Assessment of Factors Affecting Adulthood Body Mass Index among Japanese Using the Bayesian Network

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Abstract  The identification of associated factors can help control BMI (body mass index). The current study aimed to assess whether adulthood and childhood factors such as sex, age, oil intake, obesity genes, eating habits, food preferences, number of food bites per mouth, percentage of body fat, height, and weight can affect adulthood BMI. This research included 20 participants from Osaka Women’s Junior College in Japan, and cross-sectional data were used. A questionnaire was designed to assess sex, age, oil intake, eating habits, and food preferences in adulthood and childhood. Then, percentage of body fat, height, and weight were examined. Obesity genotypes such as UCP, AB2, and AB3 were assessed using a genetic testing kit. The causal effect relationship between the measured variables were analyzed via Bayesian network analysis. The factors affecting adulthood BMI were regular mealtimes, percentage of body fat, and age. Regular mealtimes were negatively associated with adulthood BMI (r = −0.57, p = 0.008). Thus, promoting regular mealtimes during childhood and adulthood can help achieve a low BMI in adulthood among the Japanese. Obesity genes (such as UCP1, ADB2, and ADB3), food preferences, and oil intake might not be directly correlated with BMI. Finally, education about regular mealtimes among children and parents could help control weight and enhance intelligence.

Keywords: body mass index, meal regularity, mealtimes, children, parents, Bayesian network

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1. Introduction

Adulthood BMI is an important factor for the development of noncommunicable diseases [1]. A high adulthood BMI increases the release of leptin, angiotensinogen, tumor necrosis factor-alpha, plasminogen activator inhibitor-1, and resistin and decreases the release of adiponectin from abdominal adipocytes. These phenomena cause noncommunicable diseases such as diabetes mellitus and periodontal and cardiovascular diseases [1]. Thus, identifying factors affecting BMI can control the development of noncommunicable diseases.

Adulthood BMI is associated with sex, age, obesity genes, eating habits, food preferences, number of food bites per mouth, and percentage of body fat [2]. Generally, obesity genes are an important factor of BMI among people in Europe [3]. Hence, they may play a role in the causal effects of BMI among Japanese.

Adult eating habits such as fast eating and frequent chewing and food preferences are developed during childhood, and they do not change significantly through several life stages based on a previous study [4]. Accordingly, it is essential to develop good eating habits and food preferences in childhood [4]. In fact, childhood eating habits affect adulthood eating habits [4]. Accordingly, the current study aimed to elucidate the causal effects between childhood and adulthood eating habits.

To date, factors affecting BMI are not fully elucidated, because causal effects between variables in cross-sectional studies were not discovered. Bayesian network was the only analysis method of causal effects without researcher’s intentions. Therefore, the current study aimed to identify
whether adulthood and childhood factors such as sex, age, oil intake, obesity genes, eating habits, food preferences, number of food bites per mouth, percentage of body fat, height, and weight affect adulthood BMI among Japanese using the Bayesian network.

2. Materials and Methods

2.1. Participants

There were 42 employees in Osaka Women’s Junior College, Fujiiidera City, Osaka Prefecture, Japan. Each employee received a document about the research plan. Twenty employees did not participate in the current study due to issues with their schedules. In total, 22 employees participated in the research. A questionnaire was used, and the survey was conducted from 11:00 to 13:00 on May 13, 2015. However, questionnaires with missing data could not be analyzed using the Bayesian network. Therefore, two participants with incomplete answers were excluded. Thus, 20 participants were included in the final analysis. Table 1 shows the distributions of participants according to age and sex. Among the participants, 8 were men and 12 women and they were aged 27–54 years. The BMI of men and women ranged from 16.9 to 27.9 kg/m² and from 15.9 to 27.6 kg/m², respectively. The participants included 4 professors and 16 office clerks. Factors such as obesity genes, eating habits, food preferences, oil intake, number of food bites per mouth, percentage of body fat, height, and weight were assessed. None of the participants dropped out from the current study, and all participants were healthy.

