# Breakfast Skipping is Positively Associated with Incidence of Type 2 Diabetes Mellitus - Evidence from Aichi Workers' Cohort Study

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## ABSTRACT

**Background:** Skipping breakfast has been suspected as a risk factor for type 2 diabetes (T2DM), but the associations are not entirely consistent across different ethnicities or sexes, and the issue has not been adequately addressed in Japanese.

**Methods:** We followed 4631 participants (3600 men, 1031 women) in a work-site aged 35-66 years in 2002 through 2011 for T2DM development. Frequency of eating breakfast was self-reported and was subsequently dichotomized to breakfast skippers who eat breakfast 3-5 times/week or less and to eaters. Cox proportional hazards models were used to adjust for potential confounding factors including dietary factors, smoking and other lifestyles, body mass index (BMI) and fasting blood glucose (FBG) at baseline.

**Results:** During 8.9-year follow-up, 285 T2DM cases (231 men, 54 women) developed. Compared to participants who reported eating breakfast everyday, maximally-adjusted hazard ratios (95% confidence intervals) of those with the frequency of almost everyday, 3-5, 1-2 and 0 days/week were: 1.06 (0.73-1.53), 2.07 (1.20-3.56), 1.37 (0.82-2.29), and 2.12 (1.19-3.76), respectively. In a dichotomized analysis, breakfast skipping was positively associated with T2DM incidence (maximally-adjusted hazard ratio: 1.73, 95% confidence interval: 1.24-2.42). The positive associations were found in both men and women, current and non-current smokers, and normal weight and overweight (BMI≥25 kg/$m^2$), or normal glycemic and impaired fasting glycemic individuals at baseline (110≤FBG<126 mg/dl) (*P*s for interaction all>0.05).

**Conclusion:** The present study in middle-aged Japanese men and women suggests that skipping breakfast may increase the risk of T2DM independent of lifestyles and baseline levels of BMI and FBG.



Keywords: breakfast; diabetes mellitus; cohort study; Japan

## INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a major cause of morbidity and mortality globally.[1] Indeed, the prevalence of diabetes in Japanese aged 40-69 was reported as high as 10.2% in male and 4.7% in female workers in large-scale companies in 2008-2010 and 15.0% in men and 8.0% in women in the National Health and Nutrition Survey in 2011.[2, 3] Diabetes is also the 14th highest cause of disability-adjusted life years (DALYs) in Japan in 2010.[4] It is estimated that diabetes prevalence will remain almost stable in the next 20 years.[5]

At the same time, skipping breakfast has been suggested to be associated with the incidence of several diseases or conditions, such as obesity,[6] insulin insensitivity,[7] cardiovascular diseases,[8] and T2DM.[9-11] However, the associations of breakfast skipping with T2DM are not entirely consistent across different ethnicities or sexes, and the issue has not been adequately addressed in Japanese. Furthermore, breakfast skipping is becoming common in Japan as the 2013 National Health and Nutrition Survey indicated that 14.4% men and 11.1% women start their day without having breakfast.[3] Since breakfast eating habit is modifiable, examining the possible causal relationship would have public health significance in the prevention of T2DM.

Therefore, we designed the present study to examine the association between breakfast skipping and the incidence of T2DM in a large-scale prospective cohort of middle-aged Japanese men and women, and to find out whether the association would be independent of diet and lifestyles, body mass index (BMI) and fasting blood glucose (FBG) levels at baseline.

## METHODS

### Study population

We used the data obtained from the Aichi workers' cohort study. The cohort included 6648 Japanese civil servants in Aichi prefecture, an urban and suburban area located in central Japan. Participants were between 35 and 66 years old at recruitment in 2002. Most workers in the cohort were engaged in clerical work. Police officers, firefighters and public school teachers were not included but health professionals working in prefectural hospitals were included in the cohort. The baseline survey conducted in 2002 included a self-administered questionnaire concerning their lifestyles and medical history, and health checkup. Written informed consents were obtained in advance separately for lifestyle questionnaire and the use of annual health checkup data.

