Male Infants Born to Older Pregnant Women Are Affected by Maternal Physique at the Beginning of the Pregnancy through Birth until 18 Months of Age

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Summary We have previously reported a positive correlation between the body mass index (BMI) of mothers and the Kaup index of infants at birth and that this correlation may have a stronger influence on the male infants, born to older mothers. Therefore, in this study, we aimed to clarify the correlation between maternal age and gender of the infants as maternal BMI and the Kaup index of infants from birth till 18 mo of age. This study was conducted from April 2010 to September 2011 in Japan. Public health nurses and registered dietitians interviewed the mothers individually under anonymous conditions, and they transferred the required information from the maternity passbook at the 18-mo health checkup. In male infants, significant positive correlations were demonstrated between maternal BMI at the beginning of pregnancy and the Kaup index of infants in mothers older than 35 y when the infants were at birth, at 4 mo and at 18 mo old. In female infants, there was no correlation between maternal BMI and the Kaup index of infants at birth. However, significant positive correlations were demonstrated between maternal BMI and the Kaup index of infants in mothers in their 20s and older than 35 y old when the infants were 4 and 18 mo old. Women who plan on pregnancy and medical professionals need to know that the maternal physique at the beginning of pregnancy affects the physique of the infants at birth and at 4 mo and 18 mo old by gender of the infants.

Key Words body mass index, infant, mother, physique, age

According to the National Health and Nutrition Survey in Japan in 2016 (1), about 20% of women of childbearing age in Japan were lean and about 10% were obese. There is a significant positive correlation between pre-pregnancy body mass index (BMI) of the mother and birth weight of the infant (2), and a lean pre-pregnancy BMI (3) is associated with greater risk of low-birth-weight infants compared with a non-lean BMI. We have previously reported a positive correlation between BMI at the beginning of pregnancy of mothers and the Kaup index of infants at birth and that this correlation varied with maternal age and gender of the infant (4, 5). Specifically, we found that male infants born to lean and older mothers (age $\geq$ 35) showed low Kaup index values. However, no studies have addressed the influence of maternal BMI on infant growth patterns after birth while considering correlation between maternal age and gender of the infants.

The Japanese Ministry of Health, Labour and Welfare has conducted nationwide birth cohort studies, namely, the Longitudinal Survey of Newborns in the 21st Century, in 2001 and 2010 (6, 7). Analysis of data from that study showed that infants born with a low birth weight demonstrated a high weight gain rate per day and a high height growth rate (8). Specifically, this acceleration of weight gain in infants born with a low body weight was such that the weight gain during a 4-mo period increased the chance of the child being dangerously overweight at the age of 7 y. Further, high body fat ratios and abdominal circumference values were recorded in infants that showed a catch-up-growth pattern from birth through the age of 2 y. In contrast, for infants where the mother was obese at the beginning of pregnancy, the obesity prevalence by the age of 4 y was twice that in infants whose mothers were not obese at the beginning of pregnancy (9). These observations
are crucial as it has been reported that such infants have a high risk of acquiring insulin resistance, diabetes, or an increase in blood pressure as adults (10–13). As damage due to malnutrition during the developmental stages, that is, the period from fertilization to 1,000 d, is irreversible, it is an extremely important period for the development of health (14).

Therefore, in this study, we aimed to clarify the correlation between maternal age and gender of the infants regarding maternal BMI and the Kaup index of infants from birth till 18 mo of age.

MATERIALS AND METHODS

Study subjects. This study was conducted from April 2010 to September 2011 in Hirakata City, located in the northern part of Osaka Prefecture. The study subjects were mothers and infants who had undergone general health checkups over a period of 18 mo. Hirakata City has a population of 406,330 (as of July 1, 2012), and compared with the national average, the youthful population of the area is somewhat high, and the ratio of the aged population is low. There were 3,560 births in the fiscal year 2009, amounting to a birth rate of 8.7%, and the ratio of low weight births was 9.9%. Health checkups were conducted once every week for a total of 52 times a year, and about 70 infants were provided these health checkups each time. A total of 3,722 individuals underwent these health checkups leading to a participant rate of 92.0%. A total of 2,974 mothers (79.9%) registered at the reception desk for the health checkups where the purpose, study items, and the procedure of the study being conducted were explained orally, along with the fact that participation in the study was completely voluntary. A total of 1,398 people (37.6%) agreed to participate in the study. Foreigners, multiple births, and infants whose mothers did not participate in the study were excluded. Additionally, 111 subjects were excluded, including 6 cases where the gender of the infant had not been recorded, 14 cases where the age of the mother had not been recorded, 6 cases where the weight or height of the mother was unknown, 22 cases where the initial examination of the mother was conducted at 20 or more weeks, 7 cases where the mother was under the age of 20 and 56 cases of premature birth. Thus, data from a total of 1,287 subjects (34.6%), including 621 male infants and 666 female infants, were included in the analysis.

