)	110.4	101.8	91.0	80.7***	93.0	106.5	114.1	93.7	104.1
23.Knee(mm)	109.2	102.8	102.0	88.3*	96.9	111.2	107.4	99.3	97.9
24.Midaxilla(mm)	56.8***	60.5***	54.5***	54.3***	72.3***	75.4***	83.9*	79.6*	79.9**
25.%Fat(%)	125.6**	117.1**	96.7	77.8***	92.1	92.8	93.4	91.1	91.7
26.Body density(g/ml)	99.1***	99.4**	100.1	100.8***	100.3	100.3	100.2	100.3	100.3
27.Fat(kg)	69.1***	68.8**	65.8***	57.7***	77.0***	80.0*	85.5	82.7	84.6*
28.Fat/Ht(kg/m)	81.0*	78.6**	70.4***	59.9***	78.0**	81.5	85.7	83.1	85.0*
29.LBM(kg)	53.4***	58.6***	72.4***	81.0***	86.6***	87.6***	93.1**	93.8**	95.7
30.LBM/Ht(kg/m)	62.6**	66.6**	76.9***	83.6**	87.6**	88.7***	93.1**	93.7***	96.3

\*P&lt;0.05, \*\*P&lt;0.01, \*\*\*P&lt;0.001

**Table 4** Percentage of girls to adult women and significant difference between girls and adult women.

No/Age group	11	12	13	14	15	16	17	18	19
	%	%	%	%	%	%	%	%	%
1.Height(cm)	92.1***	94.9***	98.0***	98.7*	99.3	100.1	99.3	99.7	100.4
2.Weight(kg)	69.4***	79.4***	85.2***	90.5***	92.9***	97.5	95.6*	100.5	97.7
3.Sitting height(cm)	91.5***	94.3***	97.1***	98.0***	99.1	100.2	99.9	99.0	99.5
4.Lower height(cm)	92.9***	95.5***	99.0	99.6	99.7	100.0	98.7	100.6	101.4
5.Chest girth(cm)	85.9***	91.7***	94.5***	97.2**	98.2*	100.5	98.9	100.8	98.1*
6.Abdominal girth(cm)	81.3***	86.7***	89.5***	93.6***	95.7**	98.5	100.2	98.0	95.0***
7.Upper arm girth(cm)	85.4***	92.2***	92.1***	95.0***	97.6	100.2	99.1	100.7	98.5
8.Thigh girth(cm)	82.8***	89.2***	91.6***	96.0***	97.6*	100.2	99.5	100.8	98.6
9.Lower leg girth(cm)	85.9***	91.6***	94.9***	97.2**	97.4**	101.1	98.4	101.8	98.4
10.Waist(cm)	87.2***	91.7***	92.6***	95.5***	95.5***	98.1	98.4	100.6	96.1***
11.Hip(cm)	84.3***	90.5***	93.1***	94.9***	96.8***	98.4	98.9	100.7	99.7
12.Body surface area(m <sup>2</sup> )	80.5***	87.2***	91.8***	94.9***	96.4***	98.9	97.6	100.1	99.2
13.Body volume(l)	68.9***	79.0***	84.4***	90.0***	92.7***	97.7	95.8*	100.6	96.6
14.Weight/Ht(kg/m)	75.0***	83.6***	86.9***	91.7***	93.5***	97.3	96.1*	100.7	97.3
15.Sitting height/Ht(cm/m)	99.3	99.4	99.1*	99.3*	99.7	100.1	100.5	99.3	99.1*
16.Lower height/Ht(cm/m)	100.8	100.7	101.0*	100.9*	100.3	99.9	99.4	100.8	101.0*
17.Triceps(mm)	68.2***	78.3***	79.9***	92.7	97.3	107.2	109.1	106.1	97.7
18.Scapula(mm)	51.5***	64.8***	69.0***	78.4***	85.7**	89.8	90.5	94.7	93.4
19.Ahdomen(mm)	53.5***	64.7***	63.5***	80.6***	92.6	103.4	105.2	103.4	100.0
20.Supra-iliac(mm)	55.1***	70.3***	68.0***	85.7**	91.4	101.0	102.5	109.0	104.0
21.Chest(mm)	61.8***	69.7***	83.2**	85.8**	89.5*	94.1	94.8	94.2	104.3
22.Thigh(mm)	73.9***	81.1***	84.1***	93.4	104.9	111.8**	116.6***	111.7**	93.4
23.Knee(mm)	69.1***	84.0***	79.8***	99.7	96.3	104.3	101.0	106.8	118.8***
24.Midaxilla(mm)	57.2***	71.8***	81.9**	85.2**	87.7**	87.4	92.8	102.6	95.9
25.%Fat(%)	85.7***	89.0**	82.1***	90.5**	95.8	103.3	103.5	101.6	95.8
26.Body density(g/ml)	100.8***	100.6**	101.0***	100.5**	100.2	99.8	99.8	99.9	100.2
27.Fat(kg)	59.6***	71.4***	70.7***	81.4***	89.1**	101.3	99.2	101.8	95.9
28.Fat/Ht(kg/m)	64.3***	75.0***	72.0***	82.6***	89.6*	101.0	99.6	102.0	95.6
29.LBM(kg)	72.5***	81.9***	89.8***	93.3***	94.1***	96.3	94.5**	100.1	98.2
30.LBM/Ht(kg/m)	78.4***	86.3***	91.5***	94.5***	94.7***	96.2*	95.1***	100.3	98.0

