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Body Size and Composition in Different Somatotypes of Japanese College-aged Women

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Abstract. The purpose of this study was to determine differences in body size, composition and structure between three somatotypes of Japanese college-aged women. The study sample consisted of 30 sedentary female college students between 18 and 20 years of age. Ten subjects had an endomorphic ectomorph somatotype (mean weight 41.95 kg), 10 had an endomorph-ectomorph somatotype (mean weight 47.12 kg) and the remaining subjects had a mesomorphic endomorph somatotype (mean weight 55.37 kg). The mean heights for these groups did not differ significantly. The mesomorphic endomorph group had a higher gross weight and a higher percentage of all adipose variables than the other two groups, though these measurements were not significantly different between the endomorph-ectomorph and the endomorphic ectomorph groups. The mean lean body weight (LBW) for the mesomorphic endomorph group was significantly larger than that of the other two groups. The endomorph-ectomorph group had the next largest LBW, and the mean for the endomorphic ectomorph group was significantly smaller than that of the other two groups. Inversely, mean values of LBW/weight(WT), LBW/total adipose tissue weight (TATW) ratio and total body water/WT were significantly lower for the mesomorphic endomorph group than for the other two groups. Furthermore, the ratios of internal adipose tissue to weight (IATW)/WT and subcutaneous adipose tissue to IATW (SATW)/IATW did not differ significantly between groups. In conclusion, college-aged women of different somatotypes within the same age and height range varied in body composition. Consequently, the notion of a small frame is incorrect. An accurate assessment of the human body's composition may provide a valuable insight into the ideal weight for optimal physiologic function.

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Keywords: body composition, internal adipose tissue weight, subcutaneous adipose tissue weight, somatotype, college-aged women

Introduction

Considerable research has been carried out on anthropometric methodology for quantifying physique status. Body size refers to the physical magnitude of the body in terms of its volume, mass, length, and surface area. Body size is often categorized as short or tall, large or small, heavy or light. On the other hand, visual appraisal is often used to describe individuals as thin (ectomorphy), muscular (mesomorphy), or fat (endomorphy). Body composition refers to the relative amounts of body constituents such as fat, muscle, water and ash. The evaluation of body composition provides an excellent opportunity for partitioning a person's gross size into two major structural components - body fat and lean body mass. Somatotype and body composition have been examined by a number of investigators studying the relationship between the two approaches to the measurement of human physique. In general, Sheldon's endomorphy and Heath and Carter's first component have been found to be fairly closely associated with body fatness (Brozek and Keys, 1951; Hunt and Barton, 1959; Damon et al., 1962; Heath and Carter, 1967; Wilmore, 1970; Slaughter and Lohman, 1976). Mesomorphy and the second component, however, showed little correlation between lean body mass and weight or height in the same studies.

It is well known that adolescent females with different somatotypes but who fall within the same age and height range vary in body composition. Our previous data (Komiya et al., 1995) revealed that when adolescent females are grouped by body mass index (BMI), sedentary females with a low BMI have physique and dimensional characteristics similar to active females. However, when quantified by the deuterium oxide (D_2O)

dilution method, the absolute and relative body fat values of active females are significantly lower than those of sedentary females, although the body weights of the two groups do not differ significantly. Furthermore, active females have a higher lean body weight (LBW) than sedentary females.

In general, modern adolescent females desire to be slimmer and "good looking". Adolescent females show marked self-consciousness about having a fat body image (Imai et al., 1994; Komiya et al., 1994). Therefore, females of even average or less than normal weight aspire to an even more slender appearance (Imai et al., 1994; Komiya et al., 1994). The body may respond to weight loss, low body fat levels, or under-nutrition by defending its energy stores. Weight loss and dieting by many adolescent females may exert powerful physiological effects, possibly including increased food efficiency, changes in metabolic rate and adipose tissue activity, increased risk of health problems, and compromised reproductive capacity.