We excluded the following participants : (1) those who did not agree to our use of the annual health checkup results (n=1045); (2) those with missing information for the following variables: frequency of eating breakfast (n=8), energy intake (n=83), and smoking status (n=48); (3) prevalent cases of diabetes mellitus defined as self-reported medication use (n=570) or baseline glucose level ≥126 mg/dl (n=128); and (4) those modifying their diet under physicians' or dieticians' suggestion (n=135), leaving 4631 participants (3600 men, 1031 women) for the present analysis.

Participants were followed until the end of follow-up (March 31, 2011), censored, or ascertainment of diabetes, whichever came first. Participants were censored when they retired except for those who provided their postal address to the researchers. The number of participants who were censored due to their retirement was 919. The study protocol was approved by the Ethics Review Committee of Nagoya University School of Medicine.

**Ascertainment of Incident T2DM**

We ascertained incidence of T2DM by two methods. First, we defined the incidence as the year when FBG level reached 126 mg/dl or over. We arbitrarily set the data of onset as July 1st for the analysis considering the fact that the checkups were usually carried out from October to December and that T2DM would generally be a chronic state without a definite onset. Second, we utilized data from self-administered questionnaire surveys on medical history, which were conducted in 2004, 2007, and

2011. In the surveys, participants reported medical histories of T2DM and other pre-specified condition. Those who had T2DM history provided information about the onset (year of diabetes diagnosis) as well as the name and the address of their present or past physician. We obtained written consent from those with the histories for our accessing their medical records via their specified physicians. We previously confirmed the accuracy (95%) of self-reports by reviewing the medical records from cases with written consent, and the details of the validation study have been reported elsewhere.[12] Health checkups were provided annually during their employment. After the retirement, participants were followed only by the questionnaire. Health checkup results of retired participants were not systematically collected.

**Frequency of eating breakfast**

In this study we assessed frequency of eating breakfast using self-administered questionnaire. Breakfast eating frequency was assessed using the following five categories: everyday, almost everyday with occasional skips, 3-5 days/week, 1-2 days/week, and none. We later reclassified the participants into two groups as breakfast eaters (those who reported their breakfast eating frequency as everyday and almost everyday with occasional skips) and breakfast skippers (those who classified themselves in the breakfast eating categories of 3-5 days/week, 1-2 days/week, and none). The reproducibility (Spearman's correlation coefficient) of the breakfast eating frequency question over 9-month period has been reported to be 0.62.[13] In addition, 2752 out of the present 4631 participants also reported breakfast eating frequency after five years from the baseline (in 2007). The agreement between these two surveys was still fair (Spearman's correlation coefficient: 0.55).

**Other dietary factors**

Self-administered brief-type dietary history questionnaire (BDHQ) was used for the assessment of diet, and intakes of nutrients, alcohol as well as total energy.[14, 15] Intakes of fish, fruits, vegetables, whole-grain cereals, coffee, sugar-sweetened beverages and snack obtained by BDHQ were adjusted for total energy intake by the nutrient density method.[14] Eating speed was self-reported in the BDHQ as very fast, relatively fast, medium, relatively slow and slow. The last two categories were combined in the analysis. Information about participants' habit of eating to satiety was also obtained in addition to the information obtained by BDHQ.

**Anthropometric measurements and biochemical analysis**

Height was measured to the nearest 0.1 cm with participants standing upright against a stadiometer without shoes. Body weight was measured to the nearest 0.1 kg with the participants in typical indoor clothing. BMI was calculated as weight (kg) divided by the square of height (meter). Venous blood samples were drawn after the participants fasted for eight hours or more, or overnight, and serum samples were frozen at -80 degree Celsius until the biochemical assay. Blood glucose was enzymatically determined by the hexokinase method. Insulin concentration was measured by solid-phase radioimmunoassay (RIABEAD II; Dinabot Co., Ltd., Chiba, Japan).

