Objective

This study investigated the relationship between frequency of skipping breakfast and annual changes in body mass index (BMI) and waist circumference (WC).

Methods

The participants were 4,430 factory employees. BMI and WC were measured repeatedly at annual medical examinations over a 5-year period. The association between frequency of skipping breakfast at the baseline examination and annual changes in anthropometric indices was evaluated using the generalized estimating equation method.

Results

The mean (standard deviation) BMI was 23.3 (3.0) kg m\(^{-2}\) for men and 21.9 (3.6) kg m\(^{-2}\) for women; and the mean WC was 82.6 (8.7) cm for men and 77.8 (9.8) cm for women. During the follow-up period, mean BMI increased by 0.2 kg m\(^{-2}\) for men and women, and mean WC increased by 1.1 cm for men and 1.0 cm for women. The annual change in the BMI of men who skipped breakfast four to six times per week was 0.061 kg m\(^{-2}\) higher, and that of those who skipped breakfast seven times per week was 0.046 kg m\(^{-2}\) higher, compared with those who did not skip breakfast. Annual changes in the WC of male participants who skipped breakfast seven times per week was 0.248 cm higher than that of those who did not skip breakfast. Skipping breakfast was not associated with changes in BMI or WC in women.

Conclusions

Skipping breakfast was closely associated with annual changes in BMI and WC among men, and eating breakfast more than four times per week may prevent the excessive body weight gain associated with skipping breakfast.
Introduction

Obesity has been increasing worldwide. Worldwide, about 39% of adults ≥18 years have a body mass index (BMI) ≥ 25 kg m⁻² in 2014 (1). Overweight/obesity is less common in Japan; 29% of men and 19% of women have a BMI ≥ 25 kg m⁻²; and mean BMI has decreased in younger and middle-aged women (2). However, the prevalence of obesity in middle-aged Japanese men remains high (2). Furthermore, the presence of prominent abdominal fat in Asians compared with Caucasians with a similar BMI has been reported (3,4), and body weight gain even in normal body weight subjects may increase the risk of metabolic abnormalities in middle-aged Japanese men.

Recently, unhealthy dietary habits related to chrononutrition, such as skipping breakfast, timing of meals, speed of eating and the order of food consumption during a meal, are reportedly associated with metabolic abnormalities (5). Skipping breakfast has been associated with a lack of feeding satiety (6), postprandial hyperinsulinemia (7), expression of the biological clock gene (8) and circadian rhythms of glucose metabolism (9–12), which may cause body weight gain. Actually, previous cross-sectional studies from Western countries showed that skipping breakfast is associated with obesity in children and adolescents (13,14). However, the association between skipping breakfast and obesity is controversial in adults. Some studies from the USA (15–17) and Asia-Pacific regions (18) have shown that skipping breakfast is associated with obesity, whereas skipping breakfast has not been associated with the prevalence of obesity in Canadian adults (19). One of the reasons for these differences may be the cultural diversity across countries. Furthermore, the Asian report was a cross-sectionally designed study, which cannot evaluate how skipping breakfast affects future changes in body weight in relatively lean Asian people.

In this 5-year prospective study of Japanese men and women, we investigated the relationship between frequency of skipping breakfast and annual changes in anthropometric indices of obesity using the generalized estimating equation method to analyse repeated measurements.

Methods

Participants

The study participants were employees of a factory that produces zippers and aluminium sashes in Toyama Prefecture, Japan. The factory employed 7,785 employees, including 5,131 men and 2,654 women. The Industrial Safety and Health Law in Japan requires employers to conduct annual health examinations for all employees. The baseline examination was carried out during the annual medical examinations in 2009. Among the 5,510 daytime workers aged 18–55 years, 4,612 (84%) responded to the dietary survey. Of these potential participants, 182 (4%) were excluded: 62 for a history of cancer at the time of the baseline examination, 20 for extremely low or high energy intake (<500 or >5,000 kcal d⁻¹) and 100 because they did not participate in consecutive annual follow-up health examinations. Therefore, 4,430 participants (2,651 men and 1,779 women) were enrolled in the study.