On the other hand, excess body weight, or more specifically excess body fat, influences the health risk profile and increases mortality and morbidity (Hubert et al., 1983; Simopoulos and Van Itallie, 1984). Although large quantities of body fat are undesirable from a health perspective, precise optimal levels of body fat or body weight for a particular individual cannot be made.

The assessment of body composition in both individuals and populations is important for both clinical investigation and medical practice. Although the body composition of Japanese adult women has been studied, few investigations involving college-aged students (Komiya et al., 1981b) have used hydrometry to assess body composition, and there is little information regarding body composition in different somatotypes of Japanese college-aged women. The purpose of this study was to determine differences in body size, composition and structure between three somatotypes of Japanese college-aged women.

Methods

Subjects. The study sample consisted of 30 sedentary college female students between 18 and 20 years of age. All subjects were healthy, and had not engaged in regular exercise training for at least 2 years. Ten of the subjects were below the 10th percentile of weight for height, while 10 were between the 10th and 25th percentiles of weight for height. The remaining subjects were between the 25th and 75th percentiles of weight for height. All measurements were carried out after a 12 - h overnight fast. The purpose of the investigation was fully explained to each subject, and all gave written informed consent before commencing the study.

Anthropometric procedures. Barefoot height and weight were obtained with an accuracy of 0.1 cm and 0.02 kg, respectively. The anthropometric dimensions included fourteen skinfold sites, nine circumference measurements, and two skeletal widths. All skinfold thickness measurements were made with a Harpenden caliper on the right side of the body. The skinfolds measured were cheek, chin, chest (nipple), chest (lateral), abdomen, suprailiac, triceps, scapula, back (superior), back (inferior), thigh (anterior), thigh (posterior), knee, and medial calf (Komiya et al., 1992b). The circumferences measured were neck, chest, waist, abdomen, biceps relaxed, forearm, thigh, and calf. Skeletal widths included the biepicondylar breadth of the humerus and the biepicondylar breadth of the femur.

Somatotype procedures. Somatotype was determined by the Heath-Carter anthropometric method (Carter, 1972). Heath and Carter (1967) modified Sheldon's original method, objectifying the system by using skinfolds, circumferences, and bone widths and introducing an M-scale (a modification of Parnell's M.4 chart, 1954) to redefine each somatotype and its components. The first component refers to relative fatness, the second to the lean body mass relative to height, and the third to the relative linearity of the individual's physique.

Body composition procedures. Body composition was assessed by the D_2O dilution method (Komiya et al., 1981a; Komiya et al., 1992a; Komiya et al., 1992b). The subjects drank 1 g D_2O per kg body weight. A urine specimen was collected before D_2O administration and 3 - h after D_2O ingestion. The D_2O fraction of distilled urine was then measured by infrared spectrophotometry (Komiya et al., 1981a). Total body water (TBW) was computed as TBW(l) $=$ D_2O dose (g)/(urinary D_2O fraction $\times 10$). The overall accuracy of the TBW procedure is reported to be 4% (Osserman et al., 1950). LBW was calculated from TBW determinations by the Pace and Rathbun formula (1945); LBW (kg) $=$ TBW/0.732. Total adipose tissue weight (TATW) was computed as weight (kg) - LBW (kg). The average value for the 14 skinfold sites was calculated and applied to the equation for determination of subcutaneous adipose tissue weight (SATW). Body surface area was calculated using the equation of Fujimoto et al. (1968) and skin weight (SW) was calculated from body weight using the Satake and Ozaki equation (1991). The density of fat was taken as 0.900 g/cm^3 (Fidanza et al., 1953).

$$\text{SATW (g)} = (\text{average of 14 skinfolds, (cm)}/2) \times \text{BSA (cm}^2) \times 0.900\ (\text{g/cm}^3) - \text{SW (g)}.$$

Internal adipose tissue weight (IATW) was calculated as the difference between TATW and SATW.

Statistical analyses. Results are presented as mean $\pm$ standard deviation (S.D). Significant difference was determined by Wilcoxon's t-test for unpaired data after analysis of variance. Differences with p values below 0.05 were considered significant.

