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The association of coffee consumption with prediabetes, diabetes, and markers of glucose metabolism in rural Vietnam: a cross-sectional study

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Abstract

Background Coffee consumption has been shown to be protective against diabetes, but the effects of coffee with additives, such as condensed milk in Vietnam, remain underexplored. This cross-sectional study aimed to examine the associations of coffee consumption with prediabetes, diabetes, and markers of glucose metabolism among 3,000 middle-aged rural residents in Vietnam.

Methods Multinomial logistic regression was used to examine the associations of coffee consumption (0, 0.1–0.9, 1–1.9, or ≥ 2 cups/day) with prediabetes and diabetes, adjusting for demographics, lifestyle factors, dietary intake, comorbidities, and use of additives. Associations with insulin resistance and insulin secretion (as assessed by homeostatic model assessment of insulin resistance (HOMA-IR) and homeostatic model assessment of β-cell function (HOMA-β)) were examined using linear regression.

Results Adjusted odds ratios (95% confidence interval) for prediabetes were 1.02 (0.78–1.32), 1.18 (0.91–1.52), 0.60 (0.35–1.03) for 0.1–0.9, 1–1.9, or ≥ 2 cups/day, respectively, compared to non-coffee drinkers (p for trend = 0.84). For diabetes, the corresponding figures were 1.74 (1.14–2.67), 1.43 (0.92–2.20), 0.59 (0.22–1.59) (p for trend = 0.50). No significant associations were observed for HOMA-IR (p for trend = 0.41) or HOMA-β (p for trend = 0.44).

Conclusion The present study among rural residents in Vietnam did not find clear associations of coffee consumption with prediabetes, diabetes, or markers of glucose metabolism, including the effects of coffee with additives, underscoring the complexity of these associations and the need for further research to confirm the findings in rural Vietnam.

Keywords Coffee, Diabetes, Prediabetes, Insulin Resistance, Insulin Secretion, Vietnam

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Introduction

Coffee is a widely consumed beverage known for its rich content of bioactive components such as caffeine and chlorogenic acids [1]. Given the broad consumption of coffee and its potential health effects, a large body of studies has examined the associations between coffee consumption and various health outcomes [2]. Specifically, coffee consumption is recognized as beneficial for cancers [3], cardiovascular diseases (CVDs) [4], and Parkinson's disease [5].

Diabetes is one such example in which coffee consumption may be beneficial [2]. Epidemiological studies have suggested that coffee's antioxidative and anti-inflammatory properties may play a protective role against diabetes [1]. A meta-analysis of 30 prospective cohort studies, conducted across high-income countries such as the USA, Japan, Finland, and the Netherlands, documented an inverse association between coffee consumption and diabetes risk; individuals in the highest category of coffee consumption (median consumption, 5 cups/day) exhibited a 29% lower risk of diabetes compared to those in the lowest category (median consumption, 0 cups/day) [6].

The present study was designed to build upon and extend the previous literature by examining the association between coffee consumption and glucose metabolisms in rural Vietnam. This investigation is particularly important for some reasons. First, most prior studies have focused on high-income countries, with limited evidence available from low- and middle-income countries (LMICs), where the burden of diabetes is rising [7]. The number of adults with diabetes in LMICs was estimated to be 432.7 million in 2021 and is projected to increase to 665.5 million by 2045 [8]. In Vietnam, diabetes prevalence has been steadily increasing; age-adjusted comparative prevalence of diabetes increased from 3.2 to 6.1% between 2011 and 2021, which is estimated to increase to 7.1% by 2045 [9]. Thus, it is crucial to identify factors associated with diabetes in this context. Given that differences in the genetic and environmental backgrounds of populations, findings from the high-income countries may not be directly applicable to LMICs, and evidence should be generated with a focus on specific contexts. Second, related to the first point, Vietnam has the distinctive coffee culture, characterized by the widespread consumption of sweetened coffee with condensed milk. Given that sweetened beverages are well-established risk factors for diabetes [10], it is critical to evaluate the potential effect of additives, such as sugar and artificial sweeteners, frequently utilized by coffee consumers in Vietnam and comparable cultures, but little has been conducted on this issue.

Therefore, this cross-sectional study aimed to examine the associations of coffee consumption, considering the effect of additives, with prediabetes, diabetes, and markers of glucose metabolism (insulin resistance and insulin secretion) among middle-aged residents in rural Vietnam. Prediabetes, a precursor of diabetes, has also been linked to various adverse health outcomes (e.g., CVDs [11–13], cancers [14]), and insulin resistance and dysfunction of insulin secretion are pivotal pathogenic components of diabetes [15, 16]. By examining these variables together, this study seeks to contribute to a comprehensive understanding of the association between coffee consumption and glucose metabolism in rural Vietnam.