Data collection

The annual health examination was carried out by trained staff and included questions about medical history and anthropometric measurements. Height was measured to the nearest 0.1 cm without shoes using a stadiometer. Weight was measured using a standard scale to the nearest 0.1 kg with participants wearing only light clothing and no shoes. BMI was calculated as weight/height² (kg m⁻²). Waist circumference (WC) was determined during minimal respiration in a standing position to the nearest 0.1 cm by measuring at the umbilical level. The height, weight and WC measurements followed the methods used in the National Health and Nutrition Survey in Japan (20), as defined by the Ministry of Health, Labour and Welfare. A questionnaire was used to identify voluntary health-related behaviours, such as smoking and regular exercise. An additional self-administered questionnaire was used to collect information regarding medical history of hypertension, dyslipidemia, diabetes and cancer. BMI and waist circumference were measured during the annual follow-up medical examinations from 2010 to 2014. The number of participants followed up each year is shown in Table 2.

Dietary assessment

Dietary habits during the month preceding the annual health examination were assessed using the self-administered Diet History Questionnaire (DHQ) (21). The DHQ was developed to estimate the dietary intakes of macronutrients and micronutrients for epidemiological studies in Japan. Detailed descriptions of the methods used for calculating dietary intakes and the validity of the DHQ have been reported previously (22–24). Estimates of dietary intake of 147 food and beverage items and their corresponding energy and nutrient values were calculated using an ad hoc computer algorithm.
developed for the DHQ that was based on the Standard Tables of Food Composition in Japan (25). Results from previous studies of middle-aged Japanese women show a 0.7% relative difference between the mean intake levels obtained from the DHQ and from 3-d diet records for total energy (21). The DHQ also includes questions concerning general eating habits, including skipping meals and eating irregularly, use of dietary supplements and most common cooking methods. Frequency of skipping breakfast was self-reported by answering the question; ‘How many times do you skip breakfast in a week?’, for which there were eight categories ranging from ‘0 (eat breakfast everyday)’ to ‘7 (never eat breakfast)’.

Statistical analysis

Statistical analyses were performed using the generalized estimating equation (GEE) method for longitudinal data (26) to estimate the relationship between baseline frequency of skipping breakfast and mean yearly changes in BMI and WC after adjusting for probable confounders. Frequency of skipping breakfast was divided into four categories, as follows; zero times per week (reference), one to three times per week, four to six times per week and seven times per week, and used in the models as dummy variables. The relationship between each skipping-breakfast category and BMI/waist circumference change was measured by the coefficient of cross-product (interaction) term between skipping breakfast level and a time variable (t = 0, 1, ..., 5). Analyses of the relationship between skipping breakfast and changes in anthropometric variables were serially adjusted for confounding factors in four GEE models: model 1, adjusted for age (continuous); model 2, adjusted for age and baseline BMI/WC; model 3, adjusted for the variables in model 2 plus lifestyle factors that may affect body weight changes; i.e. smoking status, alcohol consumption, habitual exercise, medical treatment for hypertension, dyslipidemia and/or diabetes mellitus, and interactions between frequency of skipping breakfast and these confounding factors were evaluated. Statistical analyses were carried out using IBM SPSS statistics ver. 22.0 software (IBM Corp., Armonk, NY, USA). A p-value < 0.05 was considered significant.

Written informed consent was not obtained from the participants. The Occupational Safety and Health Committee of the subject company, which consisted of employee representatives, approved the design of the present study. Employees were informed of the study design and of their right to refuse to participate. Hence, participants who answered the questionnaire were considered to have consented to the survey. The company ensured that individuals were not identifiable by providing linkable anonymous data to the researchers. The Institutional Review Committee for Ethical Issues of Kanazawa Medical University approved the study.

Results

Mean (standard deviation) participant age at baseline was 39.2 (10.3) years for men and 40.0 (9.8) years for women; mean BMI was 23.3 (3.0) kg m\(^{-2}\) for men and 21.9 (3.6) kg m\(^{-2}\) for women; and mean WC was 82.6 (8.7) cm for men and 77.8 (9.8) cm for women. Overall, 25.7% of men and 15.4% of women had a BMI \(\geq\) 25.0 kg m\(^{-2}\), and 35.3% of men and 10.0% of women exhibited abdominal obesity as defined by the Japanese criteria for metabolic syndrome (27).

