Cross-sectional associations between the types/amounts of beverages consumed and the glycemia status: The Japan Public Health Center-based Prospective Diabetes study

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ABSTRACT

Background: The associations between the types/amounts of beverages consumed in daily life and measures of the glycemia status were investigated in a Japanese population-based cohort.

Methods: Data from the baseline survey of the Japan Public Health Center-based Prospective Diabetes cohort were used. A cross-sectional analysis was performed in 3852 men and 6003 women who were evaluated under the fasting condition. The daily consumptions of coffee, green tea, oolong tea, black tea, soft drinks, fruit juices, or plain water were assessed using a self-reported questionnaire. Multivariable-adjusted linear regression analyses were performed using measures of the glycemia status (fasting plasma glucose (FPG) and glycated hemoglobin (HbA1c)) as dependent variables and the types/amounts of beverages consumed as the independent variables, to calculate the differences according to the types/amounts of beverages consumed.

Results: In the multivariable-adjusted models, coffee consumption of ≥240 mL/day was significantly associated with a change of the FPG level by 1.9 mg/dL in men (p = 0.013) and 1.4 mg/dL in women (p = 0.015), as compared to coffee consumption of 0 mL/day. No significant association of the FPG level was observed with any of the other types/amounts of beverages consumed. On the other hand, significant associations were found between the HbA1c levels and consumption of several types of beverages.

Conclusions: High coffee consumption was associated with lower FPG levels in this Japanese population. Some unexpected associations of the HbA1c levels with the consumption of some types of beverages were observed, which need to be further investigated.

1. Introduction

Diabetes mellitus is among the most prevalent of chronic diseases worldwide. Currently, the epicenter of the disease endemic has shifted from Western to Asian countries, including Japan, because of the large populations and dramatic changes in lifestyles, including the dietary patterns and physical activity levels [1]. In line with the known
association of the risk of diabetes with dietary habits, beverage consumption is also reported to be linked to the risk of diabetes. Favorable and unfavorable effects of several types of beverages on the glucose metabolism have been reported. Coffee, which is commonly consumed worldwide, could have a protective effect against the development of diabetes [2], while consumption of sweetened beverages could increase the risk of obesity and diabetes [3,4]. As for other types of beverages, the evidence remains scarce or controversial. A look at coffee and tea consumption, the subjects were also asked about the daily lives of the general population would show that people consume a variety of beverages, and it may be difficult to select any one beverage as the beverage of choice. Consumption of certain types of beverages could be closely linked to that of other types of beverages, which would make it difficult to disentangle the independent effects of each of the beverages on the glucose metabolism. This could explain why only a few studies until now have comprehensively collected data on the beverage consumption of subjects and analyzed the associations between the types of beverages consumed and the glucose metabolism.

In the present study, we investigated the associations between the types/amounts of beverages consumed by the subjects and measures of the glycemias status (hereinafter, glycemic measures) in the Japan Public Health Center-based Prospective (JPHC) Diabetes cohort, which consists of registered inhabitants of areas served by 10 public health centers (PHCs) across Japan.

Table 1
Baseline characteristics of the study participants by sex.

|                          | Men (n = 3852) | Women (n = 6003) |
|--------------------------|---------------|------------------|
| Fasting plasma glucose (mg/dl) | 99.8 (14.4) | 95.7 (13.0) |
| Hemoglobin A1c (%)       | 5.54 (0.55)  | 5.49 (0.48)    |
| Age, years               | 61.7 (6.9)   | 61.1 (6.6)     |
| Body mass index, kg/m²   | 23.6 (2.9)   | 23.7 (3.2)     |
| Family history of diabetes, yes n (%) | 418 (10.9) | 794 (13.2) |
| Smoking status, n (%)    |               |                 |
| Never                    | 1459 (37.9)  | 5764 (96.0)    |
| Past                     | 1082 (28.1)  | 62 (1.0)       |
| Current                  | 1311 (34.0)  | 177 (3.0)      |
| Alcohol intake, n (%)    |               |                 |
| Non-drinker              | 2706 (70.3)  | 5782 (96.3)    |
| 1st half                 | 676 (17.6)   | 114 (1.9)      |
| 2nd half                 | 470 (12.2)   | 107 (1.8)      |
| Leisure-time physical activity, active n (%) | 922 (23.9) | 1818 (30.3) |
| Daily time spent walking (hours/day) |                 |                 |
| <0.5                     | 666 (17.3)   | 969 (16.1)     |
| ≥0.5 and <1.0            | 975 (25.3)   | 1503 (25.0)    |
| ≥1.0 and <2.0            | 732 (19.0)   | 1284 (21.4)    |
| ≥2.0                     | 1479 (38.4)  | 2247 (37.4)    |
| Employed, yes n (%)      | 3381 (87.8)  | 2596 (43.3)    |
| Hypertension, yes n (%)  | 1725 (44.8)  | 2286 (38.1)    |

Values are the mean (standard deviation) or n (%).

2. Subjects, materials and methods

2.1. Study population and study design

The present study was based on the data obtained from research on diabetes performed in a large cohort study in Japan, namely, the Japan Public Health Center-based prospective Study (JPHC study). The JPHC study was initiated in 1990 for Cohort I, with Cohort II added in 1993. Cohort I consists of all registered Japanese inhabitants aged 40–59 years old living in areas of Japan served by 11 PHCs in Cohort I and Cohort II consists of all Japanese inhabitants aged 40–69 years old living in the same aforementioned areas at the start of each survey. The details of the study are described elsewhere [17]. The diabetes study (JPHC diabetes study) was performed in the participants of the JPHC study living in areas covered by 10 of the PHCs. Among the registered inhabitants of the JPHC study, those who underwent annual health checkups in each PHC area were recruited. A self-reported questionnaire specific to diabetes and lifestyle, and measurement of the glycated hemoglobin (HbA1c) were added to their routine health checkup examinations. The initial survey of the JPHC diabetes study was performed in 1998–1999 for Cohort II and in 2000 for Cohort I. The 5-year follow-up survey was performed in the same way in 2003–2004 for Cohort II and in 2005 for Cohort I. For the present study, data of the participants of the initial survey were included. Of the 28,363 participants who responded to the questionnaire of the initial survey of the diabetes study, 3668 participants with missing data for any of the exposure variables described later were excluded. In addition, 1025 participants who reported having been diagnosed as having diabetes or were taking medications for diabetes were also excluded, as these factors could also influence the fasting plasma glucose (FPG) and HbA1c levels. Of the remaining 23,670 participants, the 9855 participants who had been examined under the fasting condition were included in the analysis. The participants provided their written informed consent for participation in this study. The study was conducted with the approval of the ethics committee of the International Medical Center of Japan, the former name of the National Center for Global Health and Medicine, and the ethics committee of Saitama Medical University.