Methods

Study setting

Data for the present study were drawn from the baseline survey of the Khánh Hòa Cardiovascular Study (KHCS), which was conducted between June 2019 and June 2020. The KHCS is an ongoing cohort study to examine the determinants of CVDs and other health outcomes among middle-aged adults in rural Vietnam. The study took place in eight communes within one district of Khánh Hòa province. Local health center staff from each commune created participant lists of eligible individuals aged 40–59 years at the time of recruitment who had lived in the communes for at least six months and invited them to participate in the study. Eventually, a total of 3,000 residents participated in the survey (convenience sampling). The baseline survey consisted of anthropometric measurements, blood samples for biochemical measurements, and questionnaire on sociodemographics, diet, and lifestyle factors, conducted through face-to-face interviews. The questionnaire was developed with reference to the WHO STEP survey and previous literature, reflecting general and Vietnamese context. Details of the KHCS, including the assessments of the questionnaire, have been described in previous papers [17, 18].

The study procedure has been approved by the Research Ethics Committee at National Center for Global Health and Medicine (NCGM), Tokyo, Japan (approval number: NCGM-G-003172) and Pasteur Institute in Nha Trang, Vietnam (approval number: 02/2019/HĐĐĐ-IPN), and the Research Ethics Committee at the University of Tokyo, Tokyo, Japan (approval number: 2021007NI). Participants provided written informed consent prior to their participation in the study, and they were informed that they could withdraw their participation at any time during the study.

Assessment of diabetes and prediabetes

Participants were instructed to fast at least eight hours prior to blood sampling. Fasting plasma glucose (FPG) was measured by Cobas 8000 (Roche, the Switzerland), and hemoglobin A1c (HbA1c) was quantified by high-performance liquid chromatography using the HLC-723 G8 (Tosoh Bioscience, Japan).

Based on the American Diabetes Association criteria [19], diabetes was defined as FPG ≥ 7 mmol/L (≥ 126 mg/dL) or HbA1c ≥ 6.5% or the use of anti-diabetic treatment or prescribed insulin. Prediabetes was defined as FPG 5.6–6.9 mmol/L (100–125 mg/dL) or HbA1c 5.7–6.4% among individuals without diabetes. Normoglycemia was defined as FPG < 5.6 mmol/L (< 100 mg/dL) and HbA1c < 5.7%.

Assessment of insulin resistance and insulin secretion

Insulin resistance and insulin secretion were assessed by using homeostatic model assessment of insulin resistance (HOMA-IR) and homeostatic model assessment of β-cell function (HOMA-β), respectively. HOMA-IR and HOMA-β were assessed by using the following equations: HOMA IR= [fasting insulin (μU /mL) × FPG (mmol/L)] /22.5; HOMA-β= [20 × fasting insulin (μU /mL)] /[FPG (mmol/L) – 3.5] [20]. A higher level of HOMA-IR indicates higher insulin resistance while a lower level of HOMA-β reflects lowered β-cell function, indicating decreased insulin secretion. These values were log-transformed to reduce skewness for the subsequent analysis.

Assessment of coffee consumption

Participants were asked about their coffee consumption frequency and serving size for a typical week in the past year, representing their usual habits. Specifically, they were asked to report how many days per week they consumed coffee and the serving size per occasion, using a standard Vietnamese coffee cup (65 ml per cup) illustrated in a picture booklet (show card). Participants reported their usual serving size using predefined options: "less" (0–0.8 times the standard size), "equal" (0.8–1.3 times), "greater" (1.3–1.7 times), and "greater than 1.7 times." A value of 0.5, 1.0, or 1.5 was assigned for "less," "equal," and "greater," respectively, while participants selecting "greater than 1.7" specified the exact quantity. Those who consumed coffee less than once per week were regarded as non-coffee drinkers. Daily coffee consumption was then calculated by multiplying the frequency by serving size, which was then categorized into four groups (0, 0.1–0.9, 1–1.9, or ≥ 2 cups/day) (equivalent to 0, 1–64, 65–129, or ≥ 130 ml/day, respectively) based on the consumption distribution. Coffee drinkers were asked if they added sugar or condensed milk to their beverages (yes or no).

Covariates

Sociodemographic information was collected using the questionnaire: age (in years), sex (male or female), marital status (married/cohabiting or not), education (less than primary school, primary school, secondary school, or high school or higher), job (government employee, non-government employee, self-employed, farmer or fisherman, houseworker, others, or not working), and monthly household income (low, middle, or high).

