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Frequency of consumption of balanced meals, bodyweight gain and incident risk of glucose intolerance in Japanese men and women: A cohort study

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ABSTRACT

Aims/Introduction: This cohort study assessed the risk for bodyweight gain and development of glucose intolerance based on the frequency of consumption of balanced meals including grain, fish or meat and vegetables.

Materials and Methods: The participants (8,573 men, 3,327 women) were employees of a company in Japan. A self-administered questionnaire was used to evaluate the frequency of balanced meal consumption. Bodyweight changes and the incidence of glucose intolerance (glycated hemoglobin >6.0%) during the 3-year follow-up period were determined through annual health examinations.

Results: The mean bodyweight change over a period of 3 years was 0.78 kg for men and 0.84 kg for women. A lower frequency of balanced meals was associated with a higher bodyweight gain for men (P for trend = 0.004), but not for women. During the study, 464 men and 115 women developed glucose intolerance. Overall, the frequency of balanced meals was not associated with the risk of glucose intolerance in either sex. However, the interaction between the frequency of balanced meals and degree of obesity had a significant effect on the incidence of glucose intolerance in men (P = 0.005), with less frequent consumption of balanced meals being associated with a higher risk for glucose intolerance among men with a BMI ≥25.0 kg/m^2 (P for trend = 0.007).

Conclusions: A higher frequency of balanced meals, including grain, fish or meat and vegetable dishes – important components of healthy Japanese food – was associated with a lower risk of glucose intolerance in obese men, but not in non-obese men and women.

INTRODUCTION

A traditional Japanese diet, *Washoku*, is considered to contribute to the health and longevity of Japanese people. According to previous analyses of dietary patterns, a Japanese diet has been associated with health status indices, such as longevity[1-3], cardiovascular disease[1,2,4], cancer[5,6], dementia[7], sarcopenia[8] and functional disability[9]. These health benefits are thought to be due to the foods and nutrients characteristic of a traditional Japanese diet; that is, more fish and seafood products, more soy, and less animal meat and dairy foods compared with Western diets[10].

Another feature of Japanese traditional food is the combination of dishes comprising the meal, *Ichiju Sansai* (one soup and three dishes). A grain (*Shushoku*), a fish or meat (*Shusai*) and a vegetable dish (*Fukusai*) are important components of *Ichiju Sansai*. In Japan, one goal of nutritional and dietary

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habits included in the second phase of the National Health Promotion Movement in the 21st century (Health Japan 21 [the second term]) is to increase the number of individuals eating balanced meals that include these three type of dishes more than twice a day[11]. According to the results of the National Health and Nutrition Survey in Japan, 45.4% of men and 49.0% of women ate these well-balanced meals every day[12]. However, evidence regarding the effects of these meals on health remains insufficient.

In this cohort study, we evaluated the associations of the frequency of well-balanced meals, including grain, fish or meat and vegetable dishes, with bodyweight changes over a period of 3 years, and the incidence of glucose intolerance in Japanese men and women. Additionally, we evaluated the impact of obesity on the relationship between the frequency of well-balanced meals and incidence of glucose intolerance.

METHODS

Participants

The study participants were employees of a company that produces metal products, such as aluminum sashes and zippers, in Japan. The Industrial Safety and Health Law in Japan requires that employers carry out annual health examinations for all employees. In 2014, 16,042 (87%) of 18,486 employees of this company received health examinations and responded to the health questionnaire. Among these 16,042 potential participants, 4,142 were excluded: 994 had high glycated hemoglobin (HbA1c; ≥6.0%) at the time of the baseline examination, 903 had missing data from the baseline health examination or health survey and 2,245 did not participate in the follow-up examinations. Thus, 11,900 participants (8,573 men and 3,327 women) were included in the present study.

Data collection

We collected data on height, bodyweight and HbA1c from the annual health examinations in 2014 (baseline) and 2017 (follow up). Body mass index (BMI) was calculated as weight / height^2 (kg/m^2). Obesity was defined as a BMI of ≥25 kg/m^2. A self-administered questionnaire was used to collect information on smoking status, frequency of alcohol intake, exercise habits and dietary habits. The frequency of consuming a well-balanced meal was self-reported in response to the question "On how many days per week do you eat at least two meals with grain, fish or meat and vegetable dishes?" using four semiquantitative categories: "every day," "3–4 days/week," "1–2 days/week" and "< 1 day/week (almost none)." The question was similar to that used in the National Health and Nutrition Survey in Japan[12].