\*P&lt;0.05, \*\*P&lt;0.01, \*\*\*P&lt;0.001

years. Factor 4 rapidly increased, from  $-4.1$  and  $-1.8$ , at 11 years in the boys and girls, respectively, with age in the first half of the teen years, and it almost reached the adult level at the age of 17 years in the boys and at 15 years in the girls. The effect of the age factor was observed at 5-0.1% levels for every factor in both boys and girls. Figure 3 shows two-dimensional coordinates in which Factor 4, indicating the long axis, was plotted along the horizontal axis and Factors 1 through 3 along the longitudinal axis for the purpose of investigating correlations between these factors, utilizing factor analysis, according to age. The degree of change in every factor was larger in the boys than in the girls. With regard to the relationship between Factors 2 and 4, both boys and girls showed changes within approximately the same range in two factor scores.

## Discussion

It is known that body shape at adolescence is changed by the contents of physical training (Přáizková & Carter, 1976) and that various sports are associated with a specific body shape (Tanaka et al., 1977; Thorland et al., 1981; Carter, 1984; Butts, 1985; Tsunawake et al., 1994, 1995). Since the purpose of this study was to clarify the body shape of average young Japanese individuals, athletes were excluded, and the subjects were limited with reference to BMI to people of the same generation reported by the Japanese Ministry of Health and Welfare (1989). For this reason, mean Ht and body weight values of the subjects of this study were almost equal to the values reported by the Ministry, suggesting that

these means show physical characteristics of the average Japanese population ranging in age from 11 to 19 years.

Tsunawake et al. (1994, 1995) reported that Factor 1, i.e., "body fat", provides information on 40% of the adult men and 35% of the adult women, as a parameter of body shape. In other words, %Fat, Fat, skinfold thickness and circumferences of the body trunk, which had a large effect on this factor added to Factor 1, are significantly involved in the body shape of adults. Tahara et al. (1990, 1992) reported the physique, body indices and body composition of high-grade primary school boys and girls, and there were almost no sex differences in any of these values. However after puberty in girls, Fat accumulation is believed to be increased by sex hormone secretion (Wade & Gray, 1979). In the present study as well, sex differences in various values of skinfold thickness and body composition tended to increase starting from the age of about 12 years. Although Factor 1 reached the adult level at 15 years of age in both boys and girls, the nuance of Factor 1 in boys is deemed to be slightly different from that in girls. In other words, the body shape may be changed to a muscular and rather sturdy physique in boys and to a soft rounded physique, because of increased Fat, in the girls.

Factor 2 could be explained by 30% in the boys and by 27% in the girls in the total variance. As with Factor 1, Factor 2 is the scale for body shape, and thus provides a large amount of information (Tsunawake et al., 1994, 1995). The factor score for Factor 2 was within the highly negative region at 11 years of age in both boys

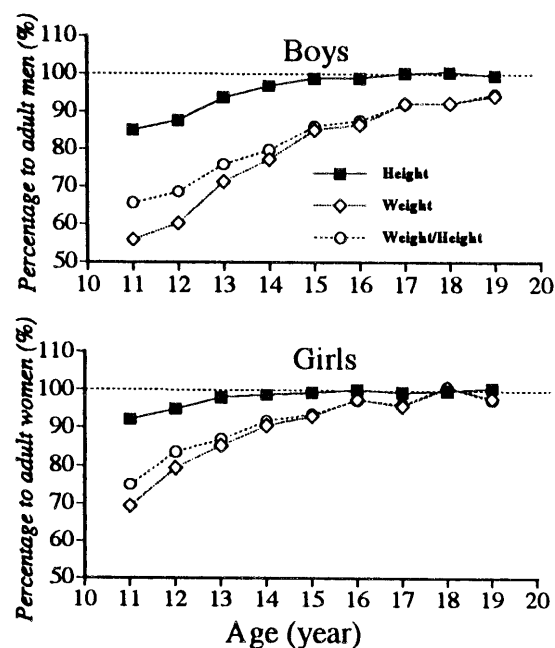


Fig. 1 Age changes in height, weight and weight/Ht on aged 11-19.