The baseline characteristics of the participants according to the frequency of skipping breakfast are shown in Table 1. Among the study participants, 68.2% of the men and 74.4% of the women ate breakfast every day, and 10.6% of the men and 6.4% of the women never ate breakfast. A higher frequency of skipping breakfast by male participants was associated with significantly younger age, lower total energy intake, lower intake of carbohydrate, higher intake of fat, higher likelihood of currently smoking and lower likelihood of habitually exercising. A higher frequency of skipping breakfast by female participants was associated with younger age, lower total energy intake, lower intake of carbohydrate, higher intake of fat, higher likelihood of currently smoking; however, habitual exercise was not associated with skipping breakfast in females. Baseline BMI and WC were not associated with frequency of skipping breakfast in either males or females.
Mean BMI in men and women increased by 0.2 kg m⁻² during the 5-year follow-up period, and mean WC increased by 1.1 cm in men and by 1.0 cm in women during the same period (Table 2).
The relationship between frequency of skipping breakfast and annual changes in the anthropometric variables as determined by the GEE method are shown in Table 3. The annual increase in the BMI of males who skipped breakfast four to six times per week was 0.075 kg m$^{-2}$ higher than that in males who ate breakfast every day (skipping breakfast zero times per week) after adjusting for age. The increase in BMI for participants who skipped breakfast four to six times per week and seven times per week were significantly higher than those who ate breakfast every day after adjusting for baseline BMI (model 2) and other confounding factors, such as lifestyle factors (model 3) and total energy intake (model 4). A higher frequency of skipping breakfast was associated with a greater increase in WC, and the annual increase in WC was about 0.20 cm higher for participants who skipped breakfast four to six times per week and seven times per week were significantly higher than those who ate breakfast every day after adjusting for baseline BMI and other confounding factors. However, frequency of skipping breakfast was not associated with an increase in BMI or WC in women.

Next, the association between frequency of skipping breakfast and annual changes in anthropometric indices stratified by confounding factors was evaluated in male participants (Table 4). Because the annual changes in anthropometric indices tended to be higher in participants who skipped breakfast four to six times per week and seven times per week, we evaluated the risk of increase in these indices for participants who skipped breakfast four to seven times per week (higher frequency group) compared with those who skipped breakfast zero to three times per week (lower frequency group). Significant interactions were observed between age ($<40$, $\geq40$ years), alcohol consumption ($0$–$20$, $\geq20$ g d$^{-1}$), and frequency of skipping breakfast and annual changes in BMI ($p$ for interaction $<0.001$ for both) and WC ($p$ for interaction $<0$ for both); a higher frequency of skipping breakfast was associated with a greater increase in anthropometric indices for younger participants and participants who drank $<20$ g d$^{-1}$ of ethanol (including those who never drank). Smoking status, habitual exercise and medical treatment for chronic disease did not affect the relationship between skipping breakfast and annual changes in BMI or WC.

**Discussion**

Recent data from the National Health and Nutrition Survey in Japan show that 14.3% of men and 10.5% of women do not eat breakfast and that skipping breakfast is more common in younger adults (2). Skipping breakfast has become a problem for children and adolescents, because skipping breakfast is associated with a decrease in academic and physical performance (28), as well as with obesity (13,14). The association between skipping breakfast and obesity is controversial in adults. Results from the Third National Health and Nutrition Examination Survey in the USA show that 25% of young adults skip breakfast and skipping breakfast is associated with obesity and metabolic syndrome (15). Similarly, some prospective studies also showed that skipping breakfast is associated with a higher risk of body weight gain and incidence of obesity in US subjects (16,17). However, reports of Canadian adults show that skipping breakfast is not associated with prevalence of obesity (19). The differences may be due to the cultural differences among countries.
For Asian people, a meta-analysis of cross-sectional studies shows that skipping breakfast is associated with overweight and obesity (18). The prospective design of the present study allowed us to evaluate changes in BMI and WC, and the results indicate that the frequency of skipping breakfast, particularly more than or equal to four times per week, is associated with a higher risk for increased BMI and WC even in non-obese men. However, the differences in annual changes in BMI and WC between male breakfast skippers and non-skippers were relatively small, at 0.05 kg m\(^{-2}\) and 0.25 cm, respectively, and the clinical impact of skipping breakfast on body weight changes may not be high even though the associations were statistically significant.