2.2. Data collection

A self-administered questionnaire was completed by each of the participants at the 5-year and/or 10-year follow-up of the JPHC study, which contained questions about previously diagnosed medical conditions, medications taken, and lifestyle factors such as the beverages consumed, physical activity levels, smoking, alcohol intake, and employment status. In addition, a separate questionnaire for the JPHC diabetes study was also completed, which contained questions about the detailed past history of diabetes, treatment of diabetes, family history of diabetes, and daily time spent walking. Both data from the JPHC study questionnaire administered upon entry into the JPHC diabetes study and the JPHC diabetes study questionnaire were used for the present study.

2.3. Measurements of beverage consumption

The JPHC questionnaire included a question on the frequency of beverage consumption with the following choices: 0, 1–2, 3–4, or 5–6 times/week and 1, ≥2, 3–4, 4–6, 7–9, or ≥10 cups/day. The types of beverages included in the question were two forms of green tea (Sencha and Bancha/Gemnaicha), oolong tea, black tea, two types of coffee (coffee excluding canned coffee and canned coffee), two types of fruit juices (apple juice and orange juice), two types of soft drinks (cola and energy drink), and two types of plain water (tap and bottled water). In regard to coffee and tea consumption, the subjects were also asked about the daily number of teaspoons of sugar that they added to the coffee or tea. The amount of consumption of each beverage (mL/day) was calculated by multiplying the frequency by the portion size (120 mL/cup...
Details of validation of the method for assessing beverage consumption
the total amount consumed daily was calculated by summing the
for Sencha, Bancha/Genmaicha, oolong tea, black tea, and coffee, 200
ml/cup for apple juice, orange juice, tap water, and bottled water, 250
ml/cup for canned coffee, colas, and energy drinks). For each beverage,
the total amount consumed daily was calculated by summing the
amounts of the two types of the beverage (listed above) consumed.
Details of validation of the method for assessing beverage consumption
in the JPHC study are reported elsewhere [18]. In brief, the validity
was evaluated by comparing the data with the dietary records for 28 or 14
days. The correlation coefficients obtained from comparisons between
the dietary records and the questionnaire responses were as follows: for
green tea: 0.44 (men) and 0.53 (women); for coffee: 0.75 (men) and 0.80
(women); for oolong tea: 0.26 (men) and 0.38 (women); for black tea:
0.45 (men) and 0.54 (women); for fruit juice: 0.22 (men) and 0.31
(women); for so soft drinks: 0.35 (men) and 0.41 (women) [18].

We divided the participants into five categories according to the
beverage consumed, such that the numbers of participants in the
different categories were as close as possible. Except for Sencha, the
category of 0 mL/day consumption was also set for each beverage. For
beverages for which more than half of the participants reported no
consumption (0 mL/day), we divided the participants into three
categories.

2.4. Measurement of the plasma glucose and HbA1c levels

Blood samples collected ≥8 h after the last caloric intake were
defined as fasting blood samples. Efforts to standardize the plasma
glucose levels measured at the laboratories in the different PHC areas
were made by the standardization committee of the JPHC study. The
standardization method is reported elsewhere [19] and the accuracy of
the measurements has been reported to be satisfactory [19]. As for the
HbA1c measurement also, details about the standardization procedure
are described elsewhere [20]. In brief, standard samples were provided
to each PHC at the time of the initial survey and at the time of the 5-year
follow-up survey. The calibration procedure was conducted using the
standard samples. The original standard samples were examined and
approved by the Japan Diabetes Society (JDS). The procedure for HbA1c
calibration used by the JDS is described elsewhere [21]. The HbA1c data
were converted to equivalent values of the National Glycohemoglobin
Standardization Program, according to a statement issued by the JDS
[22].

2.5. Other characteristics of the study participants

Information on the characteristics of the study participants were
obtained from the health checkup data and responses to the self-
administered questionnaire. Body mass index (BMI) was calculated as
the weight (in kilograms) divided by the height (in meters) squared,
which were measured during the health checkup as part of the JPHC
diabetes study. Blood pressure was measured in the right arm by trained
nurses using mercury sphygmomanometers during the health checkup.
The measurement was performed after the subject had rested for at least
5 min in the sitting position. Hypertension was defined if any of the
following criteria were met at the baseline: 1) systolic blood pressure
≥140 mm Hg and/or diastolic blood pressure ≥90 mm Hg; 2) self-
reported hypertension; 3) receiving antihypertensive medication(s).
Participants were categorized into three groups according to their
smoking history (never smoker, past smoker, current smoker). Patients
were classified according to their alcohol intake habit as non-drinkers
(consumed alcoholic beverages less than once a week) or into one of
the three tertiles of the weekly alcohol intake level. Family history of
diabetes was defined as the presence of at least one first-degree relative
with diabetes. Employment status was classified into two groups
(employed, unemployed (including housewives)). As for leisure-time
physical activity, participants were considered as physically active if
they engaged in sports activities at least 1 day of the week. The daily
time spent walking was categorized as follows: <30 min, 30 min to <1 h,
1 h to <2 h, and ≥2 h).

Table 2
Spearman correlation coefficients, stratified by sex, relating exposure and outcome variables.