and girls in this study, and also tended to increase with age. In the girls, this factor reached the adult level at 18 years, whereas it did not reach the adult level even at the age of 19 years in the boys. Thus, there was a sex difference in the age when Factor 2 reached the adult level. When considering the mean age ( $26.8 \pm 6.9$  years) of the adult men used as the standard in this study, Factor 2 is estimated to reach the adult level in the first half of the 20s in boys, while the tendency toward

gradual increase after puberty is being maintained. In previous reports on body shape by factor analysis (Masuda, 1965) and analysis of main components (Masuda, 1965; Fukushima, 1967; Kato, 1984), a factor indicating body size, which is similar to Factor 2 in this study, i.e., a factor interpreted as a size factor, has been examined. The main purpose of these studies was to examine the aspect of clothing composition, and the values determined for the physique and body indices were used.

Factor 3 provides information on longitudinal balance of the long axis of the body. This Factor score was temporarily higher than the adult level at the age of 13-15 years in boys, whereas this factor reached approximately the same level from the age of 11 years in the girls. In other words, the boys in the first half of the teen years showed a tendency for long leg length along with an increase in the long axis, whereas girls showed growth as the longitudinal balance in adult women would be nearly maintained even at a time when the long axis is markedly increased.

Factor 4 yields information about the long axis, and is closely related to bone growth. The factor score for Factor 4, in this study, was highly negative at the age of 11 years in both boys and girls and tended to increase with age. The growth of Factor 4 showed the same degree of change as that in Factor 2 in both boys and girls, as shown in Fig. 3. Furthermore, the factor reached the adult level at a younger age than that for Factor 2 in both boys and girls. The degrees of changes in the boys in the first half of the teen years were markedly larger than in the girls, suggesting that Factor

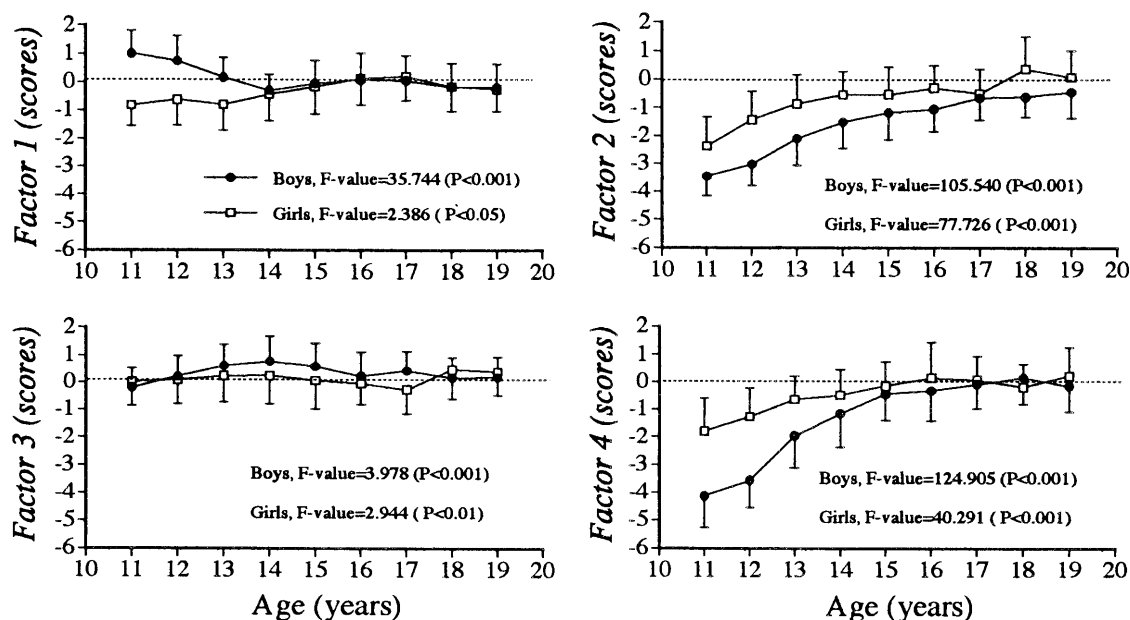


Fig. 2 Factor scores of each factor by age groups.