The study also collected the following information on lifestyle-related factors: smoking status (never, former, or current), alcohol consumption (0, 0.1–0.9, 1–1.9, or ≥ 2 drinks/day), physical activity (< 600, 600–1,199, or ≥ 1,200 metabolic equivalent (MET)-minutes/week) (based on Global Physical Activity Questionnaire (GPAQ) [21]), sleep duration (< 6, 6–6.9, 7–7.9, 8–8.9, or ≥ 9 h/day) [22], fruit consumption (0, 0.1–0.9, 1–1.9, or ≥ 2 servings/day), vegetable consumption (0, 0.1–0.9, 1–1.9, 2–2.9, or ≥ 3 servings/day), red meat consumption (0, 0.1–99, 100–199, or ≥ 200 g/day) [23], rice consumption (< 2, 2–2.9, 3–3.9, 4–5.9, 6–7.9, or ≥ 8 bowls/day), rice noodle consumption (0, 0.1–1.99, 2–3.9, 4–6.9, or ≥ 7 bowls/week), green tea consumption (0, 0.1–4.9, 5–9.9, 10–14.9, or ≥ 15 cups/day) (equivalent to 0, 0.1–199, 200–399, 400–599, or ≥ 600 ml/day, based on Vietnamese tea cup [40 ml per cup]) [18], other tea consumption (0, 0.1–4.9, 5–9.9, 10–14.9, or ≥ 15 cups/day) (same figure as green tea consumption) [18], and family history of diabetes (yes, no, or unknown). Thresholds for categorization were based on established guidelines, previous studies, or the distribution of responses in this population.

Additional variables included depressive symptoms (based on the short version of the Center for Epidemiologic Studies Depression Scale (CES-D) [24] (11 items), body mass index (BMI) (< 18.5, 18.5–22.9, 23.0–24.9, 25.0–29.9, or ≥ 30.0 kg/m^2) [25], hypertension, and dyslipidemia.

Statistical analysis

A multinomial logistic regression model was used to estimate the odds ratios (ORs) and 95% confidence intervals (CIs) of prediabetes and diabetes in relation to coffee consumption categories. In addition, OR (95% CI) per cup/day was estimated.

Model 1 was adjusted for age and sex, while model 2 was further adjusted for marital status, education, job, income, smoking status, alcohol drinking, physical activity, sleep duration, fruit consumption, vegetable consumption, red meat consumption, rice consumption, rice noodle consumption, family history of diabetes, and other beverage consumption (green tea and other tea), BMI categories, hypertension, dyslipidemia, and depressive symptoms. Model 3 was further adjusted for use of additives to beverages. The significance of the trend across categories of coffee consumption was assessed as P for trend by including the ordinal number assigned to each category as a continuous variable in the regression models.

A linear regression model was used to examine the association of coffee consumption with log-transformed

HOMA-IR and HOMA-β values, with results presented as adjusted geometric means and 95% CIs for each model. To assess the potential influence of participants currently treated with insulin and those with fasting insulin levels < 5 μU/mL and FPG < 4.5 mmol/L [26] on the study findings, sensitivity analyses were conducted by excluding these participants ($n = 6$ and $n = 78$, respectively), as HOMA estimates may be unreliable under these conditions.

All statistical analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC, USA). The statistical significance level was set at p-value < 0.05 (two-sided).

Results

In the present study, 44% of the participants reported to be coffee drinkers. Compared with non-coffee drinkers, coffee drinkers tended to be men, farmers or fishermen, current smokers, consume more red meat and rice, and drink alcohol (Table 1).

Table 2 depicts the results of multinomial logistic regression analysis examining the association of coffee consumption with prediabetes and diabetes. In the unadjusted model, compared with non-coffee drinkers, ORs (95% CI) for prediabetes were 1.01 (0.82–1.23), 1.21 (1.00–1.46), and 0.81 (0.50–1.30) among those consuming 0.1–0.9 cup/day, 1–1.9 cups/day, and ≥ 2 cups/day of coffee, respectively (p for trend = 0.23). For diabetes, the corresponding ORs (95% CI) were 1.23 (0.90–1.69), 1.16 (0.84–1.59), and 0.69 (0.29–1.66) (p for trend = 0.57). After adjusting for potential covariates in Model 1, the ORs (95% CI) for prediabetes were 1.03 (0.84–1.26), 1.14 (0.93–1.40), and 0.75 (0.46–1.22) for the respective coffee consumption categories (p for trend = 0.58), and the corresponding figures for diabetes were 1.31 (0.94–1.82), 1.10 (0.78–1.54), and 0.65 (0.26–1.58) (p for trend = 0.80). The trends of these associations remained the same even after further adjustment for potential covariates in Model 2 (p for trend = 0.78 for prediabetes; p for trend = 0.96 for diabetes) and additional adjustment for use of additives to beverage in Model 3 (p for trend = 0.84 for prediabetes; p for trend = 0.50 for diabetes). In addition, the ORs (95% CI) per cup/day for prediabetes and diabetes were 0.96 (0.87–1.05) and 0.90 (0.74–1.09), respectively, in Model 3.