Study methods. The study was conducted anonymously by public health nurses and registered dietitians who interviewed the mothers and recorded information obtained from the maternity passbook, including 4 items about the mother (gestation period and weight at the initial maternal health examination, gestation and maternal weight at birth) and 10 items about the infant (weight, height, head and chest circumference at birth and at 4 mo as well as weight and height at 18 mo of age).

Statistical analyses. The BMI at the beginning of the pregnancy was calculated by dividing the weight of the subject by the square of the height in meters ($kg/m^2$). On the basis of the standards developed by the Japan Society for the Study of Obesity (JASSO), pregnant women with BMI values $<18.5$ were categorized as underweight, those with BMI values $\geq 18.5$ but $<25$ were categorized as normal weight, and those with BMI values $\geq 25$ were categorized as overweight. The Kaup index of the infants was calculated by dividing the weight by the square of their height ($g/cm^2\times10$). Pregnant women aged between 20 and 30 y were assigned to the G1 group, those aged over 30 but less than 35 y were assigned to the G2 group, and finally, those older than 35 y were assigned to the G3 group.

We calculated the mean and standard deviation of the quantitative data. The Mann-Whitney U-test was used to test sex-based differences in the data from the two groups of infants. The Kruskal-Wallis H-test was used to determine the differences among infants born to women underweight, of normal weight and overweight. We used the $\chi^2$ test to test the correlation between categorical variables. To test the objective variables such as sex and physical attributes of the infant, multiple linear regression models were employed to assess the explanatory variables, namely, age at pregnancy, maternal BMI at the beginning of pregnancy, parity, gestational length, weight gain during pregnancy and whether the pregnant woman was exposed to smoking. All statistical analyses were performed using SPSS Statistics 19 for Windows (IBM Japan Inc., Tokyo, Japan), and $p<0.05$ was considered significant.

Ethical considerations. The purpose of the study was explained in full to all potential subjects. Thereafter, we confirmed the intention of all of the subjects to participate in the study. All of the data collected were analyzed with complete anonymity. All study procedures were performed in accordance with the declaration of Helsinki. This study was approved by the Ethical Committee of the Hirakata City Hospital (8 December 2009).

RESULTS

The characteristics of the pregnant women and infants according to infant gender

The characteristics of the pregnant women and infants, categorized according to infant gender, are shown in Table 1. There were 621 male infants (48.3%) and 666 female infants (51.7%). There were no significant differences in maternal height, weight, or BMI at the beginning of the pregnancy between mothers from the male and female infant groups. Further, age at delivery between the two groups was not significantly different.
Infants Born to Older Pregnant Women Are Affected by Maternal BMI of Pregnancy

Pregnant women, categorized by maternal age, were divided into lean and non-lean groups for comparison of physical characteristics of the beginning of pregnancy.

Male infants. Table 2-1 shows the comparison of the physical attributes of male infants born to mothers in the underweight, normal and overweight groups categorized by maternal age. The gestational length was not significantly different among the underweight, normal and overweight groups in any of the age groups. In the G1 group, there were significant differences in the weight of the infants (at all ages) among the underweight, normal and overweight groups (p = 0.015, 0.024, and 0.022 at birth, at 4 mo and at 18 mo, respectively). In the G3 group, there were significant differences in the birth weight of infants (at birth and at 4 mo) among the underweight, normal and overweight groups (p = 0.021, and 0.014 at birth and at 4 mo, respectively). Furthermore, in the G3 group, there were significant differences in the Kaup index of the infants at all ages (p = 0.011, 0.010, and 0.028 at birth, at 4 mo and at 18 mo, respectively). However, in the G2 group, the weight and Kaup index of infants (at all ages) were not significantly different among the three groups.