|                    | Coffee   | Green tea | Oolong tea | Black tea | Fruit juice | Soft drink | Water   |
|--------------------|----------|-----------|------------|-----------|-------------|------------|---------|
| **Men (n = 3852)** |          |           |            |           |             |            |         |
| Fasting plasma glucose | -0.116  | 0.019     | -0.002     | -0.002    | -0.040      | -0.035     | 0.005   |
| HbA1c              | 0.011    | 0.030     | -0.025     | -0.018    | -0.069      | -0.073     | -0.064  |
| Age                | -0.181   | *0.116   | *0.141     | *0.033    | 0.021       | 0.044      | 0.033   |
| BMI                | -0.027   | *0.147   | *0.047     | 0.019     | 0.011       | 0.078      |         |
| Alcohol intake     | 0.021    | -0.014   | 0.038      | -0.001    | *0.087      | *0.148     | *0.153  |
| Time spent walking | 0.026    | -0.027   | -0.006     | -0.017    | *0.040      | *0.100     | *0.084  |
| Coffee             | *0.149   | -0.030   |           |           |             |            |         |
| Green tea          | *0.119   | 0.020     |           |           |             |            |         |
| Oolong tea         | *0.236   | *0.044   | *0.216     | *0.163    | *0.293      |            |         |
| Black tea          | *0.071   | 0.012     | *0.149     | *0.086    | *0.170      | *0.157     |         |
| Fruit juice        | *0.048   | -0.007   | *0.053     | *0.039    | 0.020       | *0.047     | *0.028  |
| Soft drink         | *0.013   | *0.026   | 0.021      | -0.017    | *0.055      | *0.091     | *0.060  |
| Water              | *0.143   | *0.027   | *0.262     |           |             |            |         |

| **Women (n = 6003)** |          |           |            |           |             |            |         |
| Fasting plasma glucose | -0.114  | *0.086   | 0.000      | -0.016    | 0.017       | 0.000      | *0.035  |
| HbA1c              | -0.070   | *0.029   | 0.001      | -0.006    | -0.056      | -0.061     | 0.002   |
| Age                | -0.248   | *0.090   | *0.175     | *0.147    | -0.021      | -0.031     | 0.018   |
| BMI                | -0.011   | *0.040   | *0.110     | *0.034    | 0.016       | *0.059     | *0.103  |
| Alcohol intake     | *0.048   | -0.007   | *0.053     | *0.039    | 0.020       | *0.047     | *0.028  |
| Time spent walking | 0.013    | *0.026   | 0.021      | -0.017    | *0.055      | *0.091     | *0.060  |
| Coffee             | *0.143   | *0.027   | *0.262     |           |             |            |         |
| Green tea          | *0.079   | 0.016     | *0.188     | *0.177    |            |            |         |
| Oolong tea         | *0.126   | *0.082   | *0.158     | *0.101    | *0.232      |            |         |
| Black tea          | *0.070   | -0.022   | *0.140     | *0.069    | *0.153      | *0.131     |         |
| Fruit juice        | *0.143   | *0.036   |           |           |            |            |         |
| Soft drink         | *0.126   | *0.082   | *0.158     | *0.101    | *0.232      |            |         |
| Water              | *0.070   | -0.022   | *0.140     | *0.069    | *0.153      | *0.131     |         |

*p < 0.01.  
*p < 0.05.  
*p < 0.001.
Table 3
Fasting plasma glucose and the types/amounts of beverages consumed in men.

| Type of beverage | Daily consumption (mL) | Men (n = 3852) |  |  |  |  |
|------------------|------------------------|----------------|---|---|---|---|
|                  | n                      | Model 1        | Model 2        | Model 3        |
|                  |                         | Adjusted mean | Difference P-value | Adjusted mean | Difference P-value | Adjusted mean | Difference P-value |
| Coffee           | 0                      | 1160 101.4    | ref             | 101.1         | ref             | 100.8         | ref             |
|                  | 0: <120                | 1072 100.1    | –1.3            | 0.032         | 99.9            | –1.2          | 0.035           | 100.0          | –0.7          | 0.301          |
|                  | >120 and ≤240          | 765  98.8     | –2.6            | <0.001        | 98.8            | –2.3          | <0.001          | 98.9           | –1.8          | 0.014          |
|                  | >240                   | 855  98.1     | –3.3            | <0.001        | 98.8            | –2.3          | 0.001           | 98.9           | –1.9          | 0.013          |
|                  | Ptrend                 | –           | <0.001          | ref           | 0.002           | ref           | 0.029           |
| Green tea        | <240                   | 1070 100.4    | ref             | 100.2         | ref             | 100.1         | ref             |
|                  | >240 and ≤480          | 964  99.7     | –0.7            | 0.261         | 99.7            | –0.4          | 0.502           | 99.8           | –0.3          | 0.634          |
|                  | >480 and ≤720          | 937  99.6     | –0.8            | 0.261         | 99.6            | –0.5          | 0.418           | 99.7           | –0.4          | 0.483          |
|                  | >720                   | 881  99.3     | –1.1            | 0.089         | 99.5            | –0.6          | 0.326           | 99.5           | –0.6          | 0.336          |
|                  | Ptrend                 | 0.123        | ref             | 0.374         | ref             | 0.355         |
| Oolong tea       | <60                    | 2362 99.7     | ref             | 100.1         | ref             | 100.0         | ref             |
|                  | 0: <60                 | 770  99.2     | –0.5            | 0.364         | 99.0            | –1.0          | 0.078           | 99.2           | –0.7          | 0.250          |
|                  | ≥60                    | 720 100.6     | 0.8             | 0.193         | 99.7            | –0.4          | 0.526           | 99.8           | –0.1          | 0.821          |
|                  | Ptrend                 | 0.151        | ref             | 0.659         | ref             | 0.979         |
| Black tea        | 0                      | 3047 99.8     | ref             | 99.9          | ref             | 99.7          | ref             |
|                  | 0: <60                 | 561  99.6     | –0.2            | 0.736         | 99.5            | –0.4          | 0.566           | 100.1          | 0.3           | 0.633          |
|                  | ≥60                    | 244 100.1     | 0.3             | 0.740         | 99.4            | –0.5          | 0.599           | 99.9           | 0.2           | 0.821          |
|                  | Ptrend                 | 0.814        | ref             | 0.528         | ref             | 0.768         |
| Fruit juice      | 0                      | 2544 100.0    | ref             | 100.0         | ref             | 99.9          | ref             |
|                  | 0: <100                | 996  99.5     | –0.5            | 0.402         | 99.3            | –0.7          | 0.171           | 99.5           | –0.4          | 0.450          |
|                  | ≥100                   | 312 99.3      | –0.6            | 0.479         | 99.8            | –0.2          | 0.774           | 99.9           | 0.0           | 0.983          |
|                  | Ptrend                 | 0.356        | ref             | 0.449         | ref             | 0.820         |
| Soft drink       | 0                      | 2071 100.1    | ref             | 100.0         | ref             | 99.7          | ref             |
|                  | 0: <100                | 1057 99.1     | –1.1            | 0.057         | 99.3            | –0.7          | 0.220           | 99.5           | –0.2          | 0.715          |
|                  | ≥100                   | 724 99.9      | –0.2            | 0.706         | 100.0           | 0.1           | 0.887           | 100.4          | 0.7           | 0.294          |
|                  | Ptrend                 | 0.691        | ref             | 0.356         | ref             | 0.279         |
| Water            | 0                      | 809  99.8     | ref             | 100.3         | ref             | 100.0         | ref             |
|                  | 0: <200                | 610  99.8     | 0.0             | 0.971         | 100.1           | –0.2          | 0.799           | 100.2          | 0.2           | 0.827          |
|                  | ≥200 and ≤500          | 921  99.9     | 0.1             | 0.829         | 100.0           | –0.3          | 0.616           | 100.1          | 0.1           | 0.939          |
|                  | ≥500                   | 1512 99.7    | –0.1            | 0.826         | 99.3            | –1.0          | 0.104           | 99.3           | –0.7          | 0.258          |
|                  | Ptrend                 | 0.705        | ref             | 0.070         | ref             | 0.107         |

