Ideal Body Shape in Young Japanese Women and Assessment of Excessive Leanness Based on Allometry

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Abstract The present study is aimed to clarify the degree of leanness desired by contemporary young Japanese women using questionnaires and to use allometry to define the body weight boundary between the excessively lean and the others for a given height. Questionnaires on ideal body shape were distributed to female college students living in Akita and the suburbs of Tokyo. Data for 578 respondents, aged 18 to 21 years-old, were analyzed. The questionnaire asked the subjects to report their current and ideal body shape and to make a qualitative self-assessment of their weight. On average, the perceived ideal weight was 5.2 kg lower than the current weight. The results also revealed that young women have a tendency to misunderstand their body shape and to regard themselves as heavier than they really were. Meanwhile, we defined leanness as a state of insufficient lean body mass (LBM, kg) in relation to height (Ht, cm). Allometric equation of LBM on Ht and the standard error of estimate (SEE) were calculated as $LBM = 3.87 \times 10^{-3} \times Ht^{1.826}$ and 1.09, respectively. The LBM boundary between the excessively lean and the others was determined using these values according to a statistical procedure comparing normal and abnormal values. The corresponding total body weight was estimated from the boundary LBM in the literature. Subsequently the body weight boundary for each height was tabulated in order to make young women reconsider weight control. The subjects were asked to assess the body weight boundary for their own height. The boundary values were found to be consistent with the sense of the subjects. *J Physiol Anthropol* 22 (2): 105–110, 2003 <http://www.jstage.jst.go.jp/en/>

Keywords: ideal body weight, young women, allometry, criteria of leanness, boundary weight

Introduction

A desire for leanness has been increasing among young women (Lee, 1993; Lake et al., 2000) who have been interested in methods for weight reduction such as dieting. Under the condition of excessive diet especially in young women around twenty years old, it is feared that they may suffer from hypotension, irregular menstruation, anorexia nervosa or even osteoporosis in the future. Therefore, self-control is needed in order to avoid excessive weight reduction. Also, it is necessary to develop some methods of evaluation of leanness that reveal acceptable minimum body weight for young women. Information about minimum weight may lead young women to stop excessive dieting and develop healthy eating habits.

While the evaluation of obesity has been discussed often in studies, there are few biological investigations on the criteria of leanness. The evaluation of leanness has been investigated temporarily. For example, the Japanese Ministry of Health and Welfare (1986) published tables and figures for judging obesity and leanness, in which body weight less than 10 percentile by sex, age and height was regarded as excessive leanness. The report of the school health statistics survey by the Japanese Ministry of Education (1983, 1999) has been using values less than 80% of mean body weight by sex, age and height as the criteria for leanness. Recently the Japanese Society of Obesity (2000) proposed a definition of leanness as a body mass index (BMI) of less than 18.5. Similarly some investigators described the criteria of leanness (Roche et al., 1996; Malina & Bouchard, 1991; Fox, 1979), but they only showed the values based on body build indices, percentiles of body weight or skinfold thickness from the practical point of view.

Leanness should rather be defined biologically and also theoretically. Accordingly, we defined excessive leanness as a state of insufficient lean body mass (LBM) in relation to height

that stands for body size, and proposed the criteria of excessive leanness by means of a statistically determined boundary weight under a biologically growing system. In this context, we employed allometry, which shows the relationship between one body part and another part or the whole body, in order to assess leanness.

Thus, first the extent of leanness desired by young Japanese women was investigated using anonymous questionnaires in the present study. Secondly according to our definition of leanness, an evaluation method to distinguish lean young women from others was proposed using an allometric and statistical method.

Methods

Questionnaires on desired physique were distributed to 710 female college students living in Akita and the suburbs of Tokyo. Out of these respondents, data for 578 students aged 18 to 21 years-old were analyzed because of relatively sufficient numbers of subjects. The age breakdown was 116 aged 18 years, 227 aged 19 years, 142 aged 20 years, and 93 aged 21 years. The questionnaire asked respondents to report their current and ideal height and weight, and to assess their current body shape anonymously. Questions included items regarding: age, current height and weight, perceived ideal weight for current height, perceived ideal height and weight, body image, and the viewpoint to assess body shape. Data were analyzed descriptively with means and standard deviations, and cross tabulations.