Previous studies have identified several possible mechanisms to account for the relationship between skipping breakfast and body weight gain. First, skipping breakfast results in a lack of feeding satiety (6) and leads to an increased total energy intake (29–31). Skipping breakfast also affects the postprandial insulin response. A crossover design study consisting of two experimental periods of eating and omitting breakfast indicated that the postprandial insulin response tends to be lower during the period when breakfast would normally be eaten (7). Therefore, postprandial hyperinsulinemia after a meal in subjects with skip breakfast may lead to obesity. Furthermore, eating breakfast is important for resetting the body’s peripheral biological clock (8). Skipping breakfast shifts the phase of expression of the clock gene, resulting in a nocturnal lifestyle pattern, which may be associated with obesity. Some hormones associated with obesity, such as leptin (32) and ghrelin (33), and systemic functions associated with glucose metabolism, such as glycogen storage in the liver (9,10), glucose sensing and insulin secretion of the pancreas, and the gastrointestinal functions (11,12), follow circadian rhythms; changes in these biological rhythms due to skipping breakfast may also affect body weight changes.

Some lifestyle factors closely associated with skipping breakfast may also affect changes in body weight. Indeed, our study showed that a higher frequency of skipping breakfast was associated with a higher likelihood of currently smoking and a lower likelihood of habitually exercising. Our results did not change even

Table 3  Relationship of frequency of skipping breakfast and adjusted average annual change in each variable over 5 years

| Skipping breakfast (week\(^{-1}\)) | 0 | 1–3 | 4–6 | 7 |
|-----------------------------------|---|-----|-----|---|
| **Men**                           |   |     |     |   |
| Differences in annual changes of body mass index (kg m\(^{-2}\)) | Difference | p   | Difference | p   | Difference | p   |
| Model 1 Reference                  | 0.018 | 0.380 | 0.075 | 0.019 | 0.030 | 0.239 |
| Model 2 Reference                  | 0.010 | 0.559 | 0.060 | 0.026 | 0.046 | 0.022 |
| Model 3 Reference                  | 0.010 | 0.562 | 0.060 | 0.026 | 0.046 | 0.022 |
| Model 4 Reference                  | 0.010 | 0.560 | 0.061 | 0.025 | 0.046 | 0.022 |
| Differences in annual changes of waist circumference (cm) | Difference | p   | Difference | p   | Difference | p   |
| Model 1 Reference                  | 0.049 | 0.422 | 0.198 | 0.034 | 0.213 | 0.006 |
| Model 2 Reference                  | 0.042 | 0.422 | 0.160 | 0.056 | 0.247 | <0.001 |
| Model 3 Reference                  | 0.042 | 0.440 | 0.159 | 0.058 | 0.247 | <0.001 |
| Model 4 Reference                  | 0.042 | 0.439 | 0.161 | 0.055 | 0.248 | <0.001 |
| **Women**                          |   |     |     |   |
| Differences in annual changes of body mass index (kg m\(^{-2}\)) | Difference | p   | Difference | p   | Difference | p   |
| Model 1 Reference                  | 0.005 | 0.817 | 0.016 | 0.714 | 0.035 | 0.377 |
| Model 2 Reference                  | −0.012 | 0.546 | 0.010 | 0.772 | 0.002 | 0.955 |
| Model 3 Reference                  | −0.012 | 0.547 | 0.010 | 0.770 | 0.002 | 0.955 |
| Model 4 Reference                  | −0.012 | 0.547 | 0.010 | 0.763 | 0.001 | 0.970 |
| Differences in annual changes of waist circumference (cm) | Difference | p   | Difference | p   | Difference | p   |
| Model 1 Reference                  | 0.003 | 0.967 | 0.074 | 0.596 | 0.100 | 0.350 |
| Model 2 Reference                  | −0.063 | 0.391 | 0.062 | 0.634 | −0.012 | 0.900 |
| Model 3 Reference                  | −0.063 | 0.389 | 0.063 | 0.625 | −0.012 | 0.901 |
| Model 4 Reference                  | −0.062 | 0.394 | 0.067 | 0.607 | −0.015 | 0.883 |

Model 1, adjusted for age; model 2, adjusted for age, and baseline body mass index/waist circumference; model 3, adjusted for the variables using model 2 plus smoking status, alcohol consumption, and habitual exercise; model 4, adjusted for the variables using model 3 plus total energy intake (kcal day\(^{-1}\)) and medical treatment for hypertension, hyperlipidemia and diabetes mellitus at baseline.