**Other variables**

Smoking status was classified into three categories (current, former and never). The number of days engaged in leisure-time physical activity for 60 minutes or more was self-reported and it was classified into two categories: 3 days or more/week, less than 3 days/week. Work-time physical activity was assessed by the question "Are you engaged in physical labor?" and classified into two categories (yes, no). Work schedule was classified into four categories: with shiftwork including night shifts, with shiftwork but without night shifts, without shiftwork but with night works, without both shiftwork and night works. Sleep duration was classified into two categories: less than 7 hours, and 7 hours or more. Strength of perceived stress was self-reported by the following four categories: very much, much, ordinary, and little. Family history of diabetes among the first-degree relatives was self-reported and used as a dichotomized variable (yes, no) in the analysis.

**Statistical analysis**

FBG values were $log_{10}$-transformed to approximately normalize their distribution prior to the analyses, and are presented as geometric means and their 95% confidence intervals (95% CIs). Other continuous variables were summarized as means and standard deviations (SD) while percentages were used for categorical variables. One-way analysis of variance (ANOVA) or $\chi^2$ tests were used, as appropriate, to compare baseline characteristics of breakfast eaters and breakfast skippers.

Multivariable adjusted Cox proportional hazards models were used to estimate hazard rations (HRs) and 95% CIs of the risk of T2DM according to breakfast eating frequency and in breakfast skippers relative to breakfast eaters. Model 1 was adjusted for age, sex, total energy intake, smoking status, alcohol consumption, leisure-time physical activity, work-time physical activity, family history of diabetes mellitus, eating speed, perceived stress, sleep duration, work schedule, habit of eating to satiety, intakes of fruits and vegetables, fish, whole-grain cereals, coffee, sugar-sweetened beverages and snacks. In Model 2, BMI (continuous) was included in addition to all the variables in Model 1. We adjusted for FBG (continuous) in Model 3 together with the variables in Model 2.

We then performed the above analyses stratified by sex, smoking status (current, never or former) and baseline values of BMI (less than 25 $kg/m^2$, 25 $kg/m^2$ or more) and FBG (less than 110 mg/dl, 110 mg/dl or more). We also conducted sensitivity analyses by excluding incident cases who were followed up for less than 3 years (n=119) and those who were night shift workers (n=53). Furthermore, we carried out an analysis by censoring all the participants at the age of 60 (retirement age) because not all the retired participants were followed up (n of participants who were followed up after retirement= 881).

Then, we have also performed an analysis by updating breakfast skipping information to the one obtained after five years from baseline when available (approximately 70%) using time-dependent Cox regression model. For those who did not have such information, we carried forward the 2002 frequency.

Another ancillary analysis changing the outcome to impaired fasting glucose (IFG) or diabetes defined as FBG ≥110 mg/dl was performed in an attempt to examine similarity and discrepancy of our findings to a prior study that used such outcome.[16]

All statistical analyses were conducted with IBM SPSS Statistics for Windows, Version 22.0 software (IBM Corp, Armonk, New York). All tests were two-sided, and $P < 0.05$ was considered statistically significant.

## RESULTS

Out of the 4631 participants included in our analysis, 90.4% were breakfast eaters. Compared with breakfast eaters, breakfast skippers seem to have worse lifestyles. For example, breakfast skippers were more likely to be current smokers, consumed more alcohol and sugar-sweetened beverages, had less intakes of fruits and vegetables (all $P < 0.05$) (Table 1).