Table 1. Distribution of the number of participants and BMI according to sex

| Number of participants | BMI          |           |           |
|------------------------|--------------|-----------|-----------|
|                        | Men          | Women     | Men       | Women     |
|                        | Mean SD      | Mean SD   | Mean SD   | Mean SD   |
| 20s                    | 2            | 4         | 18.6      | 19.7      | 3.2       |
| 30s                    | 1            | 3         | 24.1      | 19.8      | 3.0       |
| 40s                    | 2            | 5         | 23.1      | 3.8       | 22.6      | 3.0       |
| 50s                    | 3            | 0         | 24.8      | 4.6       |           |           |
| Total                  | 8            | 12        | 22.7      | 4.0       | 20.9      | 3.1       |

The number of participants was 20. BMI: Body mass index +/- SD: Standard deviation.

2.2. Measurement of Percentage of Body Fat, Height, Weight, and BMI

The percentage of body fat and weight were assessed with a body composition meter (In Body 430, In Body Japan Inc., Tokyo, Japan). Body height was evaluated with a digital height scale (4D200R, Endo Electric, Tokyo, Japan). BMI was calculated as weight in kilogram divided by height in meters squared.

2.3. Evaluation of Eating Habits and Food Preferences Using a Self-administered Questionnaire

Food preferences and eating habits in adulthood and childhood were assessed using a self-reported questionnaire (Table 2). First, the participants answered questions regarding food preferences and eating habits in adulthood and childhood and answered the questions. The items regarding food preferences were as follows: “Do (or did) you like sugar-sweetened beverage in adulthood (or childhood)?”, “Do (or did) you like greasy food in adulthood (or childhood)?”, “Do (or did) you like fast food in adulthood (or childhood)?”, “Do (or did) you eat junk food in adulthood (or childhood)?”, “Do (or did) you like meat in adulthood (or childhood)?”, and “Do (or did) you like fish in adulthood (or childhood)?” (Table 2). Junk foods were defined as foods with high salt and fat content [5], such as potato chips and fried snack. This definition is similar as reported in a previous study [5].

The questionnaire items regarding eating habits were as follows: “Do (or did) you frequently chew food in adulthood (or childhood)?”, “Do (or did) you eat junk food in adulthood (or childhood)?”, “Do (or did) you eat fast food in adulthood (or childhood)?”, “Do (or did) you eat fast in adulthood (or childhood)?”, and “Do (or did) you follow regular mealtimes in adulthood (or childhood)” [6] (Table 2). The responses included “Not applicable at all,” “Not applicable,” “Neither,” “Applicable,” and “Very applicable,” and their corresponding scores were 1, 2, 3, 4, and 5 [3].

Table 2. Questionnaire items and responses.

| Items                                               | Scores |
|-----------------------------------------------------|--------|
| Items regarding food preferences                    |        |
| Do (or did) you like sugar-sweetened beverage in adulthood (or childhood)? |        |
| Do (or did) you like greasy food in adulthood (or childhood)? |        |
| Do (or did) you like fast food in adulthood (or childhood)? |        |
| Do (or did) you like junk food in adulthood (or childhood)? |        |
| Do (or did) you like meat in adulthood (or childhood)? |        |
| Do (or did) you like fish in adulthood (or childhood)? |        |
| Items regarding eating habits                        |        |
| Do (or did) you frequently chew food in adulthood (or childhood)? |        |
| Do (or did) you eat junk food in adulthood (or childhood)? |        |
| Do (or did) you eat fast food in adulthood (or childhood)? |        |
| Do (or did) you eat fast in adulthood (or childhood)? |        |
| Do (or did) you follow regular mealtimes in adulthood (or childhood)? |        |

The responses included “Not applicable at all,” “Not applicable,” “Neither,” “Applicable,” and “Very applicable,” and their corresponding scores were 1, 2, 3, 4, and 5.

2.4. Assessment of Oil Intake Using a Self-administered Questionnaire

Oil intake in adulthood was evaluated using a food frequency questionnaire (FFQg, Kenpakusha Co., Ltd., Tokyo, Japan). The questionnaire items quantified oil intake in adulthood.