Table 3 shows the results of linear regression analysis examining the association between coffee consumption and markers of glucose metabolism (HOMA-IR and HOMA-β). In the unadjusted model, there was a statistically significant association between coffee consumption and HOMA-IR (p for trend < 0.001) while this association became non-significant after adjusting for covariates in Model 1 (p for trend = 0.51), Model 2 (p for trend = 0.41), and Model 3 (p for trend = 0.41). Similarly, a statistically significant association was found in relation to HOMA-β in the unadjusted model (p for trend < 0.001) while this association became insignificant in Model 1(p for trend = 0.87), Model 2 (p for trend = 0.58) and Model 3 (p for trend = 0.44).

In the sensitivity analyses, excluding participants under insulin treatment ($n = 6$) (Supplementary Table 1) and those with fasting insulin levels < 5 μU/mL and FPG < 4.5 mmol/L ($n = 78$) (Supplementary Table 2), the observed associations remained statistically insignificant.

Discussion

In this cross-sectional study among 3,000 middle-aged rural residents in Khánh Hòa province, Vietnam, no clear evidence was found of an inverse association between coffee consumption and prediabetes, diabetes, or markers of glucose metabolism, as observed in previous research. On the contrary, individuals consuming 0.1–0.9 cups of coffee per day had significantly increased odds of diabetes in the fully adjusted model, compared to non-coffee drinkers.

The null finding regarding the association between coffee consumption and prediabetes, diabetes, and markers of glucose metabolism observed in this study did not align with the findings of the above-mentioned meta-analysis of 30 prospective cohort studies [6], which showed an inverse association between coffee consumption and diabetes. One possible explanation is that the difference in cultural and dietary context in Vietnam, such as preparation methods (e.g., sweetened coffee with condensed milk) and consumption patterns (e.g., serving size, coffee types), may have influenced the association differently compared to other populations studied in the meta-analysis. Furthermore, the contrast with the findings of a previous Vietnamese study, which reported a significant inverse association [27], could be attributed to differences in study design (a hospital-based case-control study in the capital city), population (hospital patients), and non-adjustment for key factors, such as additives to coffee.

More importantly, the low prevalence of coffee consumption in this study population may have contributed to the nonsignificant findings, as 56% of participants were non-coffee drinkers and another 19% consumed less than one cup per day, leaving a relatively small proportion of regular coffee drinkers, particularly those consuming ≥ 2 cups per day (2.6%). This limited number of coffee drinkers may have limited the statistical power to detect a significant association if one exists at all. Moreover, the potential protective effects of coffee may only be evident at higher levels of consumption than those observed in this study. The Vietnamese coffee cup (65 ml/cup) used as a reference in this study is considerably smaller than a regular coffee cup (typically 150–250 ml/cup), suggesting that the actual intake of coffee might be lower than

Table 1 Characteristics of participants in the Khánh Hòa cardiovascular study, Vietnam (2019–2020) ($n = 3,000$)