During a median of 8.9-year follow-up, 285 cases of T2DM (231 men, 54 women) developed (crude incidence rate: 8.2 per 1000 person-years). Participants who reported eating breakfast 3-5 days/week, 1-2 days/week, and 0 days/week had higher T2DM incidence compared to those consumed breakfast everyday (Model 3 HRs ranging 1.37-2.12) (Table 2). However, the point estimates fluctuated and were not always statistically significant, and there was no apparent positive trend in the T2DM incidence according to the number of days breakfast was skipped. In addition, T2DM incidence of those who skipped breakfast only occasionally was not higher than everyday eaters (Model 3 HR: 1.06). In the subsequent dichotomized analysis, T2DM incidence of breakfast skippers was significantly higher than that of breakfast eaters (crude incidence rate: 13.9/1000 person-years vs. 7.5/1000, Model 3 HR: 1.73). The positive associations between breakfast skipping and T2DM were similar in both men and women, current and non-current smokers, and normal weight and overweight as well as normal glycemic and impaired fasting glycemic individuals at baseline (all interaction *P*>0.05) (Table 3). Furthermore, similar associations were found in sensitivity analyses that excluded incident cases whose follow up periods in the cohort were less than 3 years (model 3 HR: 1.94, 95% CI: 1.24-2.98) and those who were night shift workers (model 3 HR: 1.91, 95% CI: 1.30-2.80). Also, the association by the analysis that censored all the participants who reached 60 years did not materially differ (model 3 HR: 1.71, 95% CI: 1.21-1.49). The analysis updating breakfast skipping information also yielded similar result (model 3 HR: 1.66, 95% CI: 1.19-2.32). In another ancillary analysis that used IFG or T2DM as the outcome among participants whose baseline FBG <110 mg/dl (men n=3371, women n=986), skipping breakfast was also significantly associated with higher incidence of IFG or T2DM (n of incidence: 707, model 3 HR: 1.29, 95% CI: 1.02-1.63, *P*=0.03).

## DISCUSSION

In the present study, we found that breakfast skipping was positively and significantly associated with T2DM incidence in middle-aged Japanese men and women, after adjustment for a number of potential confounding variables including baseline

BMI as well as FBG levels. We confirmed the associations in both men and women, and in individuals with or without overweight or IFG at baseline. Although the association in current smokers was not statistically significant, formal test of interaction did not suggest statistically significant difference in the association between current and non-current smokers. The significant and positive association between breakfast skipping and T2DM observed in our study is in line with previous studies conducted in the US.[9-11] We extended the finding to Japanese and confirmed the associations in the several subgroups.

The positive association between breakfast skipping and the risk of T2DM shown in our study would also be in line with a previous study in Japan,[16] although the study only found the association in women, did not adjust for important lifestyle variables or perform detailed stratified analyses, and used IFG as the outcome. Our ancillary analysis that employed IFG or T2DM as the outcome found weaker but similar association as the original analysis.

In the present study, we did not find dose-response association between breakfast eating (skipping) frequency and T2DM incidence. This is not consistent with a finding from the CARDIA Study (average baseline age: 32 years) that stepwise inverse association was found between breakfast eating frequency and T2DM incidence in white men and women and black men but not in black women. The reason for the discrepancy is not clear. Other studies conducted in the US did not specifically address the issue of dose-response. Also, caution is required that the definition of skipping breakfast differs by studies.[10, 11]

Since previous studies in Japan reported the association between breakfast skipping and higher BMI[6, 17] as well as regular smoking, we attempted to examine the association precisely by stratifying the analyses by these variables, and found that the associations were similar across the strata. Nonetheless, the relatively stronger effect estimates for those in the higher baseline BMI categories may somehow corroborate the belief that BMI could influence participants' dietary habits including breakfast eating behavior and hence may potentially modify its association with T2DM.[6, 17] However, whether or not this was really due to the influence of participants' prior knowledge of their BMI and FBG needs further investigation.

We speculated a few mechanisms by which breakfast skipping could potentially cause T2DM. First, it was reported that after-lunch postprandial glucose and insulin levels were significantly higher in participants who skipped breakfast than those who consumed breakfast.[18] Similarly, omitting breakfast was reported to impair postprandial insulin sensitivity.[7] Since the level of 1,5-anhydroglucitol, an indicator for short-term hyperglycemia and glycemic excursions was significantly associated with the development of diabetes independent of HbA1c levels, metabolic alterations induced by breakfast skipping may have predisposed the individuals to diabetes.[19] Second, skipping breakfast could mean having infrequent larger meals. Total energy intakes in the present study were 1942 and 1740 kcal/day in breakfast eaters and breakfast skippers respectively. We could guess that breakfast skippers had more energy intake per serving, which mean that they had larger meal size per serving than breakfast eaters. This may also be associated with future diabetes incidence through greater postprandial glucose and insulin responses. Another mechanism could be related to residual confounding of other lifestyles.[17] Although we have adjusted for a number of lifestyles, breakfast skippers may have other lifestyle and behavior characteristics that may cause T2DM.

