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Analysis of the Factors Controlling the Abdominal Circumferences in Japanese High School Students Using the Bayesian Network

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Abstract

A large abdominal circumference is one of the risk factors for non-communicable diseases. The purpose of this study is to elucidate the causal effects of large abdominal circumferences using the Bayesian network for the analysis of causal relationships. Participants were female students attending a senior high school in Japan (n=64). Cross-sectional data were used. Data from a questionnaire were collected using a self-report survey, and then abdominal circumference, percentage of body fat, and BMI were measured. Causal effects of large abdominal circumferences according to the Bayesian network were food dislikes, following regular mealtimes, cleaning-up the plate, and the existence of a habit to re-evaluate the various diets one has eaten. The abdominal circumferences of subjects without food dislikes were less than those of subjects with food dislikes (p=0.02). Abdominal circumferences depended on the following regular mealtimes (P=0.01). Important factors for reducing abdominal circumference are having no food dislikes and strictly following regular mealtimes. Educating children about the importance of eating offensive foods in elementary schools and following regular mealtimes in junior high schools may reduce abdominal circumferences.

Keywords: Abdominal circumferences; Bayesian network; female students; food dislikes

Introduction

The present study focused on factors for reducing abdominal circumferences. A large abdominal circumference facilitates the release of leptin, angiotensinogen, tumor necrosis factor-α (TNF-α), plasminogen activator inhibitor-1(PAI-1), and resist in from abdominal adipocytes, and decreases the release of adiponectin, thereby inducing-communicable diseases such as diabetes mellitus, periodontal diseases, and cardiovascular diseases [1]. Thus, a large abdominal circumference is one of the important risk factors for non-communicable diseases and controlling it would reduce the risk [2,3].

Many factors involving abdominal circumferences are interrelated [4] Accordingly, the causes of factors for reducing abdominal circumferences are sometimes obscure because of complicated associations among factors. Statistical analysis of causes of large abdominal circumferences is needed in the area of prevention of obesity to detect causal effects. Bayesian network, employed in this study, is only one analysis methodology that was used to detect causal effects so far [5].

There have been many studies to detect the factors associated with abdominal circumference [6]. These factors include physical activity [7,8], stress [9], duration of sleep [10], difficulty in enjoying life [9], skipping a meal [9], following the regular meal- times [11,12], and the existence of a habit to re-evaluate the various diets one has consumed [13]. Thus, these factors could be the predictors of large abdominal circumferences. However, the causes of a large abdominal circumference remain obscure because of the low reliability of the analysis of causal effects. Causal effects between factors can be determined by the Bayesian network, even in cross-sectional studies [5]. The purpose of this study was to elucidate factors controlling abdominal circumferences in senior high school students in Japan using the Bayesian network.

Materials and Methods

Participants

Participants included 64 female students from the all-girl Osaka Kun-Ei Jogakuin Senior High School, located in Settu city, Osaka Prefecture, Japan. The 64 participants comprised 32 freshmen and 32 sophomores from the course of the sport. Assessment of our questionnaires was performed in the 64 students (Figure 1). All students answered our questionnaires, although some missing values existed in several items. No students dropped out of the assessments. Of the 64 students, 18 dropped out of measurements of the abdominal circumference, percentage of body fat, and BMI, either due to their poor physical conditions or the conditions being unsuitable for measurements. For the measurements of abdominal circumference, percentages of body fat, and BMI, a body composition meter was employed (In Body 430, In Body Japan Inc., Tokyo, Japan). The operating conditions of the body composition meter did not permit measurements until 2 hours post meals due to the low reliability of the values. Because of this, 12 students dropped out. Owing to poor physical conditions, another 6 students dropped out. Accordingly, the abdominal circumference, percentage of body fat and BMI were measured in 46 of the 64 students. As a result, causal effects using the Bayesian network were analyzed in 46 subjects. Missing values were not allowed in the analysis by the Bayesian network [14].

The subjects were from Osaka (73.9%) and Hyogo (10.8%) prefectures; other prefectures that were represented included Aichi, Hiroshima, Kyoto, and Nara.