Results

Somatoplots for the three groups are shown in Figure 1. Here the circles represent the subjects in each of the three groups. The endomorphic ectomorph group (A) was categorized as having ectomorphy (the third component) dominant and endomorphy (the first component) greater than mesomorphy (the second component). The endomorph-ectomorph group (B) was categorized as having the first and third components equal and the second component lower, and the mesomorphic endomorph group (C) was categorized as having endomorphy dominant and the second component greater than the third.

Figure 2 shows figure-scale outline drawings for the subjects in each of the three groups.

Means of selected physical characteristics for the subjects in the three groups are shown in Table 1 along with "p" values and results of Wilcoxon's t tests. The mean heights for these groups did not differ significantly. In terms of weight the mean for the mesomorphic endomorph group (55.37kg) was significantly greater than those for the other two groups, the mean for the endomorph-ectomorph group (47.12 kg) was the next greatest, and the mean for the endomorphic ectomorph group (41.95 kg) was significantly lower than those for the other two groups. The mean BMI for the mesomorphic endomorph group (21.83) was significantly higher than those for the other two groups, the mean for the endomorph-ectomorph group (18.74) was the next highest, and the mean for the endomorphic ectomorph group (16.60) was significantly lower than those for the other two groups. The mean skeletal width and abdomen-to-hip ratio (WHR) for the mesomorphic endomorph group were larger than those for the other two groups, but did not differ significantly from each other. A sample group of the subjects were approximately the same age at menarche. However, 30% of the endomorphic ectomorph group reported irregular cycles. Changes in body weight between the ages of 12 and 18 years were significantly less common in the endomorphic ectomorph group (+4.1 kg) than in the other two groups.

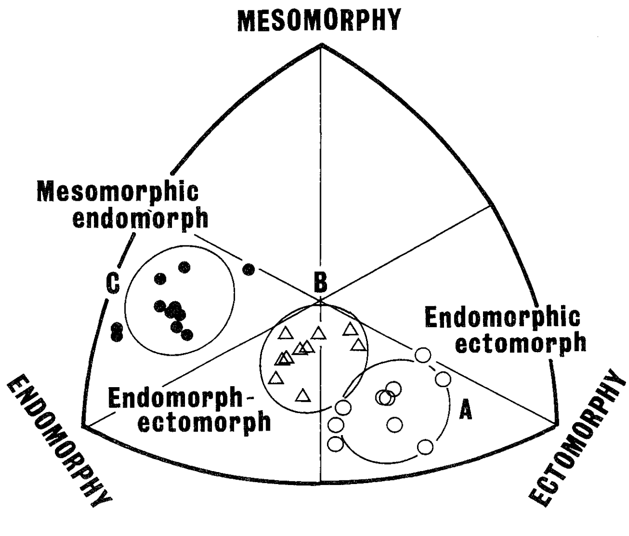

Fig. 1 Somatoplots of the subjects.

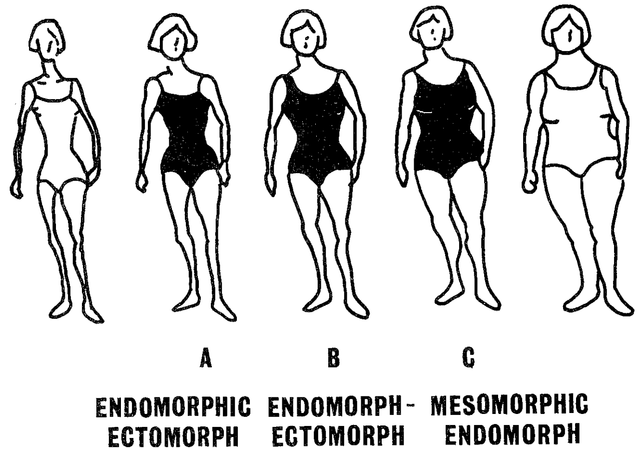

Fig. 2 Series of line-drawings of the subjects.