Diagnosis of glucose intolerance

Casual plasma glucose and HbA1c levels were measured during the medical examinations. Because we did not have access to data about diabetes treatment, participants with HbA1c >6.0% at the baseline examination, for whom the possibility of diabetes could not be ruled out[12], were excluded from the study. It was difficult to collect fasting blood samples from all participants in the health examination, so HbA1c was used to diagnosis diabetes status. Participants with HbA1c ≥6.0% at the follow-up examination were defined as having glucose intolerance, and those with HbA1c ≥6.5% as having diabetes mellitus[12].

Statistical analysis

To compare baseline characteristics and changes in the variables between baseline and follow up among the groups, analysis of variance (ANOVA) was used for continuous variables, and the Bonferroni adjustment was used as a post-hoc test. The χ^2-test was used for categorical variables. Bodyweight changes over a period of 3 years within each group were compared using ANOVA. We calculated the incidence rates for glucose intolerance according to the four reported frequencies of well-balanced meal consumption. Odds ratios (OR) and 95% confidence intervals (95% CI) were calculated using logistic regression analysis. Adjustment for possible confounders was carried out sequentially: model 1 adjusted for age and baseline BMI (continuous); model 2 adjusted for age, baseline BMI, smoking status (never smoker, ex-smoker, current smoker), alcohol consumption (nondrinker/occasional, <20, 20–39, ≥40 g/day) and frequency of habitual exercise (none, 1–2 times/week, ≥3 times/week); and model 3 adjusted for all model 2 variables plus changes in bodyweight over the 3-year study (kg; continuous). The multivariate-adjusted OR was also calculated separately for the absence and presence of obesity. Statistical analyses were carried out using the Statistical Package for the Social Sciences (SPSS version 22; IBM Corporation, Tokyo, Japan). A *P*-value of <0.05 was deemed statistically significant.

Ethical considerations

Written informed consent was not obtained from the participants. The Data Health Plan is a plan for implementing health activities effectively and efficiently based on an analysis of various data, including medical cost details and results of health examinations, carried out by the health insurance associations in Japan. Based on the health insurance association plan at the subject company, a questionnaire survey on lifestyle is carried out every year. Participants are informed that the data might be used for research purposes and told of their right to refuse to participate in the cover letter of the questionnaire. Hence, participants who responded to the questionnaire were considered to have consented. The researchers explained the study design to the president of the company, and the president of the health insurance association; the Occupational Safety and Health Committee of the subject company, which includes employee representatives, approved the study. The company provided anonymous data to researchers to ensure that no individual was identified.

RESULTS

The mean age at baseline was 40.3 years for men and 39.1 for women. The mean BMI was 23.1 kg/m^2 for men and 21.5 kg/

m^2 for women. The characteristics of the participants according to the frequency of their consumption of well-balanced meals are shown in Table 1. A lower frequency of well-balanced meals was associated with significantly lower age, higher prevalence of current smokers, and lower frequency of habitual exercise for both men and women. A lower frequency of well-balanced meals was associated with a higher prevalence of excessive drinking among men.

The mean change in bodyweight over the period of 3 years was 0.78 kg for men and 0.84 kg for women. A lower frequency of well-balanced meals was associated with a significantly greater body weight gain for men (P for trend = 0.004; Table 2). There was no association between the frequency of well-balanced meals and bodyweight change for women.

The incidence of glucose intolerance (HbA1c ≥6.0%) over the period of 3 years was 5.4% for men and 3.5% for women, and that of diabetes mellitus (HbA1c ≥6.5%) was 0.6% for men and 0.2% for women. The number of incident diabetes cases was too small, so we used glucose intolerance for subsequent analysis.

For participants as a whole, the frequency of well-balanced meals was not associated with the incidence of glucose intolerance among men or women (Table 3). The interaction between the frequency of well-balanced meal intake and the degree of

Table 1 | Baseline characteristics of study participants according to the frequency of well-balanced meals including a grain dish, a fish or meat dish and a vegetable dish