Model 1: Adjusted for age (continuous) and PHC areas.
Model 2: Model 1 + adjusted for BMI (continuous), smoking status (never, former or current smoker), alcohol intake (non-drinker or tertiles of weekly alcohol intake), family history of diabetes (yes or no), leisure-time physical activity (<1 day/week or ≥ 1 day/week), daily time spent walking (<30 min, 30 min to less than 1 h, 1 h to less than 2 h, or 2 h or more), employment status (employed or unemployed) and hypertension (yes or no).
Model 3: Model 2 + adjusted for the daily amount of teaspoons of sugar used in tea or coffee + respective beverage consumption except the variable of interest.

2.6. Statistical analysis

We conducted a cross-sectional analysis to examine the associations of the type and amounts of beverages consumed by the subjects and the FPG and HbA1c levels. The analyses were performed separately for the male and female subjects. We first examined the correlations among the type/amount of beverage consumed, the participant characteristics, and glycemic measures using the Spearman rank correlation tests. Then, multivariable-adjusted linear regression analyses were performed using multivariate models (FPG and HbA1c) as the dependent variables and the beverages consumed as the independent variables. Adjusted means and differences with p values according to the beverages consumed were estimated. In Model 1, the estimates were adjusted for age (continuous), family history of diabetes (yes, no), leisure-time physical activity (<1 day/week, ≥ 1 day/week), daily time spent walking (<30 min, 30 min to less than 1 h, 1 h to less than 2 h, ≥ 2 h), employment status (employed, unemployed), and hypertension (yes, no). In Model 3, the beverages consumed except the examining variable and the daily number of teaspoons of sugar that the subjects added to their tea or coffee were entered into Model 2. The linear trends of the beverage consumption categories were also examined. A mean value of beverage consumption was calculated and assigned to each category. Then, the p values were examined by including the variable as a continuous variable in the models. Statistical analyses were performed using STATA software version 11 (Stat Corp, College Station, TX, USA). All statistical tests were two-sided, and p values of less than 0.05 were considered as being statistically significant.
3. Results

Table 4 shows the fasting plasma glucose and the types/amounts of beverages consumed in women.

Table 4: Fasting plasma glucose and the types/amounts of beverages consumed in women.

| Type of beverage | Daily consumption (mL) | Women (n = 6003) | Men (n = 3852) |
|------------------|------------------------|------------------|----------------|
|                  | n                      |                  |                |
|                  |                        | Model 1          | Model 2        | Model 3        |
|                  |                        | Adjusted mean    | Difference     | P-value        | Adjusted mean    | Difference     | P-value        | Adjusted mean    | Difference     | P-value        |
| Coffee           | 1964                   | 96.8 ref         | 96.6 ref       | 0.032          | 96.4 ref       | 0.032          |
|                  | 0-10 < 120             |                  |                |                |                |                |
|                  | 1920                   | 95.5 -1.3        | 0.002          | 0.011          | 95.6 -0.7      | 0.119          |
|                  | 1156                   | 95.1 -1.7        | <0.001         | 0.002          | 95.1 -1.6      | 0.042          |
|                  | ≥240                   | 94.7 -2.1        | <0.001         | 0.001          | 94.6 -1.1      | 0.015          |
|                  |                        | Ptrend =         |                |                | Ptrend =       |                |
|                  |                        | 0.003            |                |                | 0.032          |                |
| Green tea        | 1326                   | 95.8 ref         | 96.6 ref       | 0.032          | 95.6 ref       | 0.032          |
|                  | 1423                   | 96.1 0.3         | 0.536          | 0.360          | 96.1 0.5       | 0.295          |
|                  | 1506                   | 95.6 -0.1        | 0.764          | 0.795          | 95.8 0.1       | 0.794          |
|                  | 1748                   | 95.4 -0.4        | 0.457          | 0.637          | 95.4 -0.2      | 0.578          |
|                  |                        | Ptrend =         |                |                | Ptrend =       |                |
|                  |                        | 0.246            |                |                | 0.316          |                |
| Oolong tea       | 0                      | 95.4 ref         | 95.6 ref       | 0.032          | 95.6 ref       | 0.032          |
|                  | 3723                   | 96.5 1.0         | 0.406          | 0.687          | 95.6 0.2       | 0.702          |
|                  | 1244                   | 95.6 -0.3        | 0.646          | 0.629          | 95.4 -0.2      | 0.493          |
|                  | 1036                   | 95.4 0.4         | 0.457          | 0.637          | 95.4 -0.2      | 0.453          |
|                  |                        | Ptrend =         |                |                | Ptrend =       |                |
|                  |                        | 0.025            |                |                | 0.513          |                |
| Black tea        | 4198                   | 95.7 ref         | 95.7 ref       | 0.032          | 95.7 ref       | 0.032          |
|                  | 1165                   | 95.8 0.1         | 0.867          | 0.699          | 95.9 0.2       | 0.318          |
|                  | 640                    | 95.4 -0.3        | 0.616          | 0.629          | 95.4 -0.3      | 0.855          |
|                  |                        | Ptrend =         |                |                | Ptrend =       |                |
|                  |                        | 0.637            |                |                | 0.664          |                |
| Fruit juice      | 3884                   | 95.6 ref         | 95.6 ref       | 0.032          | 95.6 ref       | 0.032          |
|                  | 1576                   | 95.7 0.2         | 0.667          | 0.755          | 95.7 0.1       | 0.688          |
|                  | 543                    | 96.5 0.9         | 0.108          | 0.351          | 96.2 0.5       | 0.322          |
|                  |                        | Ptrend =         |                |                | Ptrend =       |                |
|                  |                        | 0.115            |                |                | 0.352          |                |
| Soft drink       | 4254                   | 95.7 ref         | 95.7 ref       | 0.032          | 95.7 ref       | 0.032          |
|                  | 1173                   | 95.8 0.1         | 0.825          | 0.996          | 95.7 0.2       | 0.813          |
|                  | 576                    | 95.9 0.2         | 0.702          | 0.769          | 95.8 0.2       | 0.722          |
|                  |                        | Ptrend =         |                |                | Ptrend =       |                |
|                  |                        | 0.687            |                |                | 0.781          |                |
| Water            | 1539                   | 95.3 ref         | 95.5 ref       | 0.032          | 95.5 ref       | 0.032          |
|                  | 1041                   | 95.1 -0.1        | 0.845          | 0.617          | 95.2 -0.2      | 0.745          |
|                  | 1581                   | 96.1 0.9         | 0.062          | 0.197          | 96.1 0.6       | 0.185          |
|                  | 1842                   | 96.1 0.9         | 0.037          | 0.463          | 95.8 0.3       | 0.464          |
|                  |                        | Ptrend =         |                |                | Ptrend =       |                |
|                  |                        | 0.032            |                |                | 0.442          |                |
|                  | 0                      | 0.029            |                |                | 0.032          |                |

