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Influences of Genetic and Early Environmental Factors on Physique and Menarche in Young Japanese Women

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Abstract: Background: There is not enough of necessary data on the relationship between the physical condition at birth and in infancy and the current status for Japanese women. Aim: To study the relationship between young Japanese women's physical condition at birth and in infancy with their current status and investigate genetic and environmental factors' influence on their physique and menarche. Subjects and Methods: Anthropometric measurements were obtained for 204 Japanese women aged 19.4 ± 0.5 y and their condition at birth and in infancy was investigated, using the subjects' "mother-and-child healthcare record book" (*boshi-kenko-techo*). Results: The subjects' birth height and weight were correlated with their height and weight at 1 month, but not thereafter. Their current (19 y) height was correlated with their height at 3 months and thereafter, and their current weight was correlated with their weight at 3 y. The subjects in the higher 3 y height and weight quartiles had higher current values of height, weight, waist, hip, bone mineral content, and visceral fat area. Weight at 19 y was correlated with the 1.5–3 y weight increase. In a multiple regression analysis, 19 y height was predicted by 1.5 y height, mother's height, father's height, and 3 y height. The subjects with earlier menarche (9–12 y) were significantly taller at 1.5 and 3 y, but not at 19 y; at 19 y, those subjects had also higher values of body mass index (BMI), waist, %fat mass, fat/lean ratio, and visceral fat area, but lower %muscle mass and %skeletal muscle mass. Height at 19 y was correlated with parents' height, but weight and BMI were not correlated with parents' weight and BMI, respectively. The daughters' menarche age was correlated with their mother's menarche age. Nutrition method differences in infancy (breast, formula, or mixed feeding) did not influence the subjects' current physical condition. Conclusion: Japanese women's height at 19 y was influenced by their parents' height, suggesting heritability. The women's 19 y weight and BMI were not correlated with those of their parents, indicating stronger environmental factors (probably lifestyle including diet and exercise) rather than genetic factors. Daughters' adult height but not their weight and BMI may be predicted by the infancy data in mother-and-child healthcare records. Daughters' menarche age was predicted by the mothers' menarche age, suggesting heritable factors.

Keywords: Physique, Menarche, Young Women, Birth, Infant, Heritability, Environmental Factors

1. Introduction

According to the 2019 Japanese National Health and Nutrition Survey [1], the proportions of obesity (BMI ≥25 kg/m^2) and underweight (BMI <18.5 kg/m^2) among Japanese women have not changed significantly for 10 years. However, the 20.7% rate of underweight among women in their 20s was much higher compared to other generations. The percentage of women with an exercise habit was also lower in young women. One reason may be a current preference for slenderness (but objectively 'skinniness' or even 'emaciation') among young women. The above-cited survey also revealed that the proportion of young women who were trying to improve their dietary or exercise habits is lower than in past generations. These results suggest that young Japanese women may be candidates for lifestyle-related diseases such as sarcopenia, frailty, osteoporosis, metabolic syndrome, and diabetes mellitus, in the future [2–4].

Many studies have sought to determine the effects of genetic and early environmental factors on the physique and menarche of women. A study conducted in Japan reported that a woman's BMI is a significant predictor of her daughter's BMI in adolescence and young adulthood [5, 6], and that overweight/obesity in mothers and overweight/obesity at the age of 3 years (y) were associated with overweight/obesity in Japanese adolescents at 15 y [7]. In another investigation of Japanese subjects, parental (mother and also father) obesity was a risk factor for obesity in preschool children [8]. An overweight mother or father and overweight status at birth (≥3,500 g) were related to obesity in 3 y children [9].

Both birth weight and height have been reported to be associated with height in adulthood [10]. It was also shown that the velocity of weight gain from birth to 3 months was associated with overweight and fat mass in female adolescents [11]. Breast feeding was reported to be associated with lower rates of infancy weight gain and later-obesity compared to formula feeding [12]. Another matter of concern for girls is the age of menarche, a surrogate marker of female maturation. Birth weight predicted age at menarche in some studies [13], but not others [14]. Rapid infancy weight gain was associated with younger age at menarche as a significant marker of increased risk of obesity in adulthood [15–18].