The freshman class included a total of 244 female students and the sophomore class included a total of 259 female students. Due to the young age of the participants, we assumed that they could readily recall their childhood diets [15]. The study was performed in the class of sports nutrition in high school. Accordingly, all the subjects had taken the class on sports nutrition. The class, however, did not cover food dislikes. While the appearances and disappearances of food dislikes in female students differ from those of male students [16], this study focused on the impact of food dislikes in young females. Therefore, male students were not included in this study.

Design and Data collection of the study

Cross-sectional data were used. The study was conducted at Osaka Kun-Ei Jogakuin Senior High School in February 2013. We obtained informed consent from all participants.

Questionnaire

Data on the questionnaire were collected using a self-report survey. The questionnaires included 16 question items: "Do you have any food dislikes?"," How long do you sleep per day?", "How long do you exercise per day?", "How often do you dine out?", "How often do you cook at home?", "How often do you skip a meal?", "Do you find it difficult to enjoy life?", "Do you experience stress?", "Do you maintain regular meal-times?", "Do you avoid salty foods?", "Do you chew your food well?", "Do you avoid greasy food?", "Do you clean up the plate?", "Do you eat despite a full stomach?", "Do you have the knowledge of an adequate meal size?", and "Do you have a habit to re-evaluate the various diets one has eaten?" (Table 1)."How often" items evalu-

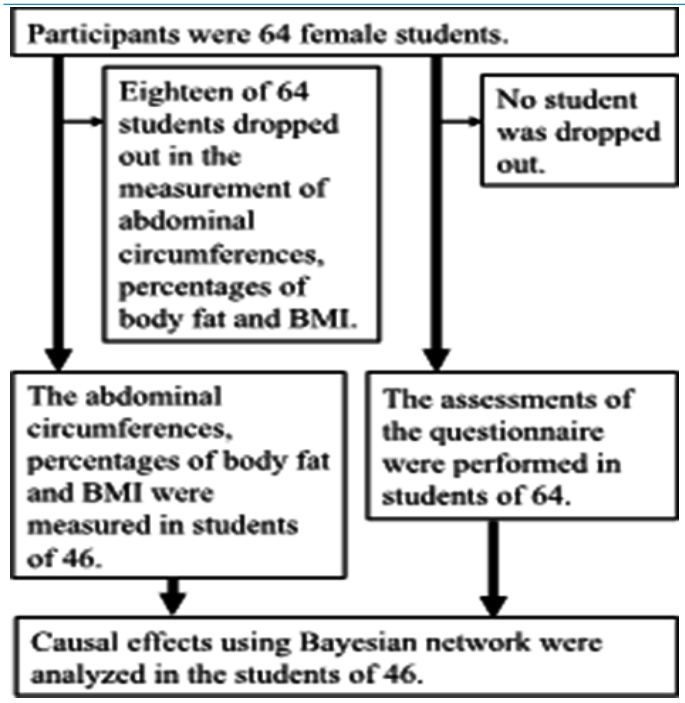

Figure1: Description of the study population. Participants were 64 female students. Causal effects using the Bayesian network were analyzed in the subjects of 46.

ated the frequency of the listed options (Table 1). Answers such as "I hardly do at all," "Once a month," "Twice a month," "Once a week," "Three times a week," and" Once a day" were given scores of 1, 2, 3, 4, 5, and 6, respectively. "Do you feel or keep or avoid or eat or know or have a habit" items evaluated the degree of the listed options (Table 1). Answers such as "Not applicable at all," "Not applicable," "Slightly not applicable," "Slightly applicable," "Applicable," and "Very applicable" were given scores of 1, 2, 3, 4, 5, and 6, respectively.

Measurement of body height, body weight, BMI, abdominal circumference and percentage of body fat

Body height and weight were measured with a digital height scale (4D200R, Endou-Denshi kougyou Co., Ltd, Niigata, Japan) and a weight scale (BC-612, Tanita Co., Tokyo, Japan). Abdominal circumference and percentage of body fat were measured with a body composition meter (In Body 430, In Body Japan Inc., Tokyo, Japan).