Table 2 shows the mean circumference measurements. The mesomorphic endomorph group had the largest measurements in all nine sites, while the endomorphic ectomorph group had the smallest. However, there was no significant difference between the endomorph-ectomorph and the endomorphic ectomorph groups in abdominal circumference.

Means and standard deviations for TATW, SATW, IATW, LBW, TBW, and their proportions relative to body weight (WT) are given in Table 3. The mesomorphic endomorph group had a higher gross weight and a higher percentage of all adipose variables than the other two groups, though these were not significantly different between the endomorph-ectomorph and the endomorphic ectomorph group. Mean IATW/WT and SATW/IATW ratios did not differ significantly between the groups. The mesomorphic endomorph group had increased TATW with no significant differences in SATW/TATW and IATW/TATW compared with the endomorph-ectomorph group. The mean LBW for the mesomorphic endomorph group (37.30 kg) was also significantly larger than those for the other two groups, the mean for the endomorph-ectomorph group (34.75 kg) was the next largest, and the mean for the endomorphic ectomorph group (30.14 kg) was significantly smaller than those for the other two groups. Inversely, mean LBW/WT (67.4%), LBW/TATW ratio (2.08), and TBW/WT (49.3%) were significantly lower in the mesomorphic endomorph group than in the other two groups.

Figure 3 shows the pattern of subcutaneous fat

Table 1 Means and standard deviations of physical characteristics of the subjects.

	Endomorphic ectomorph N=10	t	Endomorph-ectomorph N=10	t	Mesomorphic endomorph N=10	p
Age, yr	18.7±0.7	*	18.1±0.3	n.s	18.0±0.0	**
Height, cm	159.0±1.4	n.s	158.6±2.0	n.s	159.3±1.6	n.s
Weight, kg	41.95±1.30	***	47.12±1.50	***	55.37±1.49	***
Humerus width, cm	5.48±0.17	n.s	5.64±0.32	n.s	5.90±0.16	**
Femur width, cm	8.68±0.26	n.s	8.89±0.47	n.s	9.34±0.13	***
Body surface area, cm^2	13442±218.6	***	14131±311.5	***	15226±274.2	***
Body mass index, kg/m^2	16.60±0.52	***	18.74±0.25	***	21.83±0.29	***
Waist-to-hip ratio	0.757±0.029	n.s	0.762±0.037	n.s	0.788±0.032	n.s
Age at menarche, yr	12.5±1.1	n.s	12.1±1.2	n.s	12.1±1.3	n.s
Oligomenorrhea, %	30.0		0		10.0	
Changes in body weight[a], kg	+4.1±1.9	*	+9.1±6.5	n.s	+10.0±6.0	n.s

[a]; from ages 12 to 18 years. T values were calculated using unpaired Wilcoxon's t test. P values were calculated using one-way analysis of variance. n.s; non-significant, *; $p<0.05$, **; $p<0.01$, ***; $p<0.001$

Table 2 Circumference measurements of the subjects.

	Endomorphic ectomorph N=10	t	Endomorph-ectomorph N=10	t	Mesomorphic endomorph N=10	p
Neck, cm	27.7±0.6	**	28.9±0.9	**	30.3±1.0	***
Chest, cm	74.2±1.6	***	78.3±2.4	***	84.6±3.0	***
Waist, cm	56.1±1.7	**	59.3±2.4	***	64.5±1.7	***
Abdomen, cm	61.0±2.4	n.s	63.7±3.3	***	70.1±2.9	***
Hip, cm	80.7±2.7	*	83.5±1.5	***	88.9±1.5	***
Upper arm, cm	19.3±0.7	***	20.9±0.9	***	23.6±1.0	***
Forearm, cm	19.5±0.5	***	20.7±0.7	***	22.2±0.8	***
Thigh, cm	40.8±1.4	***	44.9±1.7	***	49.5±1.7	***
Calf, cm	30.1±0.8	***	32.5±0.8	***	35.3±1.2	***

T values were calculated using unpaired Wilcoxon's t test. P values were calculated using one-way analysis of variance. n.s; non-significant, *; $p<0.05$, **; $p<0.01$, ***; $p<0.001$

Table 3 Means and standard deviations of gross weight in relation to body composition and their percentages for the subjects.