Our study has several other limitations. First, although its fair reproducibility over nine months as well as five years was shown, breakfast consumption was self-reported and subject to a subjective interpretation of what constitutes a breakfast and duration of fasting before the meal. However, the possible information bias as a result would be non-differential and is not expected to influence our findings. Indeed, no material difference in our finding was seen after excluding night shift workers who may have the habit of taking early morning snacks.[20, 21] Second, there was no information of the nutrient composition of the breakfast consumed and we could not assess the effect of quality of breakfast in the association between breakfast consumption and T2DM. Since breakfast cereal intake was inversely associated with T2DM incidence,[22] the association might have been different if we had the information. Third, we ascertained T2DM incidence by single identification of diabetic FBG level. Although this definition is commonly employed in epidemiologic studies, HbA1c or oral glucose tolerance test results should ideally be used. We also utilized self-reports for T2DM ascertainment, which would have high specificity but relatively lower sensitivity.[23] Finally, observational nature of the present study would prevent any definitive statement about causality. Although our study participants were relatively homogeneous middle-aged Japanese civil servants with similar demographic, socioeconomic and environmental backgrounds, there may still be unknown or uncontrolled confounding. Since long-term randomized controlled trial would be difficult to conduct, well-designed cohort studies in the other settings may be useful since findings on the issue are still scarce and have not always been consistent.

In summary, our findings indicate that skipping breakfast would increase the risk of T2DM in middle-aged Japanese workers, and the association was independent of several dietary and lifestyle factors, baseline levels of BMI and FBG. Public health messages promoting the benefits of eating breakfast could be distributed in civil service institutions in Japan and the public at large.

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## CONFLICTS OF INTEREST

None

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Table 1. Means (SD) or percentages of participants' demographic, lifestyle, dietary habit and metabolic risk factor characteristics according to breakfast consumption status at baseline, Aichi, 2002.

| | Breakfast eaters [a] | Breakfast skippers [b] | *P* value [c] |
|---|---|---|---|
| n, % | 4188, 90.4 | 443, 9.6 | |
| Men, % | 78.2 | 73.8 | 0.04 |
| Age, year | 47.8 (7.1) | 46.0 (6.8) | <0.001 |
| Body mass index, kg/m$^2$ | 22.9 (2.8) | 22.9 (3.0) | 0.78 |
| Smoking status, % | | | |
| current | 26.7 | 44.9 | <0.001 |
| former | 23.4 | 14.2 | |
| never | 49.9 | 40.9 | |
| Leisure-time physical activity, % [d] | | | |
| 3 days or more/week | 75.5 | 84.2 | <0.001 |
| less than 3 days/week | 16.0 | 9.5 | |
| Work-time physical activity, yes, % | 5.3 | 7.7 | <0.01 |
| Family history of diabetes mellitus, yes, % | 14.8 | 17.4 | 0.14 |
| Fasting blood glucose, mg/dl [e] | 92.3 (92.0 – 92.6) | 92.5 (91.5 – 93.4) | 0.74 |
| Perceived stress, % [d] | | | |
| very much | 11.0 | 13.8 | 0.02 |
| much | 40.1 | 39.7 | |
| ordinary | 43.8 | 39.1 | |
| little | 4.9 | 6.8 | |
| Sleep duration, % [d] | | | |
| less than 7 hours/day | 52.9 | 61.6 | <0.001 |
| 7 hours or more/day | 45.5 | 35.7 | |
| Work schedule, % [d] | | | |
| without both shift work and night shifts | 84.6 | 78.3 | <0.001 |
| with shift work but without night shifts | 1.9 | 1.4 | |
| without shift work but with night shifts | 6.8 | 7.9 | |
| with shift work including night shifts | 4.9 | 11.3 | |

SD denotes standard deviation.