Female infants. Table 2-2 shows the comparison of the physical characteristics of female infants born to...
Table 2-1. Comparison of the characteristics of the mothers and infants in the underweight, normal and overweight groups of mothers categorized by the mother’s age. (Males, n=621)

|                     | G1 group (age ≥20, <30) | G2 group (age ≥30, <35) | G3 group (age ≥35) |
|---------------------|-------------------------|-------------------------|--------------------|
|                     | Underweight group | Normal group (BMI ≥18.5, <25.0) | Overweight group (BMI ≥25.0) | p value |
| Number of infants   | 28                      | 100                     | 10                 |         |
| Mother gestational length (wk) | 38.9±1.1               | 39.1±1.2               | 39.4±1.4           | 0.419   |

Infants at birth

- Weight (g): 6,387±821 (BMI <18.5), 7,285±845 (BMI ≥18.5, <25.0), 7,533±716 (BMI ≥25.0), p = 0.024
- Height (cm): 49.0±1.7 (BMI <18.5), 49.3±1.8 (BMI ≥18.5, <25.0), 49.9±1.3 (BMI ≥25.0), p = 0.497
- Head circumference (cm): 32.9±1.2 (BMI <18.5), 33.1±1.2 (BMI ≥18.5, <25.0), 33.6±1.7 (BMI ≥25.0), p = 0.075
- Chest circumference (cm): 31.7±1.4 (BMI <18.5), 32.1±1.4 (BMI ≥18.5, <25.0), 32.9±2.1 (BMI ≥25.0), p = 0.023
- Kaup index (g/cm²×10): 12.5±1.3 (BMI <18.5), 12.8±0.9 (BMI ≥18.5, <25.0), 13.5±1.7 (BMI ≥25.0), p = 0.097

4-mo-old infants

- Weight (g): 6,837±821 (BMI <18.5), 7,285±845 (BMI ≥18.5, <25.0), 7,533±716 (BMI ≥25.0), p = 0.024
- Height (cm): 62.9±2.1 (BMI <18.5), 63.6±2.2 (BMI ≥18.5, <25.0), 64.9±2.1 (BMI ≥25.0), p = 0.047
- Head circumference (cm): 41.2±1.0 (BMI <18.5), 41.9±1.1 (BMI ≥18.5, <25.0), 42.6±1.7 (BMI ≥25.0), p = 0.010
- Chest circumference (cm): 42.0±1.9 (BMI <18.5), 42.5±2.1 (BMI ≥18.5, <25.0), 42.9±2.0 (BMI ≥25.0), p = 0.372
- Kaup index (g/cm²×10): 17.3±1.6 (BMI <18.5), 18.0±1.6 (BMI ≥18.5, <25.0), 17.9±1.0 (BMI ≥25.0), p = 0.150
- Rate of weight gain (%): 120.2±12.3 (BMI <18.5), 135.2±21.7 (BMI ≥18.5, <25.0), 127.2±22.0 (BMI ≥25.0), p = 0.538

18-mo-old infants

- Weight (g): 10,453±891 (BMI <18.5), 10,839±982 (BMI ≥18.5, <25.0), 11,342±909 (BMI ≥25.0), p = 0.022
- Height (cm): 81.1±2.2 (BMI <18.5), 81.6±2.8 (BMI ≥18.5, <25.0), 82.9±2.1 (BMI ≥25.0), p = 0.135
- Kaup index (g/cm²×10): 15.9±1.2 (BMI <18.5), 16.3±1.1 (BMI ≥18.5, <25.0), 16.5±1.0 (BMI ≥25.0), p = 0.378
- Rate of weight gain (%): 251±31 (BMI <18.5), 250±37 (BMI ≥18.5, <25.0), 244±59 (BMI ≥25.0), p = 0.509

Mean ± SD

Kruskal-Wallis H test for differences among the underweight, normal and overweight groups.
Table 2-2. Comparison of the characteristics of the mothers and infants in the underweight, normal and overweight groups of mothers categorized by the mother's age. (Females, \(n=621\))

|                      | G1 group (age ≥20, <30) | G2 group (age ≥30, <35) | G3 group (age ≥35) |
|----------------------|-------------------------|--------------------------|------------------|
|                      | Underweight group | Normal group | Overweight group | Underweight group | Normal group | Overweight group | Underweight group | Normal group | Overweight group | p value | Underweight group | Normal group | Overweight group | p value |
| Number of Mothers    | 31 94 15          | 41 208 20         | 30 209 18        | 39.6±1.1 39.2±1.2 39.7±0.7 | 0.085 | 39.3±1.1 39.1±1.2 39.5±1.3 | 0.468 | 39.2±1.1 39.0±1.3 39.3±1.5 | 0.428 |
| Gestational length (wk) | 39.6±1.1 39.2±1.2 39.7±0.7 | 39.3±1.1 39.1±1.2 39.5±1.3 | 39.2±1.1 39.0±1.3 39.3±1.5 | 0.428 |