In addition, the questionnaire asked respondents to evaluate a table of the body weight boundary for excessive leanness proposed in the present study. This table was made using allometry, which is known as an empirical theory of a biologically growing system. Since an exponential function is fitted to the relationship between two growing systems as $y = bx^a$, the allometric equation of lean body mass on height is calculated as $LBM = bHt^a$, where LBM is lean body mass in kg and Ht is height in cm. A double logarithmic function can be applied to the allometric equation and the constants "a" and "b" are determined by the least square method. As is often the case with statistical tests, a boundary line to separate unusual values from usual ones is commonly 5% for both ends of the frequency distribution, that is, 2.5% for each end. The criteria of leanness were determined according to this way. Assuming that individual lean body mass normally distributes around the line of an allometric equation in the direction of the ordinate, 2.5% of the total frequency theoretically distributes below the values at the interval of the double standard error of estimate (2SEE) downward from the line. These values were regarded as LBM boundary between the excessively lean and the others.

Using data of 1636 female high school seniors who were 15 to 17 years-old and different from the subjects for the questionnaire survey, the allometric equation of LBM on height and the standard error of estimate were calculated. LBM was estimated from height, weight and skinfold thicknesses at

triceps and subscapular sites using the equations of Nagamine (1975) for body density and Brozek et al. (1963) for percent body fat.

Since it is said that essential fat is approximately 9% of body weight for young women (Lohman 1981), total body weight corresponding to boundary LBM was calculated by dividing the boundary LBM by 0.91, and the quotient of the calculation was regarded as the boundary body weight between the excessively lean and the others. The values are tabulated in the form of a chart consisting of the boundary body weight for each height.

Results

Table 1 shows current body shape as reported by the subjects in the questionnaire survey. Current height and weight were almost the same for females between the ages of 18 and 21 years. Table 2 shows perceived ideal weight, height, and the differences between ideal and current body shape of the subjects. Ideal weight for current height was less than current weight by 5.2 kg on average. Ideal height was somewhat higher than current height, but ideal weight for ideal height was almost the same as that for current height. Table 3 summarizes study results by some investigators.

The responses to the question "What do you think of your current weight?" are shown in Table 4. The choices of the self-assessment were divided into five groups: thin, a little thin, normal, a little fat, and fat. Current body shape for each group was presented in this table. Nearly seventy percent of the subjects classified their own current weight into a little fat or

Table 1 Physical characteristics of respondents

Age group	n	Height (cm)		Weight (kg)		BMI (kg/m ²)	
		Mean	SD	Mean	SD	Mean	SD
18	116	158.5	5.3	51.1	6.7	20.3	2.4
19	227	158.1	4.7	51.8	9.5	20.7	3.6
20	142	158.5	5.5	51.7	7.5	20.5	2.4
21	93	159.7	5.1	51.5	6.5	20.2	2.2
All	578	158.5	5.1	51.6	8.1	20.5	2.9

Table 2 Differences between perceived ideal and current body shape

n=573	Mean	SD	Difference from the current value	
			Mean	SD
Ideal weight (kg) for current height	46.3	4.3	-5.2	4.5
BMI (kg/m ²)	18.4	1.3	-2.0	1.8
Ideal height (cm)	161.1	4.0	2.5	5.1
Ideal weight (kg) for ideal height	46.7	3.8	-4.7	5.7
BMI (kg/m ²)	18.0	1.2	-2.4	2.0

Table 3 Comparison of perceived ideal body shape among various studies

Investigator Year of survey Subjects	Mizuno et al. 1963, 65 Students	Aoyama 1976 18–20 yr n=1050	Matsuura et al. 1985 Mean=18.6 yr n=433	Kojima et al. 1992 Mean=18.8 yr n=468	Present study 2001 18–21 yr n=578
Actual height (cm)	156.1	157.9	157.7	157.7	158.5
Actual weight (kg)	51.2	50.3	51.0	50.0	51.6
Actual BMI (kg/m ²)	21	20.2	20.5	20.1	20.5
Ideal weight (kg) for actual height	52.3 [#]	47.7	47.0	46.5	46.3
Ideal BMI (kg/m ²) calculated from actual height and ideal weight	21.5 ^{##}	19.1	18.9	18.7	18.4

[#] Ideal weight for ideal height. ^{##} Ideal BMI calculated from ideal height and ideal weight.

Mean values of body shape are presented.

Table 4 Body shape in each group of self-assessed body image

n (%)	Responses to the question “What do you think of your current weight?”									
	Thin		A little thin		Normal		A little fat		Fat	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Current height (cm)	156.4	5.3	158.2	4.4	159.3	5.1	158.0	5.3	158.8	4.9
Current weight (kg)	40.9	4.2	44.1	3.6	47.6	4.5	50.9	4.4	56.3	8.0
Current BMI (kg/m ²)	16.7	1.2	17.6	0.8	18.7	1.3	20.4	1.2	22.3	2.7

Fig. 1 Responses to the question “What is the viewpoint from which you assess your fatness or thinness?”

fat group. However, the means of current BMI for both groups were within a normal category by the criteria suggested by the Japanese Society of Obesity.