Options	Items
Do you have likes and dislikes?	Yes, No.
How long do you sleep per day? How long do you exercise per day?	Free descriptive answer.
How often do you dine out? How often do you cook at home? How often do you skip a meal?	1: I hardly do at all. 2: Once a month. 3: Twice a month. 4: Once a week. 5: Three times a week. 6:Once a day.
Do you feel difficulty in enjoying life? Do you feel stress? Do you follow regular meal-times? Do you chew well? Do you avoid greasy food? Do you clean up the plate? Do you eat with a full stomach? Do you have a habit to re-evaluate the various diets one has eaten	1: I am not applicable at all. 2: I am not applicable. 3: I am not applicable a little. 4: I am applicable a little. 5: I am applicable. 6: I am applicable very much.

Table 1. Options and items on the questionnaire.

Statistics

The Bayesian network shows causation between variables using arrows in a graph. Causal effects were calculated using a Bayesian network [4]. A Bayesian network can indicate a causal relationship using Bayes' theorem between variables without dependence on graph theory. A Bayesian network is a directed acyclic graph that is composed of a set of variables {X1, X2, . . ., XN} and a set of directed edges between the variables [5]. A variable has several possible states, e.g. true and false. Bayesian networks are very successful in probabilistic knowledge representation and reasoning. In Bayesian networks, the joint probability distribution function of all nodes can be calculated as follows:

$$P(X1, X2, \ldots, XN) = \prod_{i=1}^{N} P(X \mid Pa)$$

Where Pai is the set of random variables, whose corresponding nodes are parent nodes of Xi. A Bayesian network contains two elements: structure and parameters. Each arc begins at a parent node and ends at a child node. Pa (X) represents the parent nodes of node X. X1 is the root node because it has no input arcs. Root nodes have prior probabilities. Each child node has conditional probabilities based on the combination of states of its parent nodes. Black circles represent discrete variables, and white circles represent ordinal variables.

Differences in abdominal circumferences between food dislikes were analyzed using a t-test. Differences with $p<0.05$ were considered significant. The results of the abdominal circumferences of subjects were presented as means and standard deviations. A dependency of food dislikes to the abdominal circumferences was analyzed using linear regression analysis.

Statistical analysis was performed using SPSS Statistics 20 (IBM Japan ltd., Tokyo, Japan) and R version 3.2.0 (The R Project for Statistical Computing, Vienna, Austria).

This study was reviewed and approved by the Fukuoka Women's University Ethics Committee (No. 2010-08). We obtained informed consent from the children directly, as it was judged that they could appropriately express their intention to participate.

Results

Causal relationships involving increased abdominal circumferences

Figure 2 shows causal effects between the variables measured in the present study, as calculated using the Bayesian network theory. Arrowheads and lines indicate effects and causes, respectively (Figure 2). The Bayesian network indicated that the factors affecting abdominal circumference were food dislikes, the existence of a habit to re-evaluate the various diets one has consumed, following regular meal-times, and cleaning-up the plate (eating everything on the plate) (Figure 2). The Bayesian network showed that physical activity, stress, duration of sleep, difficulty in enjoying life, and skipping a meal were not factors affecting abdominal circumference (Figure 2).

Differences in abdominal circumferences among subjects with and without food dislikes

The measurements of the abdominal circumference of subjects without food dislikes were less than those with food dislikes ($p=0.02$, t-test, Table 2).