Infants at birth
- **Weight (g)**: 2.986±290, 3.038±386, 3.167±384, 2.949±373, 3.012±374, 3.136±357, 0.298, 2.918±340, 3.030±343, 2.939±361, 0.020
- **Height (cm)**: 48.1±1.8, 48.6±2.0, 48.7±1.6, 48.6±2.3, 48.7±2.0, 48.7±1.1, 0.134, 48.2±2.4, 48.7±1.9, 48.0±1.6, 0.347
- **Head circumference (cm)**: 32.7±1.1, 33.2±1.2, 33.3±1.1, 32.7±1.6, 33.2±1.2, 33.4±1.0, 0.152, 32.8±0.7, 33.2±1.3, 32.8±1.1, 0.064
- **Chest circumference (cm)**: 31.6±1.4, 31.8±1.8, 32.1±1.5, 31.4±1.7, 31.8±1.7, 32.4±1.5, 0.542, 31.5±1.1, 31.8±1.5, 31.4±1.7, 0.355
- **Kaup index (g/cm²×10)**: 12.9±1.0, 12.8±1.2, 13.3±1.3, 12.5±1.1, 12.7±1.2, 13.2±1.1, 0.673, 12.6±1.4, 12.8±1.1, 12.7±1.3, 0.307

4-mo-old infants
- **Weight (g)**: 6,529±609, 6,690±726, 6,945±597, 6,498±608, 6,630±672, 6,595±676, 0.119, 6,425±659, 6,609±691, 6,527±604, 0.388
- **Height (cm)**: 61.7±1.5, 62.0±2.1, 62.0±2.0, 61.9±1.9, 61.7±1.9, 62.0±1.8, 0.621, 62.2±1.8, 62.0±2.0, 61.2±2.3, 0.200
- **Head circumference (cm)**: 40.7±1.1, 41.0±2.0, 41.2±0.7, 41.0±1.1, 40.9±1.2, 41.0±0.8, 0.071, 40.6±0.9, 40.8±1.1, 40.6±1.1, 0.273
- **Chest circumference (cm)**: 40.7±1.3, 41.2±1.7, 41.7±1.5, 41.0±1.5, 41.2±1.6, 41.0±1.9, 0.116, 40.7±1.5, 41.2±1.8, 41.0±1.5, 0.229
- **Kaup index (g/cm²×10)**: 17.1±1.4, 17.4±1.6, 18.1±1.1, 17.0±1.2, 17.4±1.4, 17.1±1.4, 0.125, 16.6±1.3, 17.2±1.3, 17.4±1.2, 0.013
- **Rate of weight gain (%)** at birth to 4 mo old: 120±20, 123±29, 121±27, 121±25, 123±29, 112±25, 0.970, 123±35, 121±26, 124±23, 0.812

18-mo-old infants
- **Weight (g)**: 9.808±1.029, 10.243±933, 10.578±1032, 10.125±936, 10.188±906, 10.123±1.171, 0.013, 9.881±984, 10.213±1.015, 10.157±629, 0.444
- **Height (cm)**: 79.8±2.6, 80.2±2.3, 79.5±1.8, 80.0±2.8, 80.0±2.5, 80.1±2.6, 0.510, 80.4±2.5, 80.3±2.6, 79.0±2.6, 0.106
- **Kaup index (g/cm²×10)**: 15.4±1.2, 15.9±1.0, 17.0±1.2, 15.8±1.0, 15.9±1.0, 15.9±1.2, 0.501, 15.6±1.0, 15.8±1.080, 16.3±1.0, 0.006
- **Rate of weight gain (%)** at birth to 18 mo old: 231±42, 242±50, 236±31, 247±45, 242±46, 225±40, 0.598, 242±48, 240±41, 250±40, 0.603
- **Rate of weight gain (%)** (4 mo to 18 mo old): 50.5±11.8, 54.1±14.6, 52.5±10.4, 57.2±11.4, 54.3±13.3, 54.0±14.0, 0.641, 54.3±11.7, 54.8±14.6, 56.2±11.5, 0.703