	Endomorphic ectomorph N=10	t	Endomorph-ectomorph N=10	t	Mesomorphic endomorph N=10	p
TATW, kg	11.81±1.72	n.s	12.37±1.38	***	18.08±1.28	***
SATW, kg	4.66±1.26	n.s	5.91±1.35	***	9.44±1.83	***
IATW, kg	7.15±1.85	n.s	6.46±0.94	**	8.64±1.85	*
TATW/WT, %	28.1±3.9	n.s	26.2±2.5	***	32.7±2.3	***
SATW/WT, %	11.1±2.8	n.s	12.5±2.7	**	17.1±3.4	***
IATW/WT, %	17.1±4.5	n.s	13.7±2.0	n.s	15.6±3.3	n.s
SATW/IATW	0.84±0.50	n.s	0.98±0.31	n.s	1.20±0.62	n.s
LBW, kg	30.14±1.75	***	34.75±1.27	**	37.30±1.80	***
LBW/WT, %	71.9±3.9	n.s	73.8±2.5	***	67.4±2.3	***
LBW/TATW	2.62±0.50	n.s	2.84±0.36	**	2.08±0.23	***
TBW, l	22.06±1.28	***	25.44±0.93	**	27.31±1.33	***
TBW/WT, %	52.6±2.9	n.s	54.0±1.8	***	49.3±1.7	***

TATW; total adipose tissue weight, SATW; subcutaneous adipose tissue weight, IATW; internal adipose tissue weight, WT; body weight, LBW; lean body weight, TBW; total body water, T values were calculated using unpaired Wilcoxon's t test. P values were calculated using one-way analysis of variance. n.s; non-significant, *; $p<0.05$, **; $p<0.01$, ***; $p<0.001$

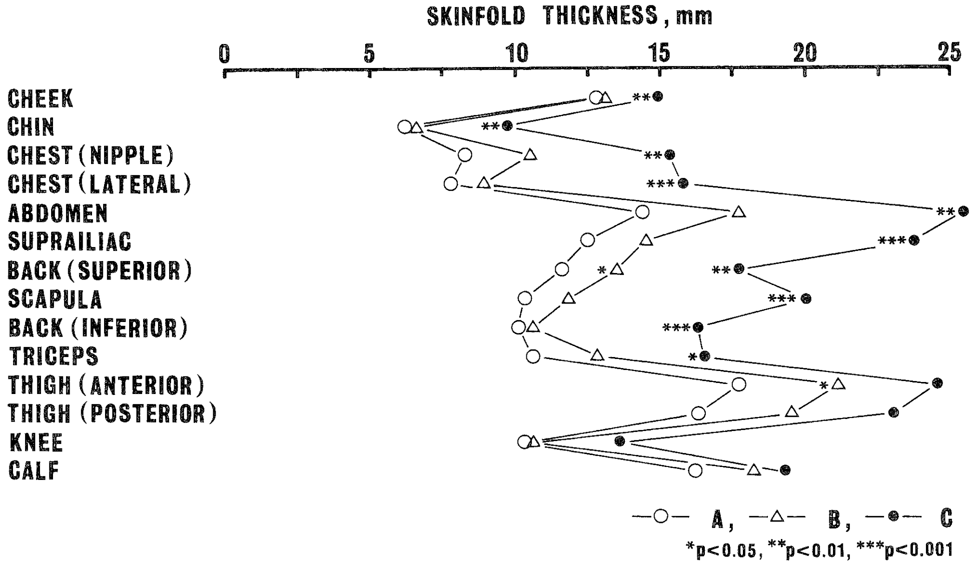

Fig. 3 Comparison of subcutaneous fat distribution of the three somatotypes.

distribution in each of the three groups. The mesomorphic endomorph group had the greatest amounts of subcutaneous fat in almost all sites except the lower extremities. However, the pattern of subcutaneous fat distribution did not differ significantly between the three groups.