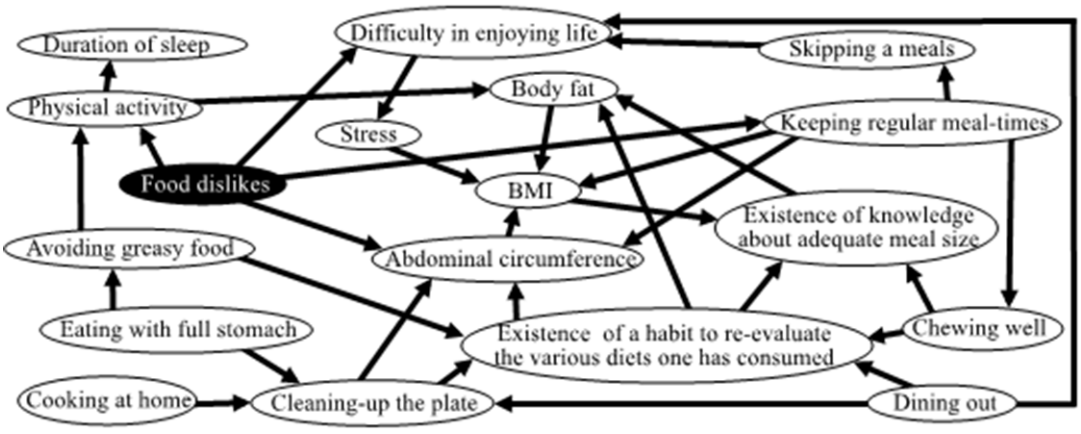

Figure 2: Causal effects between duration of sleep, duration of sleep, physical activity, stress, percentages of body fat, BMI, abdominal circumference, the existence of a habit to re-evaluate the various diets one has eaten, avoiding greasy food, eating with a full stomach, cleaning-up the plate, cooking at home, food dislikes, feeling difficulty in enjoying life, skipping a meal, following regular meal-times, chewing well, dining out. Causal effects were analyzed using the Bayesian network analysis Causes and effects are indicated by lines and arrowheads, respectively. Black circles represent discrete variables, and white circles represent ordinal variables.

	Subjects with food dislikes		Subjects without food dislikes		P§
	Mean	SD	Mean	SD	
Abdominal circumferences (cm)	73	6	68	4	0.02

The subjects were forty-two students. §probability calculated using the t-test between subjects with (n=15) and subjects without dislikes (n=27).

Table 2. Effects of food dislikes on abdominal circumferences.

Dependencies on factors affecting abdominal circumferences.

The measurement of the abdominal circumference depended on following regular mealtimes (p=0.01, linear regression, Table 3). It did not depend on having the habit to re-evaluate the various diets consumed (p=0.2, Table 3) and cleaning-up the plate (p=0.9, Table 3).

Independent variables	F-ratio	P§	Regression coefficient	SE	P§§	Section	SE	P§§
Following regular meal-times	8.08	0.01	-1.86	0.66	0.007	77.3	2.3	< 0.001
Having a habit to re-evaluate the various diets one has eaten	2.16	0.2						
Cleaning-up the plate	0	0.9						

Dependent variable: Abdominal circumferences

The subjects were 41 students.

§ probability calculated linear regression analysis (Residual degree of freedom = 39).

§§ probability calculated linear line with least the square average method (n=41).

Table 3. Effects on the abdominal circumferences.

Discussion

The present study examined factors for reducing abdominal circumferences, using a Bayesian network.

Causes of abdominal circumferences

The abdominal circumference can be controlled by regulating factors such as having food dislikes, the existence of the habit to re-evaluate the various diets one has consumed, having fixed regular mealtimes, and cleaning-up the plate (Figure 2). The abdominal circumferences of subjects with food dislikes were larger than those without. (p=0.02, Table 2). Accordingly, one of the factors for reducing abdominal circumferences would be to have no food dislikes. Food dislikes increased abdominal circumferences, which might be elevated by the intake of high-fat and sweetened foods [8].

The abdominal circumference was negatively dependent on following regular mealtimes (p=0.01, linear regression, Table 3). Following regular meal times was related to decreased energy intake overall [17]. Following regular mealtimes could prevent obesity in adulthood. Therefore, one of the factors for reducing abdominal circumferences might be to strictly follow regular mealtimes without food dislikes.