	Total	Frequency of well-balanced meals				$P^{\dagger}$
		Every day	3–4 days/week	1–2 days/week	< 1 day/week	
Men						
n	8,573	4,223	2,384	1,338	628	
Age (years)	40.3 ± 11.0	40.9 ± 11.2	39.8 ± 10.9*	39.8 ± 10.6*	39.0 ± 10.8***	<0.001
Body mass index (kg/m^2)	23.1 ± 3.2	23.2 ± 3.1	23.1 ± 3.2	23.1 ± 3.2	23.1 ± 3.7	0.889
Smoking status (%)						
Never	36.6	39.7	34.8	31.2	33.9	<0.001
Ex-smoker	23.9	25.9	23.9	21.0	17.4	
Current smoker	39.4	34.4	41.2	47.8	48.7	
Alcohol intake (%)						
Never, occasional	53.4	52.2	52.6	55.5	59.6	<0.001
<20 g/day	10.5	11.9	10.5	7.6	7.6	
20–39 g/day	19.1	19.4	20.1	18.7	13.9	
≥40 g/day	12.4	12.1	11.6	13.8	15.1	
Regular exercise (%)						
<1 time/week	46.3	42.2	45.8	51.9	63.9	<0.001
1–2 times/week	43.0	45.3	44.3	40.4	29.0	
≥3 times/week	10.5	12.5	9.7	7.5	7.0	
Women						
n	3,327	1,927	801	395	204	
Age (year)	39.1 ± 10.4	40.1 ± 10.2	38.7 ± 10.3*	37.2 ± 10.8*	35.5 ± 10.8***	<0.001
BMI (kg/m^2)	21.5 ± 3.5	21.5 ± 3.5	21.5 ± 3.5	21.7 ± 4.0	21.5 ± 3.6	0.601
Smoking status (%)						
Never	82.4	84.3	80.8	79.2	77.5	0.038
Ex-smoker	9.2	8.4	10.0	9.9	11.8	
Current smoker	8.3	7.1	9.2	10.9	10.8	
Alcohol intake (%)						
Never, occasional	81.1	81.1	81.3	80.0	82.4	0.111
<20 g/day	8.9	9.9	7.1	7.6	8.8	
20–39 g/day	6.5	5.9	7.0	9.4	4.9	
≥40 g/day	2.0	1.8	2.6	1.5	2.9	
Regular exercise (%)						
<1 time/week	66.2	64.0	69.0	66.8	74.5	0.033
1–2 times/week	27.2	28.4	26.0	27.1	21.1	
≥3 times/week	6.3	7.4	4.7	5.6	4.4	

Values are presented as *n*, mean ± standard deviation or percentage. *P < 0.05 versus "Every day" group, **P < 0.05 versus "'3–4 days/week" group for post-hoc test. †Analysis of variance was used for continuous variables, and the χ^2-test was used for categorical variables.

Table 2 | Bodyweight changes (kg/3 years) according to the frequency of well-balanced meals including a grain dish, a fish or meat dish and a vegetable dish

	Frequency of well-balanced meals				*P* for trend
	Every day	3–4 days/week	1–2 days/week	< 1 day/week	
Men	0.66 ± 0.06	0.82 ± 0.07	1.00 ± 0.10	0.90 ± 0.16	0.004
Women	0.78 ± 0.07	0.99 ± 0.11	0.94 ± 0.16	0.73 ± 0.20	0.430

Values are presented as mean ± standard error.

obesity had a significant effect on the incidence of glucose intolerance for men only (*P* for interaction = 0.005). Among obese men, compared with participants who ate well-balanced meals every day, the adjusted OR for glucose intolerance was significantly higher for those who did so 1–2 days/week (OR 1.61, 95% CI 1.07–2.42) and <1 days/week (1.73, 95% CI 1.02–2.94; *P* for trend = 0.007; model 2). These associations were similar, even after adjustment for 3-year changes in bodyweight (model 3). In contrast, there was no association between well-balanced meals and the likelihood of glucose intolerance among non-obese men, and no interaction was observed for women (*P* for interaction = 0.435).

Compared with non-obese participants who ate well-balanced meals every day, the risk of glucose intolerance was significantly higher for those who were obese and ate well-balanced meals every day (OR 1.82, 95% CI 1.36–2.45). ORs for obese participants were elevated according to the frequency of well-balanced meal intake, and ORs were the highest for the obese participants who ate such meals <1 day/week (3.58, 95% CI 2.16–5.95; Figure 1).