Mean±SD.
Kruskal-Wallis H test for differences between the underweight, normal and overweight groups.
mothers in the underweight, normal and overweight groups, categorized by maternal age. Gestational age was not significantly different among the underweight, normal and overweight groups in any of the age groups. In the G1 group, there were significant differences in the weight and Kaup index of infants aged 18 mo who belonged to the underweight, normal and overweight groups ($p=0.013$ and $0.001$ for the weight and the Kaup index, respectively). In the G3 group, there were significant differences in the Kaup index of the infants

| Males (n=621) | G1 group (age ≥20, <30) | G2 group (age ≥30, <35) | G3 group (age ≥35) |
|--------------|--------------------------|--------------------------|-------------------|
| Infants at birth | n=138 | n=250 | n=233 |
| Age | -0.031 0.698 | 0.166 0.008 | 0.006 0.926 |
| Maternal BMI | 0.182 0.027 | 0.078 0.202 | 0.216 <0.001 |
| Primiparas | 0.180 0.031 | 0.173 0.007 | 0.179 0.003 |
| Gestational length | 0.222 0.009 | 0.174 0.005 | 0.287 <0.001 |
| Smoking during pregnancy | -0.036 0.660 | -0.016 0.794 | -0.194 0.001 |
| Weight gain during pregnancy | 0.253 0.003 | 0.205 0.001 | 0.155 0.013 |

| Females (n=666) | n=140 | n=269 | n=257 |
| Infants at birth | n=140 | n=269 | n=257 |
| Age | -0.059 0.458 | -0.051 0.383 | -0.059 0.458 |
| Maternal BMI | 0.114 0.145 | 0.091 0.118 | 0.114 0.145 |
| Primiparas | 0.216 0.007 | 0.161 0.008 | 0.216 0.007 |
| Gestational length | 0.319 <0.001 | 0.269 <0.001 | 0.319 <0.001 |
| Smoking during pregnancy | 0.020 0.798 | -0.120 0.038 | 0.020 0.798 |
| Weight gain during pregnancy | 0.234 0.004 | 0.167 0.005 | 0.234 0.004 |

| 4-mo-old infants | Age | Maternal BMI | Primiparas | Gestational length | Smoking during pregnancy | Weight gain during pregnancy |
|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| Age | 0.017 0.679 | -0.090 0.147 | -0.092 0.413 | 0.203 0.000 |
| Maternal BMI | 0.222 0.011 | 0.105 0.090 | 0.237 0.009 | 0.017 0.000 |
| Primiparas | -0.069 0.432 | 0.036 0.581 | -0.024 0.700 | 0.017 0.000 |
| Gestational length | 0.001 0.992 | -0.142 0.027 | -0.024 0.702 | 0.017 0.000 |
| Smoking during pregnancy | 0.066 0.453 | -0.040 0.510 | -0.100 0.118 | 0.017 0.000 |
| Weight gain during pregnancy | 0.078 0.377 | 0.144 0.022 | 2.555 0.011 | 0.017 0.000 |

| 18-mo-old infants | Age | Maternal BMI | Primiparas | Gestational length | Smoking during pregnancy | Weight gain during pregnancy |
|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| Age | -0.019 0.824 | 0.082 0.331 | 0.034 0.584 | 0.278 <0.001 |
| Maternal BMI | 0.346 <0.001 | 0.146 0.089 | 0.278 <0.001 | 0.017 0.000 |
| Primiparas | -0.006 0.938 | 0.187 0.032 | 0.040 0.518 | 0.017 0.000 |
| Gestational length | 0.065 0.421 | -0.003 0.971 | -0.015 0.841 | 0.017 0.000 |
| Smoking during pregnancy | 0.159 0.059 | 0.125 0.145 | -0.059 0.351 | 0.017 0.000 |
| Weight gain during pregnancy | -0.012 0.889 | -0.104 0.234 | 0.030 0.634 | 0.017 0.000 |

BMI: body mass index.
aged 18 mo belonging to the underweight, normal and overweight groups \((p=0.006)\). However, in the G2 group, the weight and Kaup index of the infants were not significantly different among the underweight, normal and overweight groups in any age groups. 