According to linear regression analysis, the abdominal circumference was not affected by the habit of re-evaluating the various diets one has consumed (p=0.2, linear regression, Table 3), while Bayesian network analysis showed the causal effect between the abdominal circumference and the existence of this habit (Figure 2). The existence of the habit to re-evaluate the various diets one has consumed prevented obesity in adult hood [18], which would suggest that this habit is an important factor for adults because such a factor might be a cumulative effect over a lifetime. However, the effects of this habit might not be significant in high school students because of their young age, resulting in a low cumulative effect.

Bayesian network detected a causal effect between the abdominal circumference and cleaning-up the plate (Figure 2). However, linear regression showed no significance (p=0.9, linear regression, Table 3). The Bayesian network would be more sensitive for causal effects compared with linear regression. Therefore, while the study showed that there is a causal effect between the increased abdominal circumference and clearing the plate, the effects might be trivial.

The purpose of the present study was to detect factors for reducing abdominal circumferences. Considering the results of regression, important factors for reducing abdominal circumferences would be having no food dislikes and strictly following regular mealtimes in high school students in Japan. The existence of the habit to re-evaluate the various diets one has consumed might be one of the factors for reducing abdominal circumference in adulthood. These factors provide strategies to reduce abdominal circumferences.

Manner of controlling abdominal circumferences

As mentioned above, the factors for reducing the abdominal circumference would be having no food dislikes and strictly following regular mealtimes ("Causes of abdominal circumference" in Discussion). Teachers educating students about the importance of eating offensive foods reduced food dislikes among elementary school students [19]. This, in turn, may reduce abdominal circumference in children. On the other hand, parents educating their children in junior high school about the importance of following regular meal times induced them to do so [20], which again would reduce the abdominal circumferences of children in junior high school. Accordingly, the education of children by parents or teachers in elementary schools about the importance of eating offensive foods and following regular mealtimes in junior high school might reduce the abdominal circumferences of the students.

The present study also shows that the habit of re-evaluating the various diets one has consumed might be a factor for reducing the abdominal circumference (Figure 2). The impact of this habit would be small in high school students. However, the effects of the habit would last for a lifetime. Education aimed at encouraging the development of this habit in early life might have a significant impact.

Causes not affecting abdominal circumferences

Konttinen et al. claimed that causes of large abdominal circumferences were high stress, short duration of sleep, finding it difficult to enjoy life, and skipping a meal [9]. However, factors such as physical activity, stress, duration of sleep, difficulty enjoying life, and skipping meal did not figure as causes of abdominal circumference in the present study (Figure 2).

Physical activity was not a factor in abdominal circumference (Figure 2). However, physical activity might change the composition of the body, such as the percentage of body fat (Figure 2). Stress did not affect abdominal circumference directly (Figure 2). However, stress affected BMI (Figure 2). Thus, stress might be one of the factors involved in the shape of the body.

In this study, finding it difficult to enjoy life, skipping meals, and the duration of sleep did not affect the abdominal circumference, percentage of body fat, and BMI directly (Figure 2). It is possible that finding it difficult to enjoy life, skipping a meal, and the duration of sleep might be associated with an abdominal circumference as shown in a previous study [21]. However, the present study could not confirm these findings.

Limitations

Participants in this study were limited to females from a single high school located in Settu city, Hyogo Prefecture. Therefore, the generalization of the results should be applied with caution. However, the methods employed in this study constitute a fruitful approach to determining the conditions leading to the appearance and disappearance of dislikes.

Conclusions

Important factors for reducing abdominal circumferences among high school students in Japan may be having no food dislikes and strictly following regular mealtimes. Educating children in elementary schools about the importance of eating offensive foods and following regular mealtimes in junior high school may reduce abdominal circumferences.

Author Contributions

Conceptualization, TT., and RH.; methodology, YM and KS.; software, MT.; validation, TT. and RH.; formal analysis, RH.; investigation, RH.; resources, KS.; data curation, HSB.; writing—original draft preparation, RH, TT, and RBS.; writing—review and editing, TT.; visualization, DWW.; supervision, TT, and RBS.; project administration, TT, and RBS.; funding acquisition, TT. and RH.

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