DISCUSSION

The frequency of consuming well-balanced meals including grain, fish or meat and vegetable dishes was associated with weight gain in Japanese men. In addition, the interaction between the frequency of well-balanced meal consumption and the presence of obesity had a significant effect on the development of glucose intolerance; consumption of well-balanced meals was related to lower incident risk of glucose intolerance among obese male participants. The risk of glucose intolerance was unrelated to bodyweight gain during the follow-up period. In contrast, the frequency of well-balanced meal intake was not significantly associated with bodyweight gain or the incidence of glucose intolerance among women. A meal consisting of *Shushoku* (grain dishes), *Shusai* (fish or meat dishes) and *Fukusai* (vegetable dishes) is an important component of *Ichiju Sansai* (one soup and three dishes) in the Japanese diet. The present results showed that well-balanced meals of Japanese food decreased the risk of weight gain and impaired glucose tolerance, especially in men.

Well-balanced meal consumption was inversely associated with bodyweight gain and the incidence of glucose intolerance in men. Previous studies showed that well-balanced meal intake was associated with lower intake of carbohydrates and higher intake of protein, fish, vegetables and dietary fiber[13,14]. Total carbohydrate intake was reportedly associated with an elevated risk of diabetes in Chinese women[15] and in Japanese men with obesity[16], although no association was observed in previous studies carried out in Western countries[17-21]. The results of an international study of associations of macro- and micronutrient levels with blood pressure (INTERMAP) showed that intake of carbohydrate was higher in East Asian countries compared to Western countries[22,23]. Well-balanced meals might reduce excessive carbohydrate intake in Japanese people. High dietary fiber intake was also reportedly associated with a lower risk of bodyweight gain[24] and diabetes[25,26]. These nutritional characteristics of well-balanced meals may help prevent body weight gain and glucose intolerance.

The traditional Japanese diet has been thought to contribute to the health and longevity of Japanese people. The major components of a traditional Japanese diet; that is, high intake of fish and shellfish[27], soy beans[28], vegetables and fruits[29], and combinations of these[2], were also associated with a lower risk of cardiovascular disease. A well-balanced meal including grain, fish or meat and vegetable dishes was found to be associated with adequate nutrient intake[13,14]. However, the impact of the balance of the meal on health status is not yet sufficiently clear. In Japan, the Ministry of Health, Labor and Welfare, and the Ministry of Agriculture, Forestry and Fisheries of Japan jointly developed the Japanese Food Guide Spinning Top in 2005[30]. This guide shows the optimal balance and quantity of food in the daily Japanese diet using illustrations. Studies using a scoring system to measure adherence to this food guide showed that higher adherence scores – that is, better meal balance – were associated with lower total mortality and lower mortality from cardiovascular disease[31,32]. In a cross-sectional study of Japanese people aged 75 years, well-balanced meals were associated with the presence of ≥20 teeth[33]. A recent cross-sectional study also showed the inverse association between well-balanced meal consumption and the risk of frailty in older Japanese people[34]. The balance of the traditional Japanese diet seems to contribute to healthy longevity in part due to food intake that requires chewing well with one's own teeth, prevents frailty and carries a lower risk of cardiovascular disease.

In the present study, a low frequency of well-balanced meals was associated with the incidence of glucose intolerance in

Table 3 | Incidence and odds ratio of glucose intolerance over a period of 3 years according to the frequency of well-balanced meals including a grain dish, a fish or meat dish and a vegetable dish for all participants, non-obese participants and obese participants