The responses to the question “What is the viewpoint from which you assess your fatness or leanness?” are illustrated in Fig. 1. Frequencies and the percentages of respondents for nine categories were indicated. This figure shows that 13% of the subjects evaluate their body shape based on the relation between height and weight, but 35% of the subjects assessed themselves from the viewpoint of looks.

From the data of 1636 female students, an allometric

equation of LBM (kg) on Ht (cm) was calculated and shown in Fig. 2. The equation was expressed as $LBM = 3.87 \times 10^{-3} \times Ht^{1.826}$ ($r = 0.528$, $P < 0.01$). Standard error of estimate (SEE) was 1.09. Values at the interval of 2SEE below this equation indicate the boundary LBM between the excessively lean and the others. The boundary LBM was then converted to total body weight by the method described above by adding essential fat. Namely, total body weight corresponding to the boundary LBM was calculated by dividing the boundary LBM by 0.91. The boundary body weight for each height was tabulated in the form of a chart (Table 5).

Fig. 2 Allometric line of lean body mass on height in 1636 young women. The regression equation was calculated as $LBM = 3.87 \times 10^{-3} \times Ht^{1.826}$ ($r = 0.528$, $P < 0.01$).

Table 5 Boundary body weight of excessive leanness for each height in young Japanese women

Height (cm)	Boundary weight (kg)	Height (cm)	Boundary weight (kg)
140	32.9	160	42.6
141	33.3	161	43.1
142	33.8	162	43.7
143	34.3	163	44.2
144	34.7	164	44.7
145	35.2	165	45.2
146	35.7	166	45.8
147	36.2	167	46.3
148	36.6	168	46.8
149	37.1	169	47.4
150	37.6	170	47.9
151	38.1	171	48.4
152	38.6	172	49.0
153	39.1	173	49.5
154	39.6	174	50.1
155	40.1	175	50.6
156	40.6	176	51.2
157	41.1	177	51.7
158	41.6	178	52.3
159	42.1	179	52.9

Female students were asked to assess the values proposed in Table 5 and the responses to the question “What do you think of the boundary weight in our study?” are shown in Fig. 3. Forty percent of the students replied that the values of the boundary weight proposed in the present study were consistent with their feelings. Meanwhile, almost the same percentage of the students replied that the values of boundary weight were lighter or heavier than expected. The relationship between the self-estimated boundary weight of excessive leanness and the current height was investigated for the subjects as shown in Fig. 4. The regression equation of self-estimated boundary weight on the current height was expressed as $y =$

Fig. 3 Responses to the question “What do you think of the boundary weight in our study?”

Fig. 4 The relationship between boundary weight of excessive leanness estimated by the subjects and their current height. The regression equation was calculated as $y = -23.8 + 0.414x$ ($r = 0.585$, $P < 0.01$).

$-23.8 + 0.414x$ ($r = 0.585$, $P < 0.01$). There was not a great difference between boundary weight values calculated from this regression and our results.

Discussion

Mean height and weight of the subjects in the questionnaire survey were similar with the results of the recent National Nutrition Survey in 1999, which showed that mean height and weight for young women between the ages of 18 and 21 were approximately 158.1 cm and 51.4 kg. Therefore, it was likely that the subjects in the present study were representative of contemporary young Japanese women.

As for perceived ideal body shape, some investigators have carried out similar surveys in the past. Table 3 shows the comparison of perceived ideal body shape among various investigations. Aoyama (1978) questioned female students on ideal body shape and his results indicated a lighter ideal body weight by 2.6 kg than actual body weight. Matsuura et al. (1991) assessed body shape preferences for female college students and revealed that ideal weight was less than actual weight by 4.0 kg. Kojima et al. (1994) found ideal weight for

female junior college students to be less than actual weight by 3.5 kg. Compared to these investigations, the present study showed that young Japanese women wish to lose more weight. On the contrary, in the survey of Mizuno et al. (1968) who measured senior high school and college students in 1963 and 65, the mean values of actual and ideal body weight for girls were found to be 51.2 kg and 52.3 kg, respectively. These results suggest that body shape preference for young women may have changed around 1970. Young Japanese women seemed to begin to prefer slenderness around that time. In line with this, BMI during the past several decades decreased according to the data of the Ministry of Education (2000). Prior to the early 1980's, almost no reports of eating disorders in non-Caucasians existed, although the desire for slenderness and existence of eating disorders of young women had already been reported in the western countries (Caradas et al., 2001).

As for the reasons of slender body shape preference, effects of social pressures have been well documented. For instance, Ritchie (1988) introduced literature for the social pressures concerning environmental, occupational, developmental, personality and genetic factors, which may predispose women to eating disorders. Lake et al. (2000) investigated the effect of western culture on eating attitudes and the perception of body shape and supported existing literature that attitudes toward eating and perceptions of one's own body shape are influenced by cultural factors. The sociocultural effects seem to be complicated and vague, but it is possible that a high-growth period of the Japanese economy in the 1960's and early 1970's had been relevant to the change in the value of body shape preference.