Model 1: Adjusted for age (continuous) and PHC areas.
Model 2: Model 1 + adjusted for BMI (continuous), smoking status (never, former or current smoker), alcohol intake (non-drinker or tertiles of alcohol intake), family history of diabetes (yes or no), leisure-time physical activity (<1 day/week or ≥ 1 day/week), daily time spent walking (<30 min, 30 min to <1 h, 1 h to <2 h, or ≥2 h), employment status (employed or unemployed) and hypertension (yes or no).
Model 3: Model 2 + adjusted for the daily amount of teaspoons of sugar used in tea or coffee + respective beverage consumption except the variable of interest.

b. In men, coffee consumption was negatively correlated with the FPG levels. Fruit juice and soft drink consumptions were negatively correlated with the HbA1c levels. In men alone, a negative correlation was observed between water consumption and the HbA1c level. Correlation was also observed between the age and type of beverage consumed. Older participants showed higher consumption of green tea, and lower consumptions of coffee, oolong tea and black tea. In regard to the correlation among the types of beverages consumed, consumption of beverages other than green tea were positively correlated with each other, while green tea consumption was negatively correlated with soft drink consumption in both men and women. In women alone, green tea consumption showed a positive correlation with black tea consumption and negative correlation with oolong tea consumption.

In the linear regression models used to examine the associations between the types/amounts of beverages consumed and the FPG levels, only coffee consumption was significantly associated with the FPG level (Table 3 and Table 4). In the multivariable-adjusted model (Model 3) in men, coffee consumption of ≥240 mL/day was associated with a change of the FPG level by -1.9 mg/dL (p = 0.013) as compared to coffee consumption of 0 mL/day. In women, coffee consumption of ≥240 mL/day was associated with a change of the FPG level by -1.4 mg/dL (p = 0.015) as compared to coffee consumption of 0 mL/day. A dose-response relationship was also observed in both the male and female subjects (P for trend in men = 0.029 and P for trend in women = 0.032).
Table 5

HbA1c and the types/amounts of beverages consumed in men.

| Type of beverage | Daily consumption (mL) | Men (n = 3852) |
|------------------|------------------------|---------------|
|                  | n                      | Model 1       |
|                  |                        | Adjusted mean | Difference | P-value |
|                  |                        |               |            |         |
| Coffee           | 0                      | 1160          | 5.53       | ref      | 5.54     |
|                  | ≥0 and <120            | 1072          | 5.53       | 0.00     | 0.917    | 5.53     | 5.54     | 5.53     |
|                  | >120 and <240          | 765           | 5.51       | −0.02    | 0.546    | 5.51     | −0.02    | 0.330    |
|                  | >240                   | 855           | 5.58       | 0.05     | 0.065    | 5.57     | 0.03     | 0.188    |
|                  |                        | P trend       | 0.046      |          |          |          |          |          |
| Green tea        | <240                   | 1070          | 5.55       | ref      | 5.54     |
|                  | ≥240 and <480          | 964           | 5.51       | −0.04    | 0.130    | 5.51     | −0.03    | 0.217    |
|                  | ≥480 and <720          | 937           | 5.55       | 0.00     | 0.953    | 5.55     | 0.01     | 0.820    |
|                  | >720                   | 861           | 5.55       | 0.00     | 0.918    | 5.55     | 0.01     | 0.718    |
|                  |                        | P trend       | 0.515      |          |          |          |          |          |
| Oolong tea       | 0                      | 2362          | 5.53       | ref      | 5.54     |
|                  | ≥0 and <60             | 770           | 5.53       | 0.00     | 0.958    | 5.53     | −0.01    | 0.635    |
|                  | >60                    | 720           | 5.55       | 0.02     | 0.515    | 5.54     | 0.00     | 0.950    |
|                  |                        | P trend       | 0.502      |          |          |          |          |          |
| Black tea        | 0                      | 3047          | 5.54       | ref      | 5.54     |
|                  | ≥0 and <60             | 561           | 5.52       | −0.02    | 0.432    | 5.52     | −0.02    | 0.353    |
|                  | >60                    | 244           | 5.57       | 0.03     | 0.361    | 5.56     | 0.02     | 0.540    |
|                  |                        | P trend       | 0.497      |          |          |          |          |          |
| Fruit juice      | 0                      | 2544          | 5.54       | ref      | 5.54     |
|                  | ≥0 and <100            | 996           | 5.52       | −0.03    | 0.196    | 5.52     | −0.03    | 0.180    |
|                  | >100                   | 312           | 5.55       | 0.00     | 0.968    | 5.55     | 0.01     | 0.859    |
|                  |                        | P trend       | 0.654      |          |          |          |          |          |
| Soft drink       | 0                      | 2071          | 5.55       | ref      | 5.55     |
|                  | ≥0 and <100            | 1057          | 5.52       | −0.03    | 0.135    | 5.52     | −0.03    | 0.196    |
|                  | >100                   | 724           | 5.54       | −0.01    | 0.633    | 5.53     | −0.02    | 0.523    |
|                  |                        | P trend       | 0.622      |          |          |          |          |          |
| Water            | 0                      | 809           | 5.57       | ref      | 5.57     |
|                  | ≥0 and <200            | 610           | 5.57       | 0.01     | 0.849    | 5.58     | 0.01     | 0.856    |
|                  | >200 and <500          | 921           | 5.52       | −0.05    | 0.053    | 5.52     | −0.06    | 0.029    |
|                  | >500                   | 1512          | 5.52       | −0.05    | 0.050    | 5.51     | −0.06    | 0.012    |
|                  |                        | P trend       | 0.055      |          |          |          |          |          |