	Frequency of well-balanced meals				*P* for trend
	Every day	3–4 days/week	1–2 days/week	< 1 day/week	
Men					
Total					
N	4,223	2,384	1,338	628	
n	223	122	82	37	
Incidence (%)	5.3	5.1	6.1	5.9	
OR (95% CI)					
Model 1	1.00 (Reference)	1.02 (0.81–1.28)	1.26 (0.96–1.65)	1.27 (0.88–1.84)	0.070
Model 2	1.00 (Reference)	1.00 (0.79–1.27)	1.22 (0.93–1.60)	1.22 (0.84–1.78)	0.134
Model 3	1.00 (Reference)	1.00 (0.79–1.26)	1.19 (0.91–1.57)	1.21 (0.83–1.77)	0.177
Non-obese (BMI <25 kg/m^2)					
N	3,221	1,803	995	471	
n	141	62	40	15	
Incidence (%)	4.4	3.4	4.0	3.2	
OR (95% CI)					
Model 1	1.00 (Reference)	0.86 (0.63–1.17)	1.00 (0.69–1.44)	0.89 (0.51–1.54)	0.663
Model 2	1.00 (Reference)	0.85 (0.62–1.16)	0.97 (0.67–1.41)	0.88 (0.51–1.53)	0.584
Model 3	1.00 (Reference)	0.83 (0.61–1.14)	0.96 (0.66–1.39)	0.89 (0.51–1.55)	0.549
Obese (BMI ≥25 kg/m^2)					
N	1,002	581	343	157	
n	82	60	42	22	
Incidence (%)	8.2	10.3	12.2	14.0	
OR (95% CI)					
Model 1	1.00 (Reference)	1.31 (0.92–1.87)	1.70 (1.13–2.54)	1.88 (1.12–3.16)	0.002
Model 2	1.00 (Reference)	1.28 (0.90–1.84)	1.61 (1.07–2.42)	1.73 (1.02–2.94)	0.007
Model 3	1.00 (Reference)	1.33 (0.92–1.91)	1.59 (1.05–2.41)	1.69 (0.99–2.91)	0.010
Women					
Total					
N	1,927	801	395	204	
n	69	27	15	4	
Incidence (%)	3.6	3.4	3.8	2.0	
OR (95% CI)					
Model 1	1.00 (Reference)	1.03 (0.65–1.64)	1.14 (0.62–2.08)	0.63 (0.22–1.80)	0.772
Model 2	1.00 (Reference)	1.00 (0.63–1.60)	1.09 (0.59–2.00)	0.58 (0.20–1.65)	0.605
Model 3	1.00 (Reference)	0.99 (0.62–1.58)	1.08 (0.59–1.99)	0.57 (0.20–1.64)	0.582
Non-obese (BMI <25 kg/m^2)					
N	1673	689	335	172	
n	43	18	6	2	
Incidence (%)	2.6	2.6	1.8	1.2	
OR (95% CI)					
Model 1	1.00 (Reference)	1.06 (0.60–1.88)	0.81 (0.34–1.95)	0.65 (0.15–2.77)	0.569
Model 2	1.00 (Reference)	0.98 (0.55–1.75)	0.76 (0.31–1.84)	0.60 (0.14–2.55)	0.416
Model 3	1.00 (Reference)	0.96 (0.54–1.72)	0.76 (0.31–1.84)	0.61 (0.14–2.61)	0.413
Obese (BMI ≥25 kg/m^2)					
N	254	112	60	32	
n	26	9	9	2	
Incidence (%)	10.2	8.0	15.0	6.3	
OR (95% CI)					
Model 1	1.00 (Reference)	0.90 (0.40–2.03)	1.68 (0.72–3.95)	0.62 (0.14–2.81)	0.826

Table 3 | (*Continued*)

	Frequency of well-balanced meals				*P* for trend
	Every day	3–4 days/week	1–2 days/week	< 1 day/week	
Model 2	1.00 (Reference)	0.93 (0.41–2.12)	1.63 (0.68–3.90)	0.64 (0.14–2.96)	0.825
Model 3	1.00 (Reference)	1.04 (0.45–2.41)	1.59 (0.65–3.91)	0.56 (0.12–2.64)	0.925

BMI, body mass index; CI, confidence interval; OR, odds ratio. Model 1: adjusted for age and baseline body mass index (BMI); model 2: adjusted for age, BMI, alcohol consumption, smoking status and habitual exercise; model 3: adjusted for variables used in model 2 plus 3-year changes in bodyweight.

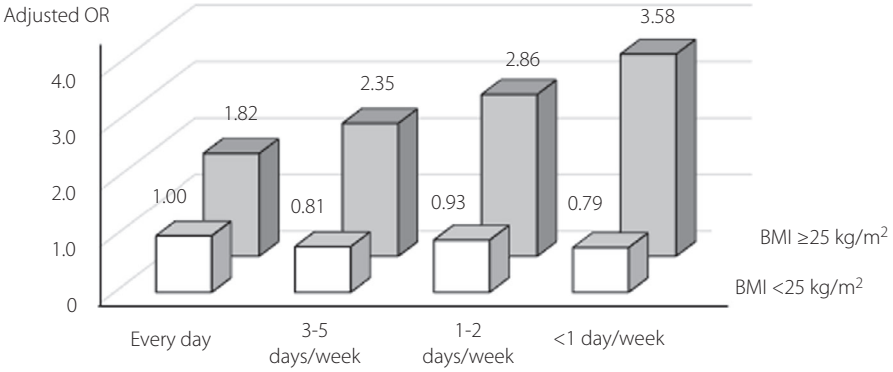

Figure 1 | Adjusted odds ratio of the incidence of glucose intolerance by the presence of obesity and the frequency of well-balanced meals including a grain dish, a fish or meat dish and a vegetable dish in 8,573 Japanese men. The odds ratios are adjusted for age, smoking status, alcohol intake, habitual exercise and 3-year changes in bodyweight. BMI, body mass index; OR, odds ratio.