However, these studies were performed with mostly European or American subjects. Asian women, particularly Japanese, may differ from western populations in a number of ways; e.g., in the susceptibility to obesity or lifestyle-related diseases. We conducted the present study to clarify (1) the relationship between the physical condition of individuals at birth and in infancy and the current status of young Japanese women, and (2) the influences of genetic and early environmental factors on the women's physique and menarche. In Japan, a mother-and-child healthcare record (MCHR) book (*boshi-kenko-techo* in Japanese) has been used to maintain healthcare records of both mothers and children since 1965. The book is distributed to all pregnant women, and the information of pregnancy, delivery, and the infant is recorded. We obtained the data of the present subjects from their birth to infancy from their MCHR books.

2. Subjects and Methods

2.1. Subjects

Initially, 224 female singleton sophomore students at Sugiyama Jogakuen University (Nagoya, Japan) were enrolled; statistical outliers (n=3) and the subjects with low birth weight (<2,500 g) (n=17) were excluded. Accordingly, 204 subjects aged 19.4 ± 0.5 y and their parents were enrolled. The study was approved by the Ethical Committee of Sugiyama Jogakuen University School of Life Studies (No. 2017-27). The subjects provided written informed consent to participate. The protocol was performed in accord with the revised Helsinki Declaration in 1983.

2.2. Methods

2.2.1. Physical Examination

Each subject's height, waist, and hip measurements were obtained by the study authors, and the waist/hip (W/H) ratio was calculated. Body composition was determined by the eight-polar bioimpedance method (InBody 720, Biospace, Tokyo, Japan). The items included body weight, fat mass, lean mass, muscle mass, skeletal muscle mass, visceral fat area (VFA), and bone mineral content (BMC). The subject's BMI, %fat mass, %muscle mass, %skeletal muscle mass, and fat/lean (F/L) ratio were calculated. Bone density was determined by measuring ultrasound velocity in the calcaneus (CM-300, Cannon Life Care Solutions, Tokyo).

2.2.2. Questionnaires

A questionnaire was administered to obtain the information on the subjects' growth. The height and weight of each subject's parents and the age of menarche of the subject's mother were also obtained by the questionnaire. A dietary survey was administered using the food intake frequency survey method (FFQ ver.6, Kenpakusha, Tokyo).

2.2.3. Mother and Child Healthcare Record (MCHR) Book

The records of each subject's health status and the progress of the pregnancy, delivery, and growth as an infant were obtained from the subject's MCHR book. The items obtained were birth weight and height, nutrition method (from birth to 7 months), and growth as an infant (height and weight to 3 y).

2.2.4. Statistical Analyses

Statistical analyses were performed using SPSS ver. 27 software (IBM, Tokyo). A normal distribution of continuous data was confirmed using the Shapiro-Wilk test, and outliers were confirmed by the Smirnov-Grubbs test. Parametric data are presented as the mean ± standard deviation (SD). Non-parametric data are presented as the median (Q1, Q3). The bivariate correlation was examined by Pearson's correlation coefficient for parametric data and by Spearman's correlation coefficient for non-parametric data. A correlation coefficient, |r|-value ≥0.4 was considered 'correlative.' We performed a multiple regression analysis by the stepwise method for the correlative variables, a multiple regression coefficient, R^2 was calculated, and the most influential factors were confirmed. For comparisons between two groups, the Mann-Whitney U-test was performed. For multiple comparisons, the Tukey-Kramer test was performed. For all data, $p<0.05$ was considered significant.

3. Results

The physical characteristics and nutrition intake of the subjects at 19 years old are summarized in Table 1, and the subjects' physique from birth to 3 y (Table 2) and the nutrition method from birth to 7 months (Table 3) obtained from the MCHR are provided. The physique was average or typical of young Japanese women as described by the National Health and Nutrition Survey, which is performed every year by the Ministry of Health, Labour and Welfare in Japan [1].

Table 4 shows the correlations of birth height, weight, and BMI and their subsequent changes up to 3 y (from the MCHR) and the subjects' present (19-y) condition. Birth height, weight, and BMI were significantly correlated with 1-month height, weight, and BMI, respectively, but not thereafter. In contrast, height at 19 y was correlated with height at 3 months and thereafter, and weight at 19 y was correlated with weight at 3 y. However, BMI at 19 y had no correlation with any of the parameters from birth to 3 y.