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after adjusting for these confounding factors. Some lifestyle factors (e.g., eating a late dinner before sleep, the duration and quality of sleep, overwork, and staying up late at night) may also affect body weight. A study from Japan showed that skipping breakfast is more closely associated with obesity than is eating dinner less than 3 h before going to bed (34). Furthermore, mental stress and depression may affect the likelihood of skipping breakfast, and other eating behaviours (35), as well as body weight (36), which may have cofounded the associations. However, we did not have access these data, which is a limitation of this study. Nevertheless, eating breakfast is associated with many lifestyle factors; therefore, it is important to encourage breakfast skippers to change their lifestyle (e.g., not to eat dinner late at night, not to stay up late, or to get up in the morning ahead of time) so that they can eat breakfast comfortably.

The results of this study showed that frequency of skipping breakfast was not associated with obesity in women. A study from Japan showed that mean body weight of young and middle-aged women decreases during these decades (2), and a lower prevalence of obesity in women may have affected the results. Similarly, the mean age of female participants in this study was 40 years, and breakfast skippers tended to be younger. In general, older age and the postmenopausal state are risks for body weight gain in women (2,37), and younger female breakfast skippers may also have a lower risk of body weight gain. Furthermore, 11% of women and 18% of men who skipped breakfast more than four times per week, and the small subsample of women who skipped breakfast may also have affected the results.

An interactive effect of the relationship between alcohol consumption and skipping breakfast on changes in obesity indices were detected in men. Among male participants who skipped breakfast zero to three times per week, the annual increases in BMI and WC were 0.031 kg m$^{-2}$ and 0.183 cm for never-drinkers and moderate drinkers (who consumed $<20$ g d$^{-1}$ of ethanol), respectively, and $-0.001$ kg m$^{-2}$ and $-0.029$ cm for excess drinkers (consumed $\geq 20$ g d$^{-1}$ of ethanol), respectively (data not shown). Furthermore, the annual increases in BMI and WC of men who never or moderately drank and skipped breakfast four to seven times per week were 0.074 kg m$^{-2}$ and 0.259 cm higher, respectively, than those of men who skipped breakfast zero to three times per week (Table 4), but changes in BMI and WC were not significantly associated with the frequency of skipping breakfast in excess drinkers. These results suggest that BMI and WC did not change in excess alcohol drinkers regardless of the frequency of skipping breakfast and that some confounding factors, such as the older age of excess drinkers and their poor nutritional

| Table 4 Relationship of frequency of skipping breakfast and adjusted average annual change in each variable over 5 years according to the baseline characteristics of the participants |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| Skipping breakfast (week$^{-1}$) | Skipping breakfast (week$^{-1}$) | Skipping breakfast (week$^{-1}$) | Skipping breakfast (week$^{-1}$) |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 0–3 | 4–7 | 0–3 | 4–7 | 0–3 | 4–7 | 0–3 | 4–7 |
| 0–3 | 4–7 | 0–3 | 4–7 | 0–3 | 4–7 | 0–3 | 4–7 |
| Age | Smiling status | Smoking status | Smoking status | Smoking status | Smoking status | Smoking status | Smoking status |
| $<40$ year | Reference | 0.064 | 0.008 | Reference | 0.211 | 0.004 | Reference | 0.257 | 0.001 |
| $\geq 40$ year | Reference | 0.017 | 0.445 | Reference | 0.087 | 0.208 | Reference | 0.172 | 0.016 |
| Smoking status | Never/Ex-smoker | Reference | 0.044 | 0.069 | Reference | 0.172 | 0.016 | Reference | 0.257 | 0.001 |
| Smoking status | Current smoker | Reference | 0.060 | 0.012 | Reference | 0.257 | 0.001 | Reference | 0.257 | 0.001 |
| Alcohol consumption | $<20$ g | Reference | 0.074 | 0.000 | Reference | 0.259 | 0.000 | Reference | 0.259 | 0.000 |
| Alcohol consumption | $\geq 20$ g | Reference | 0.006 | 0.833 | Reference | 0.259 | 0.000 | Reference | 0.259 | 0.000 |
| Habitual exercise | No | Reference | 0.052 | 0.018 | Reference | 0.223 | 0.001 | Reference | 0.223 | 0.001 |
| Habitual exercise | Yes | Reference | 0.049 | 0.058 | Reference | 0.188 | 0.021 | Reference | 0.188 | 0.021 |
| Medical treatment for hypertension, dyslipidemia and/or diabetes mellitus | No | Reference | 0.058 | 0.001 | Reference | 0.228 | 0.000 | Reference | 0.228 | 0.000 |
| Medical treatment for hypertension, dyslipidemia and/or diabetes mellitus | Yes | Reference | -0.052 | 0.227 | Reference | -0.112 | 0.424 | Reference | -0.112 | 0.424 |