[a] Breakfast eater was defined as those having breakfast eating frequency of 'everyday or almost everyday with occasional skips'.

[b] Breakfast skipper was defined as those having breakfast eating frequency of '3-5 days/week, 1-2 days/week, or none' .

[c] Obtained from ANOVA and Chi-square test for continuous and categorical variables, respectively.

[d] Proportions in each category do not add up to 100% when there was missing data.

[e] Geometric mean (95% confidence interval).

Table 1 (continued)

| | Breakfast eaters [a] | Breakfast skippers [b] | *P* value [c] |
|---|---|---|---|
| Total energy intake, kcal/day | 1942 (538) | 1740 (553) | <0.001 |
| Alcohol consumption, g/day | 13.6 (19.2) | 18.1 (26.4) | <0.001 |
| Eating speed, % [d] | | | |
| very fast | 11.4 | 12.9 | 0.67 |
| relatively fast | 35.8 | 37.9 | |
| medium | 38.5 | 35.2 | |
| slow | 12.6 | 12.4 | |
| Satiation eater, yes, % | 61.2 | 59.1 | 0.24 |
| Fruits and vegetables intake, g/1000 kcal/day | 142.3 (67.0) | 118.7 (61.2) | <0.001 |
| Fish intake, g/1000 kcal/day | 84.1 (41.9) | 84.8 (39.4) | 0.74 |
| Frequency of whole-grain cereals intake, % | | | |
| always | 8.5 | 5.7 | 0.10 |
| sometimes | 9.2 | 8.1 | |
| rarely | 14.9 | 12.6 | |
| no | 67.4 | 73.6 | |
| Frequency of coffee intake, % [d] | | | |
| 4 cups or more/day | 6.6 | 10.6 | 0.02 |
| 2-3 cups/day | 39.0 | 39.1 | |
| 1 cup/day | 24.3 | 23.7 | |
| less than 1 cup/day | 28.8 | 25.1 | |
| Frequency of sugar-sweetened beverages intake, % [d] | | | |
| 1 serving or more/day | 5.5 | 9.3 | <0.001 |
| 4-6 servings/week | 5.3 | 7.0 | |
| 1-3 servings/week | 29.9 | 36.3 | |
| never or rarely | 57.6 | 45.1 | |
| Snack intake, yes, % | 95.3 | 94.8 | 0.61 |

Table 2. Incidence rates and hazard ratios (95% confidence interval) of type 2 diabetes mellitus incidence according to breakfast consumption, Aichi, 2002-2011.

| | Frequency of eating breakfast | | | | |
|---|---|---|---|---|---|
| | Everyday | Almost everyday with occasional skips | 3-5 days/week | 1-2 days/week | None |
| n of cases/ N | 204 / 3648 | 35 / 540 | 15 / 121 | 17 / 197 | 14 / 125 |
| Crude incidence rate [a] | 7.4 | 8.4 | 16.6 | 11.4 | 15.4 |
| Crude | 1 (reference) | 1.13 (0.79-1.62) | 2.25 (1.33-3.80) | 1.54 (0.94-2.53) | 2.08 (1.21-3.58) |
| Model 1 | | 1.11 (0.77-1.60) | 1.93 (1.12-3.33) | 1.51 (0.91-2.51) | 1.96 (1.11-3.45) |
| Model 2 | | 1.11 (0.77-1.60) | 1.97 (1.14-3.39) | 1.46 (0.87-2.44) | 2.09 (1.18-3.68) |
| Model 3 | | 1.06 (0.73-1.53) | 2.07 (1.20-3.56) | 1.37 (0.82-2.29) | 2.12 (1.19-3.76) |
| | Breakfast eaters [b] | | Breakfast skippers [c] | | |
| n of cases/ N | 239 / 4188 | | 46 / 443 | | |
| Crude incidence rate | 7.5 | | 13.9 | | |
| Crude | 1 (reference) | | 1.85 (1.35-2.54) | | |
| Model 1 | | | 1.72 (1.23-2.40) | | |
| Model 2 | | | 1.74 (1.24-2.43) | | |
| Model 3 | | | 1.73 (1.24-2.42) | | |

n indicates number; N, number of participants; CI, confidence interval. [a] Crude incidence rate (per 1000 person-years). [b] Breakfast eater was defined as those having breakfast eating frequency of 'everyday or almost everyday with occasional skips'. [c] Breakfast skipper was defined as those having breakfast eating frequency of "3-5 days/week, 1-2 days/week, or none".