obese men. In previous studies from Asian countries, carbohydrate intake was associated with a higher risk of diabetes mellitus only in obese participants with BMI ≥25 kg/m^2[15,16]. Obese Asian people are at high risk of diabetes mellitus because of higher insulin demand resulting from obesity-related insulin resistance and reduced insulin secretion capacities compared with Westerners[35-37]. Dietary risk factors for diabetes, such as higher carbohydrate intake and poorly balanced meals, might have stronger effects on the incidence of glucose intolerance for obese participants with these high-risk characteristics.

Associations of well-balanced meals with bodyweight change and incidence of glucose intolerance were observed in men, but not in women. A higher percentage of women consumed well-balanced meals every day compared with men, which might be due to greater health consciousness among women. Another possible reason is that the female participants were relatively younger, which might have influenced the incidence of obesity and metabolic abnormalities. The results of the Japan National Health and Nutrition Survey[12] showed that the prevalence of obesity peaked in the 50s in men. By contrast, in women, the prevalence of obesity, as well as the prevalence of diabetes mellitus, increased with age, with the highest rates being among women aged >70 years. The mean age of the present study participants was approximately 40 years; thus, a study with older participants might clarify the risks of obesity and diabetes for women. Furthermore, the lower incidence of obesity and glucose intolerance among women compared with men might have affected the sex differences identified in the results.

The main strength of the present study was that this is the first prospective cohort study to evaluate the association between metabolic outcomes and consumption of well-balanced meals consisting of grain, fish or meat and vegetable dishes, one of the target nutritional and dietary habits included in Health Japan 21 (the 2nd term). Furthermore, bodyweight changes and the incidence of glucose intolerance were evaluated using reliable data obtained from annual examinations. The study also had some limitations. First, data on the frequency of well-balanced meal were obtained from a non-validated questionnaire. No validated questionnaire has been designed to assess adherence to this well-balanced diet. However, the question used in the present study was similar to that used in the National Health and Nutrition Survey in Japan[12]. A study that evaluated the reproducibility of this question among older Japanese found a Spearman correlation coefficient of 0.33 between

two tests separated by a 1-year interval, and the reproducibility was fair[34]. Second, the present study participants were all from a workplace. Because some individuals might be excluded from working because of poor health, participants in this study might have been healthier, and the prevalence of obesity or incidence of glucose intolerance might have been lower than in the general Japanese population. Third, we evaluated impaired glucose tolerance only by HbA1c. Because a casual blood sample was collected at the annual health examination, we did not have the data of fasting plasma glucose levels. HbA1c is an indirect measure of average blood glucose levels, and other factors might affect hemoglobin glycation independently of glycemia; for example, age, anemia and hemoglobinopathies. To diagnose the impaired glucose tolerance only by HbA1c might cause misclassification of the diagnosis. Additionally, we did not have data on medical treatment for diabetes. In general practice, an HbA1c goal for many adults with diabetes is <7%, and a more stringent HbA1c goal – that is, HbA1c <6.5% – is acceptable if this can be safely achieved without significant hypoglycemia or other adverse effects of treatment[38]. Participants with HbA1c >6.0% at the baseline examination were excluded from the present study, and most participants who were receiving medical treatment for diabetes would thus be excluded from the study. However, the incidence of diabetes mellitus, and also that of glucose intolerance, might be underestimated due to the lack of the data on medical treatment for diabetes at the follow-up examination. Furthermore, we did not have data on nutritional factors, such as total energy intake and intake of dietary fiber. Well-balanced meals have been associated with adequate nutrient intake[13-14]; however, we could not evaluate which nutritional factors of such meals contributed to preventing obesity and glucose intolerance.

In conclusion, more frequent consumption of well-balanced meals consisting of grain, fish or meat and vegetable dishes, which together constitute an important component of a healthy Japanese diet, was associated with a lower risk of bodyweight gain and glucose intolerance in Japanese men, but not in women. The dietary assessment of a well-balanced meal would be useful to identify the people at high risk of obesity and glucose intolerance. Increasing the frequency of well-balanced meals might be an acceptable lifestyle intervention for the prevention of obesity and glucose intolerance.

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DISCLOSURE

The authors declare no conflict of interest.

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