Adjusted for age, baseline body mass index/waist circumference, smoking status, alcohol consumption, habitual exercise, total energy intake (kcal day$^{-1}$), and medical treatment for hypertension, hyperlipidemia and diabetes mellitus at baseline.
status due to excess alcohol consumption, may have affected BMI and WC.

This study has several strengths, including a relatively large sample size. Additionally, although several previous cohort studies have used information collected from self-administered questionnaires, our conclusions are based on more reliable data, including formal medical examinations. However, this study also had several limitations. First, the study population included only employed subjects. Because poor health may exclude some individuals from working, the prevalence of obesity may be lower in our study than in the general Japanese population. Second, the dietary assessment data, including information on the frequency of skipping breakfast, lifestyle factors and treatment for chronic diseases, were collected only at the baseline examination. Changes in lifestyle factors and incident chronic diseases during follow up may have affected the changes in BMI and WC.

In conclusion, this observational study indicates that skipping breakfast was closely associated with annual changes in the anthropometric indices of obesity among men but not among women. These associations were particularly pronounced among younger participants. The increase in the number of obese young to middle-aged men is a major problem in Japan, and eating breakfast more than four times per week may prevent obesity in Japanese men.

Conflict of Interest Statement

No conflict of interest was declared.

Author contributions

M. S. collected the data, performed the analysis and wrote the manuscript; K. N., K. M., Y. M., T. K., Y. N., M. I. and H. N. collected the data, contributed to the discussion and reviewed/edited the manuscript; K. Y., T. T., S. Y. N, K. N., Y. S. and S. S. contributed to the discussion and reviewed/edited the manuscript. All authors approved the final version of the manuscript.