**Multiple regression analysis of the Kaup index values to assess objective variables**

The Kaup indices at birth and the ages of 4 and 18 mo were taken as objective variables of both male and female groups of infants. The variables that can affect the physical attributes of these infants, such as the maternal age, maternal BMI at the beginning of the pregnancy, parity, gestational length, smoking during pregnancy and weight gain during pregnancy were used as explanatory variables; the results of the multiple regression analysis are shown in Table 3.

**Male infants.** Significant positive correlations were found between maternal BMI at the beginning of the pregnancy and the Kaup index of infants in the G1 \((p=0.027 \text{ at birth})\), G2 \((p=0.044 \text{ and } 0.016 \text{ at 4 mo and 18 mo, respectively})\) and G3 \((p<0.001, <0.001 \text{ and } <0.001 \text{ at birth, 4 mo and 18 mo, respectively})\) groups.

**Female infants.** Significant positive correlations were found between the maternal BMI at the beginning of the pregnancy and the Kaup index of infants in the G1 \((p=0.011 \text{ and } <0.001 \text{ at 4 mo and 18 mo, respectively})\) and G3 \((p=0.002 \text{ and } <0.001 \text{ at 4 mo and 18 mo, respectively})\) groups. However, there was no correlation between maternal BMI at the beginning of the pregnancy and the Kaup index of the infants in G2.

**DISCUSSION**

We have previously reported that factors such as low maternal BMI at the beginning of the pregnancy \((4)\) and before pregnancy \((5)\) as well as a higher maternal age led to reductions in the size of infants at birth. Furthermore, this effect was greater in the male infants, compared with female infants, implying a difference due to gender of the infant. As a continuation of the previous reports, the infants were 4 and 18 mo old, and we evaluated the correlation between the maternal BMI at the beginning of the pregnancy and the Kaup index of the infants, categorized by maternal age and sex of the infants. We found a significant positive correlation between the maternal BMI at the beginning of the pregnancy and the Kaup index in male infants (at all ages) belonging to the G3 group tested with correlation in the G1 group only at birth and no correlation in the G2 group at any infant age groups tested. In contrast, in female infants, a significant positive correlation was demonstrated between the maternal BMI at beginning of the pregnancy and the Kaup index of the infants in the G1 and G3 groups when the infants were 4 and 18 mo old with no correlation at birth. In the G2 group, there was no correlation at any age.

The fetal organs adapt to the nutrient-poor intrauterine environment during the prenatal period. The adaptation is continued indefinitely \((15)\). Increases in the risk of low birth weight infants have been reported in lean expectant mothers, relative to that for expectant mothers with normal physiques \((16-19)\).

Multiple studies have addressed the relationship between BMI of the parents and the physique of their children. Linabery et al. have reported that children’s age of 2 or 3 y, the correlation between BMI of the children and maternal BMI was stronger than that between BMI of the child and paternal BMI \((20)\). Ikkaichi et al. conducted multiple regression analyses using the physiques of infants at the age of 8, 10, 13 and 15 as objective variables and the weight and height at birth, the physique and diet of the mothers, and exercise habits as explanatory variables. They reported no correlation between the weight of the infants at the ages tested and weight at birth, with the only significant correlation being that between the weight of the infants at the age of 13 and maternal BMI \((21)\). Next, in a study on subjects aged from 6 to 19 y, Morea et al. have reported that maternal weight before the pregnancy influenced the physique of the infants \((22)\). The results of these studies are in agreement with our results in that, regardless of the weight of the infants at birth, there was a correlation between the physique of the infants after birth and the maternal BMI. However, no studies addressed the effects on infant growth after birth, or the correlation with maternal age, as a function of the gender of the infants.

Abu-saad and Fraser have reported that protein, iron, folic acid, magnesium, calcium, zinc, and vitamin C are crucial nutrients that affect the birth status of infants \((23)\). On the other hand, Uno et al. have investigated food intake patterns in pregnant women who were lean before pregnancy and found no significant differences in total energy intake between the lean group and the non-lean groups in Japan. However, compared with the non-lean group, main dishes and protein, iron, magnesium, and folic acid intakes were significantly lower in the lean group, and pregnant women who were lean before pregnancy were more anemic \((24)\). It is known that anemic mothers give birth to low-birth-weight infants \((25)\).