Significance of the effect of age on factor scores by ANOVA. Values are means and SD.

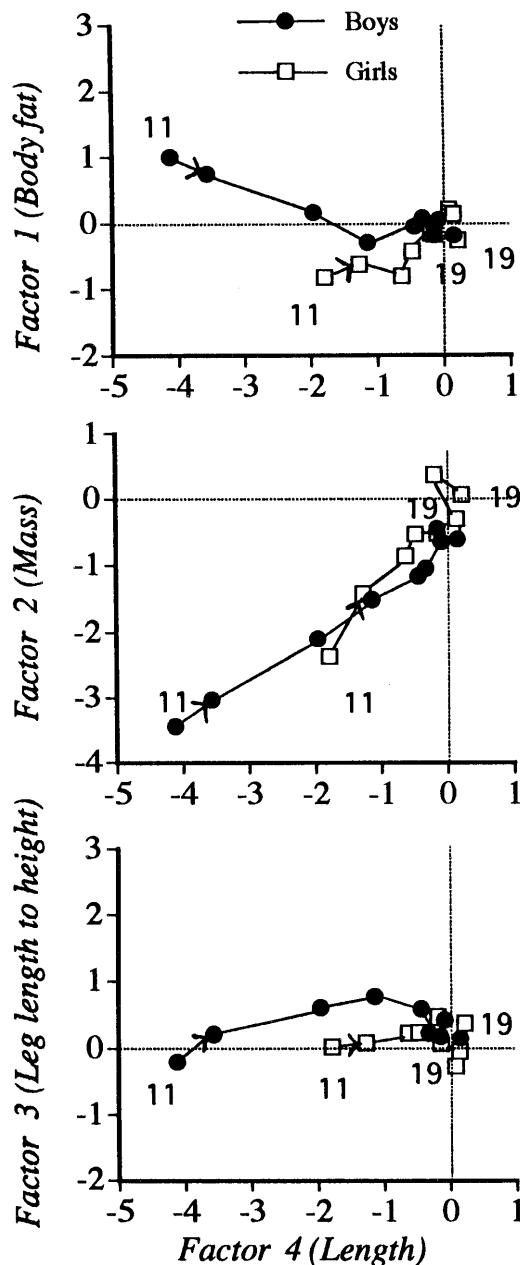


Fig. 3 Factor scores of aged 11-19 on a two dimensional chart. Values are means.

4 is a factor indicative of substantial sex difference. Hoshi (1984) found that the degree of annual increase in Ht is maximal at 12 years and 9 months in boys and at 10 years and 7 months in girls. The degree of annual increase in Ht was also investigated in the present study. It peaked at 12-13 years in boys, and this finding is consistent with that reported by Hoshi (1984). In girls, however, Ht showed no marked fluctuations at the ages of 11-13 years, suggesting that the time when Ht peaked may have passed. The difference in the degrees of change between boys and girls is considered to be attributable to the difference in the time of growth.

From the aspect of the scale for the adult body shape, the body shapes of young individuals are suggested to show the following changes: "body fat" and "length" reach the adult levels at about 15 years of age in both boys and girls, and "mass" reaches the adult level in the early 20s in boys and by about 18 years in girls, through rapid increases in "mass" and "length" from a small and lean body shape in the first half of the teen years. The longitudinal balance of the long axis has already reached the adult level at the age of 11 years for both boys and girls.

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## References

- Behnke A R, Wilmore J H (1974) Evaluation and regulation of body build and composition. Prentice-Hall, Inc, Englewood Cliffs, N J, 20-52
- Brožek J, Grande F, Anderson J T, Keys A (1963) Densitometric analysis of body composition; Revision of some quantitative assumptions. *Ann N Y Acad Sci* 110: 113-140
- Butts N K (1985) Profiles of elite athletes: physical and physiological characteristics. In Butts N K, Gushiken T T, Zarins B eds. *The elite athletes*. Spectrum Publication, Inc, N Y, 183-207
- Carter J E L (1984) Somatotype of Olympic athletes from 1948 to 1976. *Medicine Sport Sci* 18: 80-109
- Fukushima T (1967) A note on the Classification of human physique by principal component analysis. *J Anthropol Soc Nippon* 75: 69-82
- Fujimoto S, Watanabe T, Sakamoto A, Yukawa K, Morimoto K (1968) Studies on the physical surface area of Japanese: part 18 calculation formulas in three stages over all age(in Japanese). *Jap J Hyg* 23: 443-450
- Hoshi H (1984) Some findings on the physical status and body types in Japanese viewed from the report of the survey on the physical status in Japanese(in Japanese). *J Anthropol Soc Nippon* 92: 281-293
- Kato S (1984) A consideration on the validity of dividing the materials into the chronological age groups for classification of physical types during the growth period (1-18 years) (in Japanese). *J Home Economics* 35: 707-712
- Kawabe T, Takai S, Akiyoshi T, Ohtsuka R, Suzuki T (1980) Indices of body build in children: evaluation by using principal components analysis on cross-sectional data. *J Anthropol Soc Nippon* 88: 411-422
- Komiya S (1988) The physique, body shape and body composition of Japanese(in Japanese). *Kyushu J Phys Educ Sports* 2: 1-12
- Masuda T (1965) Application of principal component