Model 1: Adjusted for age (continuous) and PHC areas.
Model 2: Model 1 + adjusted for BMI (continuous), smoking status (never, former or current smoker), alcohol intake (non-drinker or tertiles of alcohol intake), family history of diabetes (yes or no), leisure-time physical activity (<1 day/week or ≥ 1 day/week), daily time spent walking (<30 min, 30 min to <1 h, 1 h to <2 h, or ≥2 h), employment status (employed or unemployed) and hypertension (yes or no).
Model 3: Model 2 + adjusted for the daily amount of teaspoons of sugar used in tea or coffee + respective beverage consumption except the variable of interest.

As for the association between the types/amounts of beverages consumed and the HbA1c level (Table 5 and Table 6), analysis using Model 3 showed that coffee and water consumptions were significantly associated with the HbA1c level in the men. Coffee consumption of ≥240 mL/day was associated with a change of the HbA1c level by 0.06% (p = 0.027) as compared to coffee consumption of 0 mL/day. Water consumption of ≥500 mL/day was associated with a change of the HbA1c level by −0.06% (p = 0.022) as compared to water consumption of 0 mL/day. In women, oolong tea and black tea consumptions were significantly associated with the HbA1c levels. Oolong tea consumption of ≥60 mL/day was associated with a change of the HbA1c level by 0.05% (p = 0.005), as compared to oolong tea consumption of 0 mL/day. Black tea consumptions of 1–59 mL/day and ≥60 mL/day were associated with changes of the HbA1c levels by 0.04% (p = 0.016) and 0.04% (p = 0.036), respectively, as compared to black tea consumption of 0 mL/day.

4. Discussion

The present study was conducted to investigate the associations between the types/amounts of beverages consumed and the glycemic measures in the JPHC Diabetes cohort. The associations between the types/amounts of beverages consumed and glucose metabolism have been reported from previous studies [2–16,18,23–26]. However, assessment of the beverage of choice in daily life seemed complicated and was correlated with the participants’ preferences, characteristics, and lifestyles. In the present study, we comprehensively collected information on the types/amounts of beverage consumed using a questionnaire adapted to the lifestyles of the Japanese population and examined the associations.

The cross-sectional analysis demonstrated that high coffee consumption was significantly associated with a decrease of the FPG level in both men and women. No significant association was observed between...
consumption of any other type of beverage and the FPG level. On the other hand, significant associations were observed between the HbA1c level and consumptions of several types of beverages. High coffee consumption was associated with an increase of the HbA1c level and high water consumption was associated with a decrease of the HbA1c level in women.

In regard to the association of glucose metabolism with coffee consumption, a meta-analysis [2] of 28 prospective studies reported the existence of an inverse association between coffee consumption and the risk of type 2 diabetes. In the present study, an inverse association was observed between coffee consumption and the FPG level in both men and women, suggesting that coffee consumption might have a favorable effect on glucose metabolism. However, unexpectedly, a significant positive association was observed between coffee consumption and the HbA1c level in men. The association remained unchanged even after the inclusion of 4625 men who had originally been excluded because their evaluations were performed under non-fasting conditions (Table 7). The conflicting results could be explained by the effect of coffee consumption on the postprandial glucose levels. A meta-analysis [27] reported that short-term trials showed impaired postprandial glucose response after coffee consumption, whereas long-term trials showed improved glucose metabolism. The slight postprandial increases in the glucose levels in those with higher coffee consumption could cumulatively result in an increase of the HbA1c level. The possible mechanism of the postprandial glucose increase could be the caffeine-mediated impairment of glucose uptake in the skeletal muscle [28] via adenosine receptor antagonism [29] or epinephrine release [30], which could alter glycemic index of foods. In addition, before the mid 2000’s when sugar-free drinks became popular with improved health consciousness, most canned coffees contained sugar, which could also explain the postprandial glucose increase.

Table 6
HbA1c and the types/amounts of beverages consumed in women.

| Type of beverage | Daily consumption (mL) | Women (n = 6003) | Model 1 | Model 2 | Model 3 |
|------------------|------------------------|-----------------|---------|---------|---------|
|                  | n                      |                  | Adjusted mean | Difference | P-value | Adjusted mean | Difference | P-value | Adjusted mean | Difference | P-value |
| Coffee           | 0 > 100 and < 120      | 1920            | 5.49     | ref      | 5.49     | ref      | 5.48     | ref      |
|                  | > 120 and < 240        | 1156            | 5.48     | 0.01     | 0.728    | 5.49     | 0.01     | 0.710    | 5.50     | 0.02     | 0.214 |
|                  | > 240                  | 943             | 5.49     | 0.00     | 0.989    | 5.50     | 0.01     | 0.792    | 5.50     | 0.03     | 0.198 |
|                  |                         |                 | P trend  | 0.987    | 0.760    | 0.00     | 0.293    |
| Green tea        | 0 > 240                | 1326            | 5.50     | ref      | 5.50     | ref      | 5.50     | ref      |
|                  | > 240 and < 480        | 1423            | 5.49     | 0.00     | 0.810    | 5.50     | 0.00     | 0.925    | 5.50     | 0.00     | 0.891 |
|                  | > 480 and < 720        | 1506            | 5.48     | 0.01     | 0.416    | 5.48     | 0.01     | 0.455    | 5.48     | 0.01     | 0.420 |
|                  | > 720                  | 1748            | 5.49     | 0.01     | 0.605    | 5.49     | 0.01     | 0.587    | 5.49     | 0.01     | 0.485 |
|                  |                         |                 | P trend  | 0.638    | 0.568    | 0.00     | 0.465    |
| Oolong tea       | 0 > 60                 | 3723            | 5.47     | ref      | 5.48     | ref      | 5.48     | ref      |
|                  | > 60                   | 1244            | 5.50     | 0.03     | 0.033    | 5.50     | 0.02     | 0.165    | 5.50     | 0.02     | 0.230 |
|                  |                         |                 | P trend  | <0.001   | <0.001   | 0.00     | 0.00     | 0.00     | 0.00     | 0.00     | 0.00  |
| Black tea        | 0 > 60                 | 4198            | 5.48     | ref      | 5.48     | ref      | 5.48     | ref      |
|                  | > 60                   | 1165            | 5.51     | 0.03     | 0.072    | 5.51     | 0.03     | 0.065    | 5.52     | 0.04     | 0.016 |
|                  |                         |                 | P trend  | 0.023    | 0.039    | 0.00     | 0.029    |
| Fruit juice      | 0 > 100                | 3864            | 5.49     | ref      | 5.49     | ref      | 5.49     | ref      |
|                  | > 100                  | 1576            | 5.49     | 0.00     | 0.864    | 5.49     | 0.00     | 0.791    | 5.49     | 0.00     | 0.742 |
|                  |                         |                 | P trend  | 0.986    | 0.556    | 0.00     | 0.499    |
| Soft drink       | 0 > 100                | 4254            | 5.50     | ref      | 5.50     | ref      | 5.50     | ref      |
|                  | > 100                  | 1173            | 5.49     | 0.01     | 0.605    | 5.48     | 0.01     | 0.422    | 5.49     | 0.01     | 0.483 |
|                  |                         |                 | P trend  | 0.093    | 0.069    | 0.00     | 0.073    |
| Water            | 0 > 200 and < 500      | 1581            | 5.49     | 0.00     | 0.790    | 5.49     | 0.00     | 0.944    | 5.49     | 0.00     | 0.934 |
|                  | >500                   | 1842            | 5.51     | 0.02     | 0.162    | 5.50     | 0.00     | 0.850    | 5.50     | 0.00     | 0.991 |
|                  |                         |                 | P trend  | 0.029    | 0.376    | 0.00     | 0.512    |