We next analyzed 3 y height and weight by quartiles (Table 5). The subjects who were in the upper quartiles (Q3 and Q4) of 3 y height showed significantly greater height, weight, waist, hip, VFA, and BMC values at 19 y compared to the lowest quartile (Q1). The 3 y body weight showed similar tendency. Table 6 shows the growth velocity of height and weight from birth to 3 y. The subjects' weight at 19 y was significantly correlated with the increase in weight from 1.5 y to 3 y.

Table 1. *The subjects' characteristics.*

	Unit	Number	Mean ± SD or Median (Q1, Q3)			Range
Physical characteristics at 19 y old						
Height	cm	204	158.5	±	5.2	142.6–173.6
Weight	kg	204	49.7	±	5.7	32.7–68.8
BMI	kg/m^2	204	19.7	±	2.0	15.5–25.8
Waist	cm	204	70.3	±	5.8	52.8–91.2
Hip	cm	204	90.0	(86.0, 92.6)		70.0–110.5
W/H		204	0.78	±	0.04	0.68–0.97
%Muscle mass	%	204	69.5	±	4.9	46.8–82.0
%Skeletal muscle mass	%	204	39.6	±	2.8	30.3–46.7
%Fat mass	%	204	25.8	±	5.0	13.2–41.0
F/L		204	0.40	±	0.36	0.15–0.41
VFA	cm^2	204	23.2	±	13.0	5.0–78.3
BMC	kg	204	2.18	±	0.23	1.60–2.80
Bone density	m/sec	175	1567	±	36	1470–1677
Menarche	y	183	12.6	±	1.5	9.0–18.0
Father						
Height	cm	175	171.6	±	6.4	154.0–189.0
Weight	kg	171	67.0	(61.9, 73.0)		48.0–100.0
BMI	kg/m^2	171	22.8	(21.2, 24.5)		16.7–33.6
Mother						
Height	cm	185	157.8	±	5.3	145.0–173.0
Weight	kg	176	52.0	(49.0, 58.0)		37.5–80.0
BMI	kg/m^2	176	20.8	(19.5, 22.9)		15.8–32.4
Menarche	y	161	12.5	±	1.2	9.0–15.0
Pre-pregnancy weight	kg	145	49.6	±	6.0	35.0–65.0
Pre-pregnancy BMI	kg/m^2	139	20.0	±	2.3	15.1–26.6
Weight gain during pregnancy	kg	145	9.4	±	2.7	1.5–16.8
Nutrient intake/day						
Energy	kcal	192	1763	±	326	952–2711
Protein	g	192	63.4	±	14.5	30.2–127.8
Fat	g	192	63.9	±	15.5	27.3–108.2
Carbohydrate	g	192	226	±	43	109–374
Dietary fiber	g	192	11.7	±	3.5	4.8–26.9
Calcium	mg	192	469	±	146	155–994
Iron	mg	192	6.7	±	1.7	2.7–13.2
Salt	g	192	8.3	±	2.9	3.4–25.2

Parametric data are mean ± SD, and non-parametric data are median (Q1, Q3).

Table 2. *Body height, weight, and BMI from birth to 3 y old.*

	Unit	Mean ± SD or Median (Q1, Q3)			Range
At birth					
Height	cm	49.4	±	1.9	45.0–56.0
Weight	kg	3.0	(2.8, 3.3)		2.5–4.1
BMI	kg/m^2	12.5	(11.9, 13.3)		10.1–16.5
1-month old					
Height	cm	53.4	(52.1, 55.0)		48.5–58.5
Weight	kg	4.1	(3.8, 4.4)		3.2–5.5
BMI	kg/m^2	14.5	(13.6, 15.3)		11.5–17.0
3-month old					
Height	cm	62.3	±	2.2	54.8–67.5
Weight	kg	6.5	±	0.7	5.0–8.3
BMI	kg/m^2	16.8	±	1.5	13.4–24.6
1.5-year old					
Height	cm	79.5	±	2.7	72.6–88.8
Weight	kg	10.1	±	0.9	7.9–13.8
BMI	kg/m^2	15.9	±	1.1	13.2–19.4

	Unit	Mean ± SD or Median (Q1, Q3)			Range
3-year old					
Height	cm	92.6	±	3.5	83.4–105.0
Weight	kg	13.5	±	1.5	10.4–19.6
BMI	kg/m^2	15.7	±	1.1	13.4–18.8

Parametric data are mean ± SD, and non-parametric data are median (Q1, Q3). n= 204.