Model 1 : Adjusted for age, sex, total energy intake, smoking status, alcohol consumption, leisure-time physical activity, work-time physical activity, family history of diabetes mellitus, eating speed, perceived stress, sleep duration, work schedule, satiation eater, fruits and vegetables intake, fish intake, and intake frequencies of whole-grain cereals, coffee, sugar-sweetened beverages, and snack

Model 2 : Model 1 + body mass index, Model 3 : Model 2 + fasting blood glucose ($Log_{10}$-transformed)

Table 3. Incidence rates and hazard ratios (95% confidence interval) of type 2 diabetes mellitus according to breakfast consumption stratified by sex, body mass index, fasting blood glucose, and smoking status at baseline, Aichi, 2002-2011.

| | Breakfast eaters [a] | Breakfast skippers [b] | Breakfast eaters [a] | Breakfast skippers [b] |
|---|---|---|---|---|
| Sex | Men | | Women | |
| n of cases/ N | 197 / 3273 | 34 / 327 | 42 / 915 | 12 / 116 |
| Crude incidence rate [c] | 7.8 | 13.8 | 6.4 | 14.4 |
| Model 3HR | 1 (reference) | 1.54 (1.05-2.28) | 1 (reference) | 2.29 (1.05-5.02) |
| Smoking status | Current smoker | | Never or former smoker | |
| n of cases/ N | 85 / 1118 | 22 / 199 | 154 / 3070 | 24 / 244 |
| Crude incidence rate | 10.2 | 14.9 | 6.6 | 13.1 |
| Model 3 HR | 1 (reference) | 1.41 (0.85-2.33) | 1 (reference) | 2.17 (1.36-3.46) |
| Body mass index | Less than 25 kg/m$^2$ | | 25 kg/m$^2$ or more | |
| n of cases/ N | 148 / 3298 | 28 / 332 | 91 / 890 | 18 / 111 |
| Crude incidence rate | 5.9 | 11.0 | 13.6 | 23.6 |
| Model 3 HR | 1 (reference) | 1.67 (1.08-2.58) | 1 (reference) | 1.98 (1.13-3.47) |
| Fasting blood glucose | Less than 110 mg/dl | | 110 mg/dl or more | |
| n of cases/ N | 177 / 3943 | 36 / 414 | 62 / 245 | 10 / 29 |
| Crude incidence rate | 5.9 | 11.5 | 41.4 | 55.1 |
| Model 3 HR | 1 (reference) | 1.80 (1.23-2.64) | 1 (reference) | 1.62 (0.75-3.52) |

n indicates number; N, number of participants.

[a] Breakfast eater was defined as those having breakfast eating frequency of 'everyday or almost everyday with occasional skips'.

[b] Breakfast skipper was defined as those having breakfast eating frequency of "3-5 days/week, 1-2 days/week, or none".

[c] Crude incidence rate (per 1000 person-years)

Model 3 was adjusted for age, sex (if appropriate), total energy intake, smoking status (if appropriate), alcohol consumption, leisure-time physical activity, work-time physical activity, family history of diabetes mellitus, eating speed, perceived stress, sleep duration, work schedule, satiation eater, fruits and vegetables intake, fish intake, and intake frequencies of whole-grain cereals, coffee, sugar-sweetened beverages, and snack, body mass index (continuous), and fasting blood glucose (Log10-transformed)

*P* value for interaction were 0.49 for sex, 0.26 for smoking status, 0.85 for body mass index, and 0.59 for fasting blood glucose.

373