- analysis and factor analysis to the measurements of the human body: a trial for designing ready-made garments. *Pep Stat Appl Res, JUSE* 12: 30-48
- Osawa S (1992) Factor analysis. In Osawa S, Inagaki A and Kikuta H eds. *Multivariate analysis for life science*. (In Japanese). Kaseikyouikusha, Tokyo, 63-14
- Párizková J, Carter J E L (1976) Influence of physical activity of somatotype in boys. *Am J Phys Anthropol* 44: 327-340
- Saeki S, Tahara Y, Tsunawake N, Nishizawa S (1990) Body composition (hydrostatics) and skinfold thickness in Junior High school boys, aged 12 to 15(in Japanese). *Jpn J School Health* 32: 583-591
- Tahara Y, Tsunawake N, Saeki S, Nishizawa S (1990) Body composition (hydrostatics), skinfold thickness and evaluation of obesity in boys, aged 10 to 12(in Japanese). *Jpn J School Health* 32: 290-298
- Tahara Y, Tsunawake N, Saeki S, Yamasaki M, Uekata M, Yukawa K (1992) Body composition (densitometry - hydrostatics) and skinfold thickness in Elementary School girls, aged 10 to 12(in Japanese). *Jpn J School Health* 34: 434-443
- Tahara Y, Yukawa K, Tsunawake N, Saeki S, Nishiyama K, Urata H, Katsuno K, Hukuyama Y (1993a) Body composition (densitometry - hydrostatics), skinfold thickness, BMI and their relationships in Junior High School girl(in Japanese). *Jap J Public Health* 40: 353-362
- Tahara Y, Tsunawake N, Saeki S, Yamasaki M, Katsuno k, Yukawa K (1993b) Body composition (densitometry - hydrostatics) and skinfold thickness in Senior School students, aged 15 to 18(in Japanese). *Jpn J School Health* 35: 492-501
- Tanaka N, Tsujita J, Hori S, Senga Y, Otsuki T, Yamasaki T (1977) Studies on physique and body shape of athletes with special reference to differences in physique among athletes of various kinds of sports(in Japanese). *Jpn Phys Fitness Sports Med* 26: 114-123
- The Japanese Ministry of Health and Welfare ed (1989) *Dietary allowance of Japanese*. 4th ed (In Japanese). Daiichishuppan Inc, Tokyo, 111-130
- Thorland W G, Johnson G O, Fagot T G, Tharp G D, Hammer R W (1981) Body composition and somatotype characteristics of Junior Olympic athletes. *Med Sci Sports Exerc* 13: 332-338
- Tsunawake N, Tahara Y, Yukawa K, Senju H, Katsuno K (1993a) Body composition, maximal oxygen uptake, and maximal oxygen debt on elite senior high school(Kyushu Bunka Gakuen) female volleyball players(in Japanese). *Jpn Phys Fitness Sports Med*, 42: 339-349
- Tsunawake N, Tahara Y, Yukawa K, Senju H (1993b) Body composition,  $\text{VO}_2$  max and  $\text{O}_2$  debt max in elite senior high school male cyclists(in Japanese). *Ann Physiol Anthropol* 12: 351-362
- Tsunawake N, Tahara Y, Yukawa K, Katsuura T, Harada H, Kikuchi Y (1994) Classification of body shape of male athletes by factor analysis. *Ann Physiol Anthropol* 13: 383-392
- Tsunawake N, Tahara Y, Yukawa K, Katsuura T, Harada H, Kikuchi Y (1995) Characteristics of body shape of female athletes based on factor analysis. *Appl Human Sci* 14: 55-61
- Wade G N, Gray J M (1979) Gonadal effects on food intake and adiposity ; a metabolic hypothesis. *Physiol Behav* 22: 583-593

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