Table 3. *Nutrition from birth to 7 months.*

	Birth to 1 months	1 to 3 months	3 to 7 months
Breast feeding	71 (34.8%)	88 (43.1%)	94 (46.1%)
Mixed feeding	120 (58.8%)	80 (39.2%)	74 (36.3%)
Formula feeding	13 (6.4%)	36 (17.6%)	36 (17.6%)

Table 4. *Correlations of height, weight, and BMI at birth and at 19 y.*

	At birth			19 Years		
	Height	Weight	BMI	Height	Weight	BMI
At birth						
Height	—	0.648*	−0.056	—	—	—
Weight	—	—	0.685*	—	—	—
BMI	—	—	—	—	—	—
1 Month						
Height	0.560*	0.513*	0.166	0.359	0.372	0.143
Weight	0.518*	0.664*	0.420*	0.201	0.246	0.159
BMI	0.157	0.400*	0.422*	−0.038	0.069	0.125
3 Months						
Height	0.303	0.366	0.061	0.475*	0.297	0.027
Weight	0.308	0.268	0.068	0.385	0.354	0.157
BMI	0.086	0.074	0.018	0.089	0.196	0.175
1.5 Years						
Height	0.372	0.273	0.031	0.636*	0.402*	0.036
Weight	0.316	0.232	0.022	0.496*	0.398	0.126
BMI	0.052	0.037	−0.003	0.029	0.138	0.140
3 Years						
Height	0.286	0.183	−0.012	0.630*	0.456*	0.107
Weight	0.286	0.194	−0.001	0.475*	0.514*	0.275
BMI	0.313	0.103	0.014	0.042	0.310	0.327
19 Years						
Height	0.315	0.231	0.019	—	0.517*	−0.07
Weight	0.269	0.194	0.012	—	—	0.815*
BMI	0.095	0.059	−0.007	—	—	—

* Pearson's correlation coefficient or Spearman's rank correlation coefficient |r|≥0.4.

Table 5. *Quartile analyses of 3-y-old height and weight.*

3 y height	cm	Q1 (n=53)			Q2 (n=52)			Q3 (n=50)			Q4 (n=49)		
		83.4–90.3			90.4–92.2			92.3–94.8			94.9–105.0		
19 y height	cm	154.1	±	4.5	157.6	±	3.1***	160.3	±	4.9*** #	162.7	±	4.9*** ### §
19 y weight	kg	45.9	±	5.6	48.5	±	4.4*	51.1	±	4.2*** #	53.6	±	5.5*** ###
Waist	cm	67.7	±	6.2	68.9	±	5.5	71.7	±	4.4** #	72.8	±	5.4*** ##
Hip	cm	86.2	±	5.4	88.8	±	5.1	90.6	±	6.7*	90.3	±	6.2*
VFA	cm^2	18.8	±	12.2	21.4	±	12.9	25.6	±	12.9*	27.0	±	14.3*
BMC	kg	2.02	±	0.21	2.12	±	0.15*	2.24	±	0.18*** ##	2.37	±	0.09*** ### §§§

3 y weight	cm	Q1 (n=54)			Q2 (n=50)			Q3 (n=52)			Q4 (n=48)		
		10.4–12.3			12.4-13.2			13.3-14.3			14.4-19.6		
19 y height	cm	155.3	±	4.2	157.7	±	4.6*	160.2	±	4.9***	161.1	±	5.2*** ##
19 y weight	kg	45.9	±	4.0	48.7	±	4.6*	51.5	±	5.6*** #	53.1	±	5.7*** ###
BMI	kg/m^2	19.0	±	1.7	19.5	±	1.8	20.0	±	1.9*	20.4	±	2.0*
Waist	cm	67.7	±	5.0	69.7	±	5.2	71.0	±	6.1*	72.8	±	5.6*** #
Hip	cm	86.4	±	5.6	89.4	±	4.7*	89.9	±	7.2*	90.2	±	6.0**
VFA	cm^2	20.3	±	13.3	19.9	±	9.3	26.2	±	12.4#	26.4	±	15.3
BMC	kg	2.02	±	0.15	2.15	±	0.17**	2.24	±	0.12***	2.32	±	0.24*** ##

**p*<0.05, ***p*<0.01, ****p*<0.001 vs Q1. #*p*<0.05, ##*p*<0.01, ###*p*<0.001 vs Q2. §*p*<0.05, §§§*p*<0.001 vs Q3.

Table 6. *Correlations of the growth velocity of height, weight, and BMI and the subjects' present status.*