2.5. Examination of the Numbers of Food Bites Per Mouth Using Video Recording Systems

We recorded the eating behaviors of the participants during lunch time between 11:00 and 13:00 in a meeting room in the university. Then, the numbers of food bites were counted. Ten video cameras (HC-230, Panasonic Corporation, Osaka, Japan) fixed on tripods were used to assess the face of each participant from the start until the
end of meals. Each camera captured the behaviors of two participants in a frame. The numbers of food bites per mouth were calculated as the sum of the numbers of food bites divided by the total numbers of times that food was placed in the mouth from the start until the end of meals. Twenty lunch boxes with the same contents were prepared by a caterer (Ichifuji Catering Co., Ltd., Tokyo, Japan). Lunch boxes were served to each participant. The lunch box contained rice (118 g), deep-fried shrimp (10 g), deep-fried lotus root (18 g), simmered vegetable including shiitake mushroom, carrots, and string beans with soy sauce (57 g), fried fishcake products, such as Satsuma-age, seasoned with soy sauce (24 g), boiled spinach (20 g), sliced peaches in syrup (27 g), and green tea (350 mL). The lunch box contained 411 kcal of energy, 14.8 g of protein, 8.64 g of lipid, and 66.3 g of carbohydrate. The participants started lunch at the same time and finished at different times.

2.6. Determination of Obesity Genes

Obesity genotypes such as UCP, AB2, and AB3 were examined. Oral mucous membrane cells were collected with a cotton swab and assessed using a genetic testing kit (Takara Bio Inc., Shiga, Japan).

2.7. Statistical Analysis

Causal effects were calculated using the Bayesian network [7], which can indicate causal relationships using the Bayes’ theorem between variables without dependence on graph theory. Thus, the Bayesian network shows causation between variables using arrows in a graph. It is a directed acyclic graph comprising a set of variables \( \{X_1, X_2, ..., X_N\} \) and a set of directed edges between the variables [5]. A variable has several possible states such as true and false. The Bayesian networks are successful in probabilistic knowledge representation and reasoning. Further, the joint probability distribution function of all nodes can be calculated as follows:

\[
P(X_1, X_2, ..., X_N) = \prod_{i=1}^{N} P(X_i | Pa_i),
\]

where \( Pa_i \) is the set of random variables whose corresponding nodes are the parent nodes of \( X_i \).

The correlations between eating habits and food preferences in childhood and adulthood were analyzed using the Spearman’s rank correlations. Further, the correlations between eating habits, food preferences, and percentage of body fat and BMI were examined. The effects of obesity gene on eating habits and food preferences were analyzed using two-way analysis of variance.

This study was reviewed and approved by the Ethics Committee of Mukogawa Women’s University (no. 16-28), and informed consent was obtained.

3. Results

3.1. Causal Relationships between Obesity Genes and Eating Habits and Food Preferences in Childhood and Adulthood and BMI

![Figure 1. Causal effects between food preferences and eating habits in childhood and adulthood and percentage of body fat and BMI. Causal effects were analyzed using the Bayesian network (n = 20). Causes and effects are indicated by lines and arrowheads, respectively. Black and white circles represent discrete and ordinal variables, respectively.](image-url)
Figure 1 shows the causal effects between the variables measured, as assessed using the Bayesian network. Arrow heads and lines indicate the effects and causes, respectively. The factors affecting adulthood BMI were regular mealtimes in adulthood, percentage of body fat, and age.

3.2. Associations between Eating Habits and Food Preferences in Childhood and Adulthood and BMI

Table 3 shows the correlations between eating habits, food preferences in adulthood, and percentage of body fat and BMI. Frequent chewing and fast eating in adulthood were positively associated with those in childhood ($r = 0.64$, $n = 20$, $p = 0.002$; $r = 0.93$, $n = 20$, $p = 0.001$; Spearman’s rank correlations). Frequent chewing in adulthood was positively associated with fast eating in childhood ($r = −0.69$, $n = 20$, $p = 0.001$).