According to the response to the question "What do you think of your current weight?", subjects had a tendency to misperceive their body shape (Table 4). They were apt to overestimate their body weight. In the same way, some researchers reported that young females in the western countries tend to misperceive themselves as overweight (Matsuura et al., 1991). The most frequent response to the question "What is the viewpoint from which you assess your fatness or leanness?" was "looks," which was, if anything, sensuous and groundless. These results mean that the subjects thought of their body shape with the heart rather than the head. Tiggemann and Pickering (1996) pointed out an important role of mass media in women's body dissatisfaction and drive for thinness. They said that media promote impossible standards of body shape by presenting women of ideal body image being extremely thin. In Japan, some investigators also assumed that the slender body shape preference might be partly attributable to a tendency to praise thinness as beauty in the society (Fukunaga & Kobayashi, 1993; Imai et al., 1994; Kojima et al., 1994). Meanwhile, it was said that the perceived body shape preferences of opposite sex were regarded as the standards for young women in judging their body shapes (Fallon & Rozin, 1985; Cohn et al., 1987). The female samples in those investigations desired to be thinner than the figures they considered most attractive to boys. While it was said that mass

media leads women to weight reduction, a desire of leanness seemed to be related to awareness of the opposite sex. If this is true, a desire of leanness is instinctive and deeply rooted. According to the results of the National Nutrition Survey in 1999, the annual survey in Japan, BMIs calculated from the mean values of height and body weight for women were lower until the age of eligibility for marriage. Thereafter, BMIs rose. This phenomenon also implies that the awareness of the opposite sex is considerably related to the desire for leanness.

As mentioned at the beginning, it is necessary to propose the acceptable minimum body weight for young women. The knowledge of the minimum weight may lead young women to stop excessive weight reduction. In other words, it is likely that the presentation of a boundary body weight between the excessively lean and the other groups may make young women reconsider their weight control.

We showed the table of the boundary body weight between the excessively lean and the others. At that time, we assumed that essential fat is about 9% of body weight for young women according to a review by Lohman (1981), and calculated back to the total body weight from the boundary LBM. Essential fat is contained at the site of bone marrow, central nervous systems, mammary glands and other organs. Some investigators estimated essential fat to be higher than 9%, but we adopted the minimum percentage in this study from the viewpoint of excessive leanness. When BMIs for each height were calculated from Table 5, the values were 16.7 for 150 cm, 16.6 for 160 cm, and 16.6 for 170 cm. At the mean height of the subjects in this study, the lack of body weight for the excessive leanness corresponded to approximately 20% of the mean weight. This percentage agreed with one of the diagnostic criteria for anorexia nervosa, where the lack of body weight is regarded as 20% or more than standard weight.

There were a considerable number of subjects who thought the values in Table 5 were unexpected. Nevertheless the regression equation of their expected boundary weight on actual height indicated no great difference between their senses and our results. That is, as shown in Fig. 4, the values of boundary weight for each height calculated from the regression equation were 38.3 kg for 150 cm, 42.4 kg for 160 cm, and 46.6 kg for 170 cm. Incidentally, sixty-nine percent of the subjects considered the boundary values reasonable or less than expected. It seemed that many young women knew the limits for weight reduction, although they intended to become slender.

In conclusion, young Japanese, as well as western, women have a tendency to believe that they are fat even if they are classified into the thin or normal category. They have been getting thinner over the past 25 years or more and are continuing to do so. The boundary weight of excessive leanness for each height was statistically calculated from an allometric equation and found to be consistent with the sense of the subjects. It is desirable that young women do not wish to lose weight below the limits of the boundary weight proposed in this study. As is generally known, excessive weight

reduction affects the human body especially young women of reproductive age. Diet often employed in the way of weight reduction has a risk for the development of rich and healthy eating habits. While there is a trend that leanness is ideal for preventing us from life-style-induced diseases, we should note that body fat is also beneficial to store energy, retain heat under cold conditions, and protect the organs of the body.

Since self-reported height and weight were employed in this study, their reliability should be tested elsewhere. There are some investigations on the differences between self-reported and directly measured height and weight. Mable et al. (1988) described that the report in the body image questionnaire was highly reliable for the college students, while Nishizawa et al. (2002) found that self-reported values slightly underestimated the actual weight in the junior and senior high school students. Meanwhile, the boundary weights proposed here are easily changeable in connection with the calculation, which depends on percentages of essential fat. It is unclear to what extent the information about minimum weight leads young women to stop excessive weight loss. There is room for further investigation on these points.

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