19 y	Height	Weight	BMI
Weight increase during pregnancy	−0.031	0.038	0.070
Birth to 1 month			
Height	0.029	0.037	0.025
Weight	0.087	0.192	0.169
BMI	−0.061	0.046	0.114
Birth to 3 months			
Height	0.128	0.030	−0.048
Weight	0.269	0.258	0.129
BMI	0.082	0.145	0.122
3 months to 1.5 y			
Height	0.297	0.191	0.017
Weight	0.266	0.176	0.017
BMI	−0.069	−0.096	−0.072
1.5 y to 3 y			
Height	0.240	0.315	0.191
Weight	0.269	0.439*	0.328
BMI	0.004	0.125	0.175

* Pearson's correlation coefficient $|r|\geq 0.4$.

Table 7. *Multiple regression analyses of 19 y height and weight.*

	Non-stdn. Factor	Stdn. Factor	p-Value	95% CI		VIF
				Lower	Upper	
19 y height						
(Constant)	−10.253			−28.911	8.405	
1.5 y height	0.630	0.329	0.000	0.343	0.918	2.901
Mother's height	0.354	0.367	0.000	0.266	0.442	1.073
Father's height	0.227	0.285	0.000	0.151	0.303	1.186
3 y height	0.256	0.176	0.025	0.332	0.480	3.058
R^2=0.661						
19 y weight						
(Constant)	17.595			9.088	26.101	
3 y weight	1.567	0.442	0.000	1.066	2.068	1.028
Mother's pre-pregnancy weight	0.224	0.248	0.001	0.096	0.351	1.028
R^2 = 0.283						

Stdn.: standardization, VIF: variance inflation factor.

Table 8. *Anthropometric characteristics by age at menarche.*

		Menarche				*p*-Value
		9–12 y (n=81)		13–18 y (n=102)		
Birth height	cm	49.1	(48.0, 50.0)	49.1	(48.0, 50.5)	ns
Birth weight	kg	3.0	(2.8, 3.2)	3.0	(2.8, 3.3)	ns
1.5 y height	cm	80.0	(78.5, 81.7)	79.1	(77.3, 81.1)	<0.05
1.5 y weight	kg	10.1	(9.5, 10.7)	9.9	(9.4, 10.5)	ns
3 y height	cm	92.2	(91.0, 96.1)	91.9	(89.8, 94.3)	<0.05
3 y weight	kg	13.3	(12.6, 14.7)	13.2	(12.4, 14.1)	ns
19 y height	cm	157.8	(154.6, 162.7)	158.7	(155.2, 161.5)	ns
19 y weight	kg	50.8	(46.3, 54.3)	48.8	(45.3, 52.3)	ns
BMI	kg/m^2	20.0	(18.8, 21.4)	19.5	(18.2, 20.7)	<0.05
Waist	cm	71.3	(68.4, 74.9)	68.8	(65.7, 72.4)	<0.01
Hip	cm	91.0	(86.5, 94.4)	89.8	(86.3, 92.1)	ns
W/H		0.78	(0.75, 0.81)	0.77	(0.75, 0.79)	ns
%Fat mass	%	27.4	(24.1, 31.0)	24.8	(21.7, 28.0)	<0.001
%Muscle mass	%	67.9	(64.7, 71.0)	70.7	(67.6, 73.5)	<0.001
%Skeletal muscle mass	%	39.0	(36.6, 40.9)	40.7	(38.3, 41.9)	<0.001
F/L		0.38	(0.32, 0.45)	0.33	(0.28, 0.39)	<0.001
VFA	cm^2	26.9	(17.5, 36.5)	18.3	(10.3, 26.8)	<0.01
Bone density	m/sec	1568	(1549, 1594)	1564	(1543, 1586)	ns

Values are median (Q1, Q3). ns: not significant.

Table 9. *Correlations of height, weight, BMI, and age at menarche between the subjects and their parents.*

19 Years	Height	Weight	BMI	Menarche
Father				
Height	0.507*	0.363	0.081	0.012
Weight	0.172	0.235	0.132	−0.029
BMI	−0.099	0.026	0.082	−0.058
Mother				
Height	0.527*	0.218	−0.101	−0.01
Weight	0.115	0.208	0.150	−0.191
BMI	−0.104	0.107	0.182	−0.188
Pre-pregnancy weight	0.146	0.321	0.258	−0.126
Pre-pregnancy BMI	−0.104	0.107	0.182	−0.188
Menarche	0.086	−0.031	−0.089	0.400*

* Pearson's correlation coefficient or Spearman's rank correlation coefficient $|r| \geq 0.4$.