Table 4 depicts the correlations between eating habits and food preferences in adulthood and percentage of body fat and BMI. Preference for fast food and greasy foods in adulthood was positively associated with those of childhood ($r = 0.62$, $n = 20$, $p = 0.004$; $r = 0.64$, $n = 20$, $p = 0.002$; Spearman’s rank correlations).

3.3. Effects of Obesity Genes on Eating Habits and Food Preferences

Table 5 shows the effects of obesity genes on eating habits and food preferences in adulthood and childhood. Two-way analysis of variance showed no significant difference in terms of eating habits and food preferences according to obesity genes.

Table 3. Correlations between regular mealtimes in adulthood, food preferences in adulthood, and percentage of body fat and BMI

| Preference for fast food in adulthood | Preference for junk food in adulthood | Preference for meat in adulthood | BMI | Percentage of body fat |
|--------------------------------------|--------------------------------------|---------------------------------|-----|------------------------|
| Preference for greasy food in adulthood | 0.74 (0.001)                        | 0.74 (0.001)                    | 0.35 (0.1) | −0.57 (0.008) | −0.43 (0.05) |
| Regular mealtimes in adulthood | (0.001)                             | (0.001)                         | (0.001) | (0.001) |
| Preference for sugar-sweetened beverage in adulthood | 0.79 (0.001) | 0.47 (0.03) |
| BMI | 0.65 (0.002) |
| Percentage of body fat | −0.50 (0.02) |
| Age | 0.46 (0.03) |

Numbers in the left column show Spearman’s rank correlation coefficients between items. Numbers in parentheses show the probability of correlations between items ($n = 20$). BMI: Body mass index.

Table 4. Correlations between eating habits and food preferences in childhood and adulthood

| Preference for fast food in childhood | Preference for greasy food in childhood | Preference for sugar-sweetened beverage in childhood | Intake of junk food in adulthood | Preference for meat in adulthood | Preference for fish in adulthood | Intake of junk food in adulthood | Preference for fish in adulthood | Frequent chewing in adulthood |
|--------------------------------------|----------------------------------------|-----------------------------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|-----------------------------|
| Preference for fast food in adulthood | 0.62 (0.001)                         | 0.72 (0.001)                                       | 0.72 (0.001)                   | 0.64 (0.002)                   | 0.79 (0.001)                   | 0.61 (0.004)                   | 0.64 (0.002)                   | 0.017 (0.9) |
| Preference for greasy food in adulthood | 0.64 (0.002)                         | 0.79 (0.001)                                       | 0.72 (0.001)                   | 0.70 (0.001)                   | 0.66 (0.001)                   | 0.61 (0.004)                   | 0.64 (0.002)                   | 0.017 (0.9) |
| Preference for sugar-sweetened beverage in childhood | 0.70 (0.001) | 0.66 (0.001)                                       | 0.72 (0.001)                   | 0.70 (0.001)                   | 0.66 (0.001)                   | 0.61 (0.004)                   | 0.64 (0.002)                   | 0.017 (0.9) |
| Intake of junk food in adulthood | 0.64 (0.002)                         | 0.72 (0.001)                                       | 0.72 (0.001)                   | 0.70 (0.001)                   | 0.66 (0.001)                   | 0.61 (0.004)                   | 0.64 (0.002)                   | 0.017 (0.9) |
| Preference for junk food in childhood | 0.69 (0.001)                         | 0.64 (0.002)                                       | 0.64 (0.002)                   | 0.64 (0.002)                   | 0.64 (0.002)                   | 0.61 (0.004)                   | 0.64 (0.002)                   | 0.017 (0.9) |
| Preference for fish in adulthood | 0.31 (0.17)                         | 0.62 (0.003)                                       | 0.35 (0.1)                     | 0.35 (0.1)                     | 0.35 (0.1)                     | 0.35 (0.1)                     | 0.35 (0.1)                     | 0.017 (0.9) |
| Preference for meat in adulthood | 0.75 (0.001)                         | 0.55 (0.01)                                       | 0.25 (0.2)                     | −0.43 (0.001)                  | −0.43 (0.001)                  | −0.43 (0.001)                  | −0.43 (0.001)                  | −0.43 (0.001) |
| Fast eating in childhood | 0.55 (0.01)                         | 0.25 (0.2)                                       | 0.25 (0.2)                     | −0.43 (0.001)                  | −0.43 (0.001)                  | −0.43 (0.001)                  | −0.43 (0.001)                  | −0.43 (0.001) |
| Regular mealtimes in childhood | 0.52 (0.01)                         | 0.25 (0.2)                                       | 0.25 (0.2)                     | −0.43 (0.001)                  | −0.43 (0.001)                  | −0.43 (0.001)                  | −0.43 (0.001)                  | −0.43 (0.001) |
| Number of food bites per mouth | 0.15 (0.5)                           | −0.53 (0.01)                                      | −0.53 (0.01)                   | −0.43 (0.001)                  | −0.43 (0.001)                  | −0.43 (0.001)                  | −0.43 (0.001)                  | −0.43 (0.001) |
| Frequent chewing in adulthood | −0.47 (0.03)                         | −0.69 (0.001)                                      | −0.69 (0.001)                  | −0.43 (0.001)                  | −0.43 (0.001)                  | −0.43 (0.001)                  | −0.43 (0.001)                  | −0.43 (0.001) |