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Reference

1. World Health Organization, Global Health Observatory. [Web page]. URL: http://www.who.int/gho/en/ (accessed Sep 25, 2016).
2. The National Health and Nutrition Survey in Japan. 2014. Office for Life-style Related Diseases Control, General Affairs Division, Health Service Bureau, Ministry of Health, Labour and Welfare (in Japanese), 2015.
3. Park YW, Allison DB, Heymsfield SB, Gallagher D. Larger amounts of visceral adipose tissue in Asian Americans. Obes Res 2001; 9:381–387.
4. He Q, Horlick M, Thornton J, et al. Sex and race differences in fat distribution among Asian, African-American, and Caucasian prepubertal children. J Clin Endocrinol Metab 2002; 87:2164–2170.
5. Ramsey KM, Marcheva B, Kohsaka A, Bass J. The clockwork of metabolism. Annu Rev Nutr 2007; 27:219–240.
6. Benton D, Slater O, Donohoe RT. The influence of breakfast and a snack on psychological functioning. Physiol Behav 2001; 74:559–571.
7. Farshchi HR, Taylor MA, Macdonald IA. Deleterious effects of omitting breakfast on insulin sensitivity and fasting lipid profiles in healthy lean women. Am J Clin Nutr 2005; 81:388–396.
8. Hiroa A, Nagahama H, Tsuboi T, Hiroa M, Tahara Y, Shibata S. Combination of starvation interval and food volume determines the phase of liver circadian rhythm in Per2::Luc knock-in mice under two meals per day feeding. Am J Physiol Gastrointest Liver Physiol 2010; 299:G1045–G1053.
9. Ishikawa K, Shimazu T. Circadian rhythm of liver glycogen metabolism in rats: effects of hypothalamic lesions. Am J Physiol 1980; 238:E21–E25.
10. Roesler WJ, Khandelwal RL. Diurnal variations in the activities of the glycolgen metabolizing enzymes in mouse liver. Int J Biochem 1985; 17:81–85.
11. Houghton SG, Iqbal CW, Duenes JA, Fatima J, Kasparek MS, Sarr MG. Coordinated, diurnal hexose transporter expression in rat small bowel: implications for small bowel resection. Surgery 2008; 143:79–93.
12. Pan X, Terada T, Okuda M, Inui K-I. The diurnal rhythm of the intestinal transporters SGLT1 and PEPT1 is regulated by the feeding conditions in rats. J Nutr 2004; 134:2211–2215.
13. Haug E, Rasmussen M, Samdal O, et al. Overweight in school-aged children and its relationship with demographic and lifestyle factors: results from the WHO-Collaborative Health Behaviour in School-aged Children (HBSC) study. Int J Public Health 2009; 54:167–179.
14. Szajewska H, Ruszczynski M. Systematic review demonstrating that breakfast consumption influences body weight outcomes in children and adolescents in Europe. Crit Rev Food Sci Nutr 2010; 50:113–119.
15. Deshmukh-Taskar P, Nicklas TA, Radcliffe JD, O’Neill CE, Liu Y. The relationship of breakfast skipping and type of breakfast consumed with overweight/obesity, abdominal obesity, other cardiometabolic risk factors and the metabolic syndrome in young adults. The National Health and Nutrition Examination Survey (NHANES). Public Health Nutr 2013; 16:2073–2082.
16. van der Heijden AAW, Hu FB, Rimm EB, van Dam RM. A prospective study of breakfast consumption and weight gain among U.S. men. Obesity 2007; 15:2463–2469.
Odegaard AO, Jacobs DR, Steffen LM, Van Horn L, Ludwig DS, Pereira MA. Breakfast frequency and development of metabolic risk. Diabetes Care 2013;36:3100–3106.

Horikawa C, Kodama S, Yachi Y, et al. Skipping breakfast and prevalence of overweight and obesity in Asian and Pacific regions: a meta-analysis. Prev Med (Baltim) 2011;53:260–267.

Barr SI, DiFrancesco L, Fulgoni VL. Association of breakfast consumption with body mass index and prevalence of overweight/obesity in a nationally-representative survey of Canadian adults. Nutr J 2016;15:33.

The National Health and Nutrition Survey in Japan. Office for Lifestyle Related Diseases Control, General Affairs Division, Health Service Bureau, Ministry of Health, Labour and Welfare (in Japanese), 2004.

Sasaki S, Yanagibori R, Amano K. Self-administered diet history questionnaire developed for health education: a relative validation of the test-version by comparison with 3-day diet record in women. J Epidemiol 1998;8:203–215.

Sasaki S, Ushio F, Amano K, et al. Serum biomarker-based validation of a self-administered diet history questionnaire for Japanese subjects. J Nutr Sci Vitamino (Tokyo) 2000;46:285–296.

Okubo H, Sasaki S, Rafamantanantsaoa HH, Ishikawa-Takata K, Okazaki H, Tabata I. Validation of self-reported energy intake by a self-administered diet history questionnaire using the doubly labeled water method in 140 Japanese adults. Eur J Clin Nutr 2008;62:1343–1350.

Kobayashi S, Honda S, Murakami K, et al. Both comprehensive and brief self-administered diet history questionnaires satisfactorily rank nutrient intakes in Japanese adults. J Epidemiol 2012;22:151–159.

Science and Technology Agency. Standard Tables of Food Composition in Japan (in Japanese). 5th rev. Printing Bureau of the Ministry of Finance: Tokyo, 2005.

Zeger SL, Lian K.Y. Longitudinal data analysis for discrete and continuous outcomes. Biometrics 1986;42:121–130.

Fulkerson JA, Sherwood NE, Perry CL, Neumark-Sztainer D, Story M. Depressive symptoms and adolescent eating and health behaviors: a multifaceted view in a population-based sample. Prev Med (Baltim) 2004;38:865–875.