The results of the multiple regression analyses of 19 y height and weight are given in Table 7. For height, 19 y height was used as the dependent variable, and height of mother, father, at birth, 3 months, 1.5 years, and 3 years, and menarche were used as independent variables. For weight, 19 y weight was used as the dependent variable, and weight at birth, 3 months, 1.5 years, and 3 years, mother's pre-pregnancy weight, and mother's weight increase during pregnancy were used as independent variables. The subjects' 19 y height was predicted by their 1.5 y height, their mother's height, their father's height, and their 3 y height, and the following multiple regression equation was shown to be useful:

$$\text{19 y height} = -10.253 + 0.630 \times \text{1.5 y height} + 0.354 \times \text{mother's height} + 0.227 \times \text{father's height} + 0.256 \times \text{3 y height}$$

We also observed that the 19 y weight data were explained by the 3 y weight and the mother's pre-pregnancy weight, but the equation was not useful (not shown).

The subjects' ages at menarche are dichotomized in Table 8. The subjects with earlier menarche (9–12 y vs. 13–18 y) were significantly taller at 1.5 y and 3 y, but not at 19 y; they had also higher BMI, waist, %fat mass, F/L ratio, and VFA values but lower %muscle mass and %skeletal muscle mass values at 19 y.

We also analyzed the influence of the subjects' parents. Table 9 shows the correlations between the subjects' height, weight, BMI, and menarche and their parents' height, weight, and BMI values, and their mothers' age at menarche. The height of the daughters/subjects at 19 y was significantly correlated with parents' height. However, the subjects' weight and BMI at 19 y had no correlations with their parents' weight and BMI, respectively. The daughters' menarche was significantly correlated with the mothers' menarche.

There were no differences in the subjects' physique at 19 y among the nutrition methods (breast, formula, or mixed) during infancy (data not shown).

4. Discussion

We investigated the relationships between the physical condition at birth and in infancy and the current physical status in young Japanese women and the influences of genetic and early environmental factors on their physique and menarche. Our analyses revealed that the subjects/daughters' height was influenced by their parents' height, suggesting the heritable nature of height. However, the daughters' weight and BMI were affected by environmental factors rather than genetic factors. Thus, the future height, but not weight or BMI, of daughters may be predicted by the infancy data in their MCHR books. We also observed that the daughters' age at menarche was predicted by the age of menarche of their mothers, suggesting a genetic effect.

It has been reported that high weight at birth is associated with a higher BMI in adulthood; however, low weight at birth was also identified as a risk factor for adult obesity [19]. Birth weight was also reported to be positively associated with bone mass and fat-free mass in girls [20]. The positive association between birth height and adult height was reported to be even stronger than that between birth weight and adult weight [10]. However, in the present study, birth height and weight were correlated with 1-month height and weight, respectively, but not thereafter. These results are consistent with other reports that birth weight was unrelated to adult obesity, but weight at 0.3 years and after and BMI at 7 years and after were correlated with adult weight [21].

In a Japanese study, overweight mother or father and overweight at birth (≥3,500 g) were significantly related to obesity in 3 y children [9]. In contrast, in our study population of Japanese women, height at 19 y was correlated with 3-month height and thereafter, and weight at 19 y was correlated with 3 y weight. In the quartile analyses of 3 y height and weight, the subjects in the higher quartiles had significantly higher height, weight, waist, hip, VFA, and BMC at 19 y. Their weight at 19 y was significantly correlated with the increase of weight from 1.5 y to 3 y, suggesting that the growth velocity of weight during that period may affect adulthood weight.