The numbers in the upper row show Spearman’s rank correlation coefficients between items. The numbers in parentheses show the probability of the correlations ($n = 20$).
Table 5. Effects of obesity genes such as UCP1, ADB2, and ADB3 on eating habits and food preferences in adulthood and childhood

| Independent variables | Age | Percentage of body fat | Preference for greasy food in adulthood | Preference for fish in childhood | Oil intake in adulthood | Preference for junk food in childhood | Preference for sugar-sweetened beverage in adulthood | Preference for meat in adulthood | Frequent chewing in childhood |
|-----------------------|-----|------------------------|----------------------------------------|-------------------------------|------------------------|--------------------------------------|----------------------------------|-------------------------------|-----------------------------|
| UCPI                  |     |                        |                                        |                               |                        |                                      |                                   |                               |                             |
| ADB2                  |     |                        |                                        |                               |                        |                                      |                                   |                               |                             |
| ADB3                  |     |                        |                                        |                               |                        |                                      |                                   |                               |                             |
| Sex                   | 3.7 | 0.07                   | -0.01                                  | 1.3                          | 0.6                    | 0.7                                   | 0.4                               | 0.04                          | 0.9                         | 0.7                         |

Data were analyzed using one-way analysis of variance (n = 20). Dependent variables: age, percentage of body fat, preference for greasy food in adulthood, preference for fish in childhood, oil intake in adulthood, preference for junk food in childhood, preference for sugar-sweetened beverage in adulthood, preference for meat in adulthood, and frequent chewing in childhood.

3.4. Causal Relationships with Quantitative Relationships

For a detailed analysis and better visualization, the results of the Bayesian network analysis (Figure 1) were integrated with those of the correlation analyses (Table 3 - Table 4) and analysis of variance (Table 5). Figure 2 shows the causal relationships between quantitative relationships.

4. Discussion

The current study was aimed to identify whether factors such as eating habits, food preferences, oil intake, number of food bites per mouth, and obesity genes affect BMI.

4.1. Causal Factors of Controlling BMI

The factors affecting adulthood BMI were regular mealtimes in adulthood, percentage of body fat, and age (Figure 1). Regular mealtime in adulthood was negatively associated with adulthood BMI (p = 0.008, Table 4). Thus, adulthood BMI could be negatively affected by the extent of regular mealtimes in adulthood (Figure 2) as in a previous study with 64 percipients [8]. A low adulthood BMI might prevent the development of noncommunicable diseases [2]. Accordingly, regular mealtimes in adulthood could reduce BMI.