Several previous studies have assessed nutrient intake patterns in Japanese pregnant women \((26, 27)\), which pointed out that the total energy intake in pregnancy was not enough in either case. In this study, we guess that the positive correlation between the BMI of pregnant women and the Kaup index of infants is also related to the state of food intake by women before pregnancy.

In animal experiments, Chow and Lee reported that when pregnant rats were given a reduction in feed of 25%, the rats showed lower body weight values compared with the control group up to 40 wk of age after birth, and the difference was clearly shown in male pups when compared with the females \((28)\). On the other hand, Suzuki et al. examined the association between smoking during pregnancy and the BMI of infants. No gender difference was found, but their results showed that the BMI rose for boys, especially after the age of three \((29)\). Our study showed that there was a sex difference in the effect of the BMI at the beginning of pregnancy on the Kaup index of the infants. In the future,
studies should be conducted in relation to those sex differences.

Significant positive correlations were found between primiparas and the Kaup index of infants at birth. In contrast, at 18 mo old, significant positive correlations were demonstrated between primiparas and the Kaup index of infants in the G1 male and G2 female infant groups. Takano and Fujimura reported that first infants showed the smallest size at birth (30). It is necessary to take into consideration the fact that pluripara mothers are older than primiparas when analyzing by age.

In our study of 1,287 subjects, maternal age at birth ranged from 21 to 46 y, with an average age of 33.0 y. Conducted roughly in the same fiscal year as this study, the Ministry of Health, Labour and Welfare published a Specified Report of Vital Statistics in Japan in 2010, which states that the average maternal age at birth was 31.2 y; the average age of the subjects in this study was slightly higher than the national average (31).

According to the National Health and Nutrition Survey in Japan in 2010, published by the National Institute of Health and Nutrition in 2012, the average BMI for women in their 30 s was 21.3, and the proportion of lean women was 16.8%; these values are similar to those reported for pregnant women in this study (32). Furthermore, compared with the results of the National Growth Survey on Preschool Children in Japan in 2010, published by the Ministry of Health, Labour and Welfare in 2010, the physical characteristics of infants showed almost identical results at birth and at both 4 and 18 mo of age (33). Judging by these results, our group of pregnant women and their infants conform to the average Japanese population.

The limitations of this study include the low response rate of 37.6%. We conducted the interview 18 mo after the birth when the mother and infant attended a health checkup and recorded information obtained from the maternity passbooks. The low response rate was because we only recruited subjects who agreed to our study procedure. Nonetheless, we received answers from 1,398 subjects. Further, because the proportion of lean pregnant women in this study was similar to the Japanese national average published in the National Health and Nutrition Survey in Japan in 2010 (32), as was the average physique of the infants at the various ages we analyzed, we considered it appropriate to analyze the correlation between the physique of the pregnant mothers and the physique of their infants. Moreover, several studies have suggested a difference in the growth of breast-fed versus bottle-fed infants (34, 35). In addition, Huh et al. (36) reported that early introduction of baby food was more likely to cause obesity in the infants. The limitation of this study is that we did not consider the initial nourishment method or the time of starting baby food.

To summarize, we show a positive correlation between the maternal BMI at the beginning of the pregnancy and the physical measurements of infants at birth and at ages of 4 and 18 mo. On the basis of our results and available evidence in the literature, it appears that the mother's intake of energy and nutrients influences the physique of the infants. In male infants, significant positive correlations were demonstrated between the maternal BMI at the beginning of pregnancy and the Kaup index of infants in mothers ≥35 y old when the infants were born and when they were 4 and 18 mo old. In female infants, there was no correlation between maternal BMI at the beginning of pregnancy and the Kaup index of infants at birth. However, significant positive correlations were found between the maternal BMI at the beginning of pregnancy and the Kaup index of infants in mothers ≥35 y old or in their 20s when the infants were 4 and 18 mo old.

CONCLUSIONS

The findings of the current study suggest that the correlation between maternal BMI at the beginning of the pregnancy and the Kaup index of the infants may vary depending on the age of the pregnant women and the gender of the infants. In particular, the positive correlation between the maternal BMI in elder women and the physique of infants was observed in male infants not only at birth, but also at 4 and 18 mo of age. The women who plan on pregnancy and medical professionals need to know that the maternal BMI at the beginning of pregnancy affects the physique of the infants not only at birth but also at 4 and 18 mo old.

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