Model 1: Adjusted for age (continuous) and PHC areas.
Model 2: Model 1 + adjusted for BMI (continuous), smoking status (never, former or current smoker), alcohol intake (non-drinker or tertiles of alcohol intake), family history of diabetes (yes or no), leisure-time physical activity (<1 day/week or ≥ 1 day/week), daily time spent walking (<30 min, 30 min to <1 h, 1 h to <2 h, or ≥2 h), employment status (employed or unemployed) and hypertension (yes or no).
Model 3: Model 2 + adjusted for the daily amount of teaspoons of sugar used in tea or coffee + respective beverage consumption except the variable of interest.
The association between green tea consumption and glucose metabolism remains controversial [5–7,9,10]. A meta-analysis [26] of 17 small-scale trials reported that green tea consumption was associated with significant reductions of the FPG and HbA1c levels. On the other hand, observational studies have found no association between green tea consumption and the plasma glucose or HbA1c level, whereas oolong tea consumption was associated with a reduction of the FPG level. Although evidence is scarce, past studies [12,31] have suggested that consumptions of these teas could exert favorable glucose-lowering effects. However, in the present study, no such effect was observed. Instead, female participants consuming 60 mL/day or more of these beverages showed a significant increase of the HbA1c level as compared to those who did not consume them. The results were also confirmed by analysis of a larger sample size (Table 8). As shown in Table 2, age was negatively associated, while alcohol intake was positively correlated with oolong tea and black tea consumptions in women, suggesting that those who consumed oolong tea or black tea were younger and more likely to drink alcohol, implying that their associations with the glucose metabolism could have been influenced by unhealthy lifestyles. In addition, like canned coffees, canned black teas also contained sugar in the earlier era, which could also have

### Table 7

| Type of beverage | Daily consumption (mL) | Men (n = 8477) |
|-----------------|------------------------|----------------|
|                 | n                      | Adjusted mean | Difference | P-value | Adjusted mean | Difference | P-value | Adjusted mean | Difference | P-value |
|                 |                        | Model 1       | Model 2     | Model 3     |
| Coffee          | 0                      |               | 5.52       | ref        | 5.53       | ref        | 5.51       | ref |
|                 | ≥1 day/week            | 2571          | 5.54       | 0.02       | 0.297      | 5.54       | 0.01       | 0.490      | 5.54       | 0.03       | 0.071   |
|                 | ≥2 h                  | 2435          | 5.54       | 0.01       | 0.558      | 5.54       | 0.01       | 0.764      | 5.55       | 0.04       | 0.051   |
|                 | ≥3 h                  | 1617          | 5.58       | 0.06       | 0.001      | 5.58       | 0.04       | 0.013      | 5.59       | 0.08       | <0.001  |
|                 | ≥4 h                  | 1854          | 5.58       | 0.01       | 0.422      | 5.56       | 0.01       | 0.528      | 5.56       | 0.01       | 0.455   |
|                 | ≥5 h                  | 2325          | 5.56       | 0.06       | 0.006      | 5.57       | 0.03       | 0.073      | 5.57       | 0.03       | 0.065   |
|                 | ≥6 h                  | 2153          | 5.54       | 0.01       | 0.458      | 5.56       | 0.01       | 0.421      | 5.56       | 0.02       | 0.365   |
|                 | ≥7 h                  | 2092          | 5.56       | 0.01       | 0.422      | 5.56       | 0.01       | 0.528      | 5.56       | 0.01       | 0.455   |
|                 | ≥8 h                  | 2029          | 5.56       | 0.01       | 0.422      | 5.56       | 0.01       | 0.528      | 5.56       | 0.01       | 0.455   |
| Green tea       | <240                  | 1970          | 5.56       | 0.01       | 0.422      | 5.56       | 0.01       | 0.528      | 5.56       | 0.01       | 0.455   |
|                 | ≥240 and < 480        | 2325          | 5.56       | 0.01       | 0.422      | 5.56       | 0.01       | 0.528      | 5.56       | 0.01       | 0.455   |
|                 | ≥480 and < 720        | 2153          | 5.54       | 0.01       | 0.458      | 5.56       | 0.01       | 0.421      | 5.56       | 0.02       | 0.365   |
|                 | ≥720                  | 2029          | 5.56       | 0.01       | 0.422      | 5.56       | 0.01       | 0.528      | 5.56       | 0.01       | 0.455   |
|                 | ≥800                  | 1970          | 5.56       | 0.01       | 0.422      | 5.56       | 0.01       | 0.528      | 5.56       | 0.01       | 0.455   |
| Oolong tea      | <60                   | 6718          | 5.53       | 0.01       | 0.558      | 5.54       | 0.00       | 0.948      | 5.54       | 0.00       | 0.798   |
|                 | ≥60                   | 1417          | 5.53       | 0.01       | 0.558      | 5.54       | 0.00       | 0.948      | 5.54       | 0.00       | 0.798   |
| Black tea       | <60                   | 6718          | 5.54       | 0.01       | 0.558      | 5.54       | 0.00       | 0.948      | 5.54       | 0.00       | 0.798   |
|                 | ≥60                   | 1417          | 5.53       | 0.01       | 0.558      | 5.54       | 0.00       | 0.948      | 5.54       | 0.00       | 0.798   |
| Fruit juice     | <100                  | 5517          | 5.53       | 0.01       | 0.558      | 5.54       | 0.00       | 0.948      | 5.54       | 0.00       | 0.798   |
|                 | ≥100                  | 2272          | 5.54       | 0.01       | 0.558      | 5.54       | 0.00       | 0.948      | 5.54       | 0.00       | 0.798   |
|                 | ≥200                  | 688           | 5.53       | 0.01       | 0.558      | 5.54       | 0.00       | 0.948      | 5.54       | 0.00       | 0.798   |
| Soft drink      | <100                  | 4383          | 5.56       | 0.01       | 0.558      | 5.54       | 0.00       | 0.948      | 5.54       | 0.00       | 0.798   |
|                 | ≥100                  | 2431          | 5.53       | 0.01       | 0.558      | 5.54       | 0.00       | 0.948      | 5.54       | 0.00       | 0.798   |
|                 | ≥200                  | 1683          | 5.52       | 0.01       | 0.558      | 5.54       | 0.00       | 0.948      | 5.54       | 0.00       | 0.798   |
| Water           | <100                  | 1745          | 5.56       | 0.01       | 0.558      | 5.54       | 0.00       | 0.948      | 5.54       | 0.00       | 0.798   |
|                 | ≥100                  | 1311          | 5.55       | 0.01       | 0.792      | 5.55       | 0.01       | 0.663      | 5.56       | 0.00       | 0.888   |
|                 | ≥200 and < 500        | 2149          | 5.52       | 0.01       | 0.653      | 5.54       | 0.02       | 0.236      | 5.54       | 0.02       | 0.312   |
|                 | ≥500                  | 3272          | 5.55       | 0.01       | 0.653      | 5.54       | 0.02       | 0.236      | 5.54       | 0.02       | 0.312   |