Discussion

The most widely used measures of body size are height and body weight. Body composition refers to the relative amounts of body constituents such as fat, muscle, water and ash. Body size and composition are largely predetermined by genetic inheritance. Although body size can be altered only slightly, body composition can change substantially with diet and exercise. In general, resistance training can substantially increase muscle mass, and a sound diet combined with vigorous exercise can significantly decrease body fat. Such changes can be of major importance in achieving optimal physiologic function.

It is well known that adolescent female of different somatotypes within the same age and height range vary in body composition. Excess body weight, or more specifically excess body fat, influences the health risk profile and increases mortality and morbidity (Hubert et al., 1983; Simopoulos and Van Itallie, 1984). However, there seems to be a lower biologic limit beyond which a person's body mass cannot be reduced without impairing health.

Our data revealed that when college-aged women were grouped by somatotype, the mesomorphic endomorph group had a greater gross weight and a higher percentage of all adipose variables than the endomorph-ectomorph and endomorph ectomorph groups. Gross TATW and SATW were generally smallest in the endomorphic ectomorph group. However, mean IATW/WT and SATW/IATW ratios did not differ significantly between the three groups. Inversely, mean LBW/WT, TBW/WT, and LBW/TATW ratios were significantly lower in the mesomorphic endomorph group than in the other two groups.

Although small quantities of body fat are desirable from a health perspective, a precise optimal level of body fat or body weight for a particular individual cannot be determined. Frisch et al. (1973) proposed a body weight with 17% body fat as being the critical body weight. It is argued by some that hormonal and metabolic disturbances that may affect the menses are triggered if body fat falls below these levels (Freedson et al., 1983; Frisch et al., 1980). This theoretical limit is termed minimal body fat mass, and for the college-aged women in this study it was equivalent to 7.1, 8.0, and 9.4 kg, respectively. Freedson et al. (1983) and Frisch et al. (1980) have suggested 22% body fat as the level required to maintain a normal menstrual cycle. This theoretical limit is termed the optimal body fat mass, and for the college-aged women in this study it was equivalent to 9.2, 10.4, and 12.2 kg, respectively. Although absolute and relative body fat values for the women in the present study were within normal limits, 30% and 10% of the endomorphic ectomorph and mesomorphic endomorph group reported irregular menstrual cycles, respectively. However, all the endomorph-ectomorph group reported regular cycles. The lean-to-fat ratio (LBW/TATW) appears to be important for normal menstrual function (perhaps through the role of peripheral fat in the conversion of androgens to estrogens). The endomorph-ectomorph group's mean LBW/TATW was 2.84, which is significantly larger than that for the mesomorphic endomorph group, and at least 8% higher than that for the endomorphic ectomorph group. The major fat depot, storage fat, consists of fat that accumulates in adipose tissue. Although the proportional distribution of storage fat in males and females is similar (McArdle et al., 1991), the total percentage of internal fat (IATW) in females, which includes sex-specific fat, is higher than in males. More than likely, the additional internal fat is biologically important for hormone-related functions. Therefore, it was not surprising that mean values for relative internal fat (IATW/WT) and subcutaneous-to-internal fat ratio (SATW/IATW) did not differ significantly between the three groups.

In conclusion, college-aged women with different somatotypes but within the same age and height range varied in body composition. For example, a weight of 42 kg (height of 159 cm; BMI=16.6) would be light for a normal college-aged woman, but relative internal fat did not differ significantly between these groups of normal college-aged women whatever their gross weight. In college-aged women a lean-to-fat ratio of 2.62 would be high for a mesomorphic endomorph woman, but just right for an endomorph-ectomorph woman. Consequently, the notion of a small frame is incorrect. Assessment of body composition provides additional information, beyond the basic measures of height and weight, for both clinical investigation and medical practice. An accurate assessment of the human body's composition can provide a valuable insight into the ideal weight for optimal physiologic function. Therefore, the basic issue of optimal body size needs further research and experimentation, including detailed endocrine studies, to complement body composition and anthropometric measurements.

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