The velocity of weight gain from birth to 3 months was shown to be associated with overweight, fat mass, and waist circumference in female adolescents [11]. Rapid weight gain in early infancy was positively associated with the body fat percentage in young Japanese women [22]. However, in the present study no association was observed between weight gain in early infancy and the body fat percentage at 19 y. Our multiple regression analysis of the 19 y height data demonstrated that 19 y height was predicted by the subjects' 1.5 y height, mother's height, father's height, and 3 y height, whereas 19 y weight was not predicted by these factors, indicating that acquired environmental factors such as diet and exercise may be more important for weight. Age at menarche has been used to approximate the duration of growth in height [13]. In the present study, when dichotomized, the group with earlier menarche (9−12 y) showed significantly greater height at 1.5 y and 3 y, but not at 19 y. They had also higher BMI, waist, %fat mass, F/L ratio, and VFA, but lower %muscle mass and %skeletal muscle mass at 19 y. Birth weight did not predict the age at menarche in our subjects, which is consistent with some studies [13] but not others [14]. This may be because the outliers of weight and the subjects with low birth weight (<2,500 g) were excluded in the present study.

Although rapid weight gain in infancy has been associated with younger age at menarche as a significant marker of an increased risk of obesity in adulthood [15–18], in the present subjects, no such association was observed. The present subjects with later menarche (13–18 y) had higher %muscle mass and %skeletal muscle mass, and lower BMI, waist, %fat mass, F/L ratio, and VFA compared to those with earlier menarche (9–12 y). However, the final height and weight values were not significantly different between the two groups, suggesting that the physique is not different, but the body composition is different. The subjects with later menarche had more lean mass and less fat, i.e., they were more 'muscular,' compared to those with earlier menarche.

However, in the previous studies, girls who were overweight before menarche were reported to be more likely to be overweight as adults, whereas early menarche (at ≤12 y) did not elevate this risk, indicating that the apparent influence of early maturation on overweight in adulthood is largely a result of the influence of elevated relative weight on early maturation [23, 24]. Earlier age at menarche may be a transgenerational marker of a faster growth tempo, characterized by rapid weight gain and growth (particularly during infancy) and leading to taller childhood stature but likely earlier maturation and therefore shorter adult stature [25]. In the present subjects, the age of the daughter's menarche was significantly correlated with the age of the mother's menarche. Towne et al. estimated that approximately one-half of the phenotypic variation among girls from developed nations in the timing of menarche is due to genetic factors [26].

Our analyses also showed that the height of the daughters at 19 y was significantly correlated with their parents' height, but weight and BMI were not. It has been reported that the BMI of a mother is a significant predictor of her daughter's BMI in adolescence and young adulthood [5, 6]. Daughters may be more influenced by their mothers than their fathers — not genetically but by the environment including the mother's feeding choices, i.e., breast or formula feeding in the infant and diet thereafter. It may thus be possible that maternal obesity contributes additionally to the child's weight. However, in the present study, mother's prepregnant and present BMI and weight were not associated with their daughter's BMI or weight. Maternal weight gain during pregnancy also did not influence the present weight of the daughters.

It has been reported that overweight/obesity in mothers and overweight/obesity at 3 y of age (but not birth weight) were associated with overweight/obesity in Japanese adolescents at age 15 years [7]. In Japanese preschool children, parental (mother and also father) obesity was shown to be a risk factor for obesity [8]. However, there was no association between these indices in the present study. The reason for this discrepancy in findings is unknown, but we speculate that one factor may be that the subjects studied herein were 19 y young adults and the association may have disappeared between 15 and 19 y of age.

Finally, although it has been reported that breast feeding is associated with lower rates of infancy weight gain and later obesity [12], in the present study no difference in physique was observed between the breast-fed and formula-fed subjects, probably because (1) the subjects were rather uniform, and (2) infant formula has been improved to mimic the nutritional composition of breast milk as closely as possible [27]. However, because breast milk has a variety of other benefits beyond somatic growth, including the modulation of postnatal intestinal function, immune ontogeny, and brain development [27], we do not deny the advantages of breast feeding over formula feeding.

This study has some limitations. A small number of outliers and the subjects with low birth weight were excluded; accordingly, the present results may not be applicable to subjects with extremely low birth weight. Secondly, because only Japanese women were studied, the results may not be applicable to other populations. The present findings should thus be interpreted with caution.

5. Conclusion

The height of daughters was influenced by their parents' height, suggesting the genetic nature. However, the daughter's weight and BMI were not correlated with those of their parents, indicating stronger environmental factors, probably lifestyle factors including diet and exercise rather than genetic factors. The future height of daughters (but not their weight and BMI) may be significantly predicted by the infancy data in their MCHR books. Their age at menarche was predicted by the mothers' age at menarche, suggesting heritable factors.

Conflicts of Interest

The authors state that they have no competing interests.

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