Model 1: Adjusted for age (continuous) and PHC areas. Model 2: Model 1 + adjusted for BMI (continuous), smoking status (never, former or current smoker), alcohol intake (non-drinker or tertiles of alcohol intake), family history of diabetes (yes or no), leisure-time physical activity (<1 day/week or ≥ 1 day/week), daily time spent walking (<30 min, 30 min to <1 h, 1 h to <2 h, or ≥2 h), employment status (employed or unemployed) and hypertension (yes or no). Model 3: Model 2 + adjusted for the daily amount of teaspoons of sugar used in tea or coffee + respective beverage consumption except the variable of interest.
exacerbated the postprandial glucose increase and associated increase of the HbA1c level.

A recent meta-analysis [3] reported that consumptions of fruit juices and soft drinks were associated with an increase in the risk of type 2 diabetes, and it would seem reasonable to assume that consumption of soft drinks and fruit juices might have unfavorable effects on glucose metabolism. However, no such findings were observed in the present study. More than a half of the participants in this study were categorized as individuals who did not consume any beverage at all. The participants might be too small to exert a clinically relevant difference.

There have been conflicting reports regarding the association between plain water consumption and glucose metabolism. One cohort study [14] failed to report any significant association between consumption of water and the risk of diabetes, while others [13,15,16] have reported that high consumption of plain water was associated with a decreased risk of diabetes. The association of glycemic measures with plain water consumption has been rarely reported. The paucity of research might be due to the difficulty in evaluating the independent effects of plain water consumption. As shown in Table 2, plain water consumption was positively correlated with the consumption of all other types of beverages, except green tea. The present study conducted adjustments for the effects of consumption of other types of beverages and found no significant association between plain water consumption and the FPG level. In the analysis of the HbA1c levels, higher water consumption was significantly associated with a decrease of the HbA1c level in men. However, the result could be incidental, because the significant association became attenuated when a larger sample size was analyzed (Table 7).
The present study had several limitations. First, the data on the types/amounts of beverages consumed and lifestyles were collected based on a self-reported questionnaire. Although the validation study reported fair correlations between the dietary records and responses to the questionnaire, misclassification of the information could have influenced the results to some extent. Since such misclassification is considered to be non-differential, the associations observed in the present study could have been underestimated. Second, although we comprehensively collected information on the types/amounts of beverages consumed using a questionnaire adapted to the Japanese lifestyle, the laboratory measurements were performed with strict standardization.

In conclusion, we investigated the association between the types/amounts of beverages consumed and measures of the glycemia status in a population-based cohort across Japan. The cross-sectional analysis showed that high coffee consumption was significantly associated with a decrease of the FPG level in both men and women. In regard to the association with the HbA1c level, high coffee consumption was associated with an increase of the HbA1c level, and high water consumption was associated with a decrease of the HbA1c level in men. High oolong tea and black tea consumptions were associated with an increase of the HbA1c level in women. Some of the results observed were unexpected. In this point, focusing not only on types/amounts of beverages but also components of such beverages as caffeine could offer clues for elucidating the association between beverage consumption and glycemic measures. In this regard, further research is required.

CRediT authorship contribution statement

Yusuke Kabeya: Writing – original draft, Formal analysis. Atsushi Goto: Writing – review & editing, Supervision. Masayuki Kato: Investigation, Supervision, Methodology. Yoshihiko Takahashi: Investigation, Supervision, Methodology. Akhiro Isoaga: Investigation, Supervision, Methodology. Yumi Matsushita: Investigation, Supervision, Methodology. Tetsuya Mizoue: Investigation, Supervision, Methodology. Manami Inoue: Investigation, Supervision, Methodology. Norie Sawada: Investigation, Supervision, Methodology, Funding acquisition. Takashi Kadowaki: Conceptualization, Methodology, Supervision, Funding acquisition. Shoichiro Tsugane: Conceptualization, Methodology, Supervision, Funding acquisition. Mitsuhiko Noda: Conceptualization, Methodology, Investigation, Supervision, Funding acquisition.

Declaration of competing interest

There are no competing interests to declare.

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