4.2. Methods of Controlling BMI

As mentioned in the previous section (Causal factors of controlling BMI), regular mealtimes in adulthood might be correlated with a low adulthood BMI. Education about the importance of regular mealtimes to children can facilitate regular mealtimes during elementary school years, as shown in a study conducted in Yugoslavia [5]. To reduce the BMI of Japanese, education about the importance of regular mealtimes should be introduced during elementary school years.

A previous study in Korea has reported the impact regular mealtimes on academic performance [9]. Results showed that regular mealtimes had more impact on academic performance than socioeconomic status and physical status in older teenagers [9]. Accordingly, education about the importance of regular mealtimes in the classroom might increase academic performance and control BMI.

Generally, the mealtimes of children were significantly controlled by their parents [10]. Thus, regular mealtimes...
among parents could be a modulator of BMI and/or the academic performance of children. Further, promoting education about regular mealtimes to parents might control the BMI of children and could promote health and intelligence.

4.3. Associations between Factors in Childhood and Adulthood

Factors in childhood, such as fast eating, frequent chewing, and preference for greasy and fast food were associated with those in adulthood (Figure 1). Generally, childhood factors could be important in establishing eating habits and food preferences [4]. Thus, controlling preferences for greasy and fast food, fast eating, and increasing the frequent chewing in childhood could control the same factors in adulthood. Accordingly, education about controlling such behaviors in childhood might help control the behavior of children for a life-time.

4.4. Effects of Obesity Genes on BMI

Obesity genes such as UCP1, ADB2, and ADB3 did not affect BMI (Figure 1). Hence, these genes could not regulate adulthood BMI among Japanese. Generally, obesity genes are important factors of BMI among Europeans [3]. The effects of obesity genes on BMI might differ in terms of culture. Body image is a factor of BMI [11]. Japanese students want to be thin because of body dissatisfaction [12], and they have a lower BMI than Europeans [12]. The rate of body dissatisfaction was higher in Japanese than in people of diverse cultures, such as those in the USA, Hong Kong, and Israel [11]. Significant body dissatisfaction are correlated with a low BMI among Japanese [11]. Therefore, obesity genes might have a lesser effect on BMI than body dissatisfaction in Japan. The current study showed that obesity genes such as UCP1, ADB2, and ADB3 were not associated with BMI based on the Bayesian network analysis.

4.5. Impact of Factors Affecting BMI

Food preferences, fast eating, oil intake, and obesity genes such as UCP1, ADB2, and ADB3 did not have causal effects on BMI (Figure 1). However, previous research showed that BMI was correlated with obesity genes, food preferences, fast eating, and oil intake [2]. Moreover, the current study showed significant correlations between these factors and BMI. There were differences in the statistical methods used in the previous and current studies. That, this research used the Bayesian network, which showed causal effects using the Bayesian probability theory. Moreover, our study focused on the causal effects of the associations between factors. The impact of regular mealtimes on BMI might be more significant than that of obesity genes, food preferences, fast eating, and oil intake if the focus was on causal effects.

4.6. Limitations of This Study

The current study assessed factors affecting BMI according to previous studies. However, as mentioned in the previous text, body image might also be correlated with BMI. Therefore, other important factors such as body image were not assessed, and further studies assessing the impact of body image and unknown factors on BMI should be conducted in the future.

The number of participants was limited to only 20, and they were from a single institution located in Fujisidera City, Osaka Prefecture, Japan. Therefore, the results should be generalized with caution. Nevertheless, the results of this study provided an important approach for identifying factors affecting adulthood BMI.

5. Conclusion

Regular mealtimes could be associated with a low adulthood BMI in Japanese. Therefore, education about the importance of regular mealtimes in childhood can help achieve a low adulthood BMI. Moreover, obesity genes (such as UCP1, ADB2, and ADB3), food preferences, and oil intake might not be directly correlated with BMI among Japanese. Finally, promoting education about the importance of regular mealtimes among children and parents could promote health and intelligence.

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Conflict of Interest and Funding Disclosure

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