		Coffee consumption categories			
	All participants ($n = 3,000$)	**0 cup/day ($n = 1,680$)**	**0.1–0.9 cup/day ($n = 577$)**	**1–1.9 cups/day ($n = 665$)**	**≥ 2 cups/day ($n = 78$)**
Age, mean [SD]	49.9 [5.5]	49.9 [5.6]	49.4 [5.4]	50.3 [5.5]	50.1 [5.3]
Sex (women), n (%)	1,840 (61.3)	1,262 (75.1)	317 (54.9)	242 (36.4)	19 (24.4)
Marital status (married/cohabitating), n (%)	2,691 (89.7)	1,497 (89.1)	514 (89.1)	611 (91.9)	69 (88.5)
Education, n (%)					
Less than primary school	352 (11.7)	228 (13.6)	59 (10.2)	57 (8.6)	8 (10.3)
Primary school	863 (28.8)	520 (31.0)	154 (26.7)	163 (24.5)	26 (33.3)
Secondary school	1,068 (35.6)	575 (34.2)	202 (35.0)	265 (39.9)	26 (33.3)
High school or higher	717 (23.9)	357 (21.3)	162 (28.1)	180 (27.1)	18 (23.1)
Job, n (%)					
Government employee	295 (9.8)	148 (8.8)	82 (14.2)	62 (9.3)	3 (3.9)
Non-government employee	483 (16.1)	252 (15.0)	89 (15.4)	123 (18.5)	19 (24.4)
Self-employed	595 (19.8)	336 (20.0)	119 (20.6)	131 (19.7)	9 (11.5)
Farmer or fisherman	870 (29.0)	459 (27.3)	161 (28.0)	222 (33.4)	28 (35.9)
Houseworker	527 (17.6)	374 (22.3)	77 (13.3)	67 (10.1)	9 (11.5)
Other	111 (3.7)	45 (2.7)	22 (3.8)	35 (5.3)	9 (11.5)
Not working (retired or unemployed)	119 (4.0)	66 (3.9)	27 (4.7)	25 (3.8)	1 (1.3)
Household income, n (%)					
Low	1,002 (33.4)	594 (35.4)	185 (32.1)	201 (30.2)	22 (28.2)
Middle	1,045 (34.8)	573 (34.1)	208 (36.1)	232 (34.9)	32 (41.0)
High	920 (30.7)	490 (29.2)	181 (31.4)	225 (33.8)	24 (30.8)
missing	33 (1.1)	23 (1.4)	3 (0.5)	7 (1.1)	0 (0.0)
Smoking status, n (%)					
Never	2,036 (67.9)	1,331 (79.2)	376 (65.2)	309 (46.5)	20 (25.6)
Former	350 (11.7)	166 (9.9)	65 (11.3)	106 (15.9)	13 (16.7)
Current	614 (20.5)	183 (10.9)	136 (23.6)	250 (37.6)	45 (57.7)
Alcohol consumption, n (%)					
0 drink/day	2,114 (70.5)	1,357 (80.8)	367 (63.6)	346 (52.0)	44 (56.4)
0.1–0.9 drink/day	416 (13.9)	147 (8.8)	105 (18.2)	148 (22.3)	16 (20.5)
1–1.9 drinks/day	201 (6.7)	76 (4.5)	47 (8.2)	75 (11.3)	3 (3.9)
≥ 2 drinks/day	269 (9.0)	100 (6.0)	58 (10.1)	96 (14.4)	15 (19.2)
Physical activity, n (%)					
< 600 MET-minutes/week	252 (8.4)	153 (9.1)	31 (5.4)	61 (9.2)	7 (9.0)
600–< 1,199 MET-minutes/week	120 (4.0)	70 (4.2)	17 (3.0)	27 (4.1)	6 (7.7)
≥ 1,200 MET-minutes/week	2,628 (87.6)	1,457 (86.7)	529 (91.7)	577 (86.8)	65 (83.3)
Sleep duration (< 6 h/day), n (%)	315 (10.5)	185 (11.0)	64 (11.1)	58 (8.7)	8 (10.3)
Fruit consumption (≥ 2 servings/day), n (%)	357 (11.9)	194 (11.6)	78 (13.5)	77 (11.6)	8 (10.3)
Vegetable consumption (≥ 3 servings/day), n (%)	384 (12.8)	228 (13.6)	86 (14.9)	64 (9.6)	6 (7.7)
Red meat consumption (≥ 200 g/day), n (%)	323 (10.8)	138 (8.2)	66 (11.4)	101 (15.2)	18 (23.1)
Rice consumption (≥ 8 bowls/day), n (%)	320 (10.7)	145 (8.6)	73 (12.7)	88 (13.2)	14 (18.0)
Rice noodle consumption (≥ 7 bowls/day), n (%)	475 (15.8)	268 (16.0)	72 (12.5)	126 (19.0)	9 (11.5)
Green tea consumption, n (%)					
0 cup/day	2,235 (74.5)	1,393 (82.9)	377 (65.3)	422 (63.5)	43 (55.1)
0.1–4.9 cups/day	419 (14.0)	156 (9.3)	113 (19.6)	136 (20.5)	14 (18.0)
5–9.9 cups/day	131 (4.4)	43 (2.6)	31 (5.4)	49 (7.4)	8 (10.3)
10–14.9 cups/day	74 (2.5)	32 (1.9)	18 (3.1)	21 (3.2)	3 (3.9)
≥ 15 cups/day	141 (4.7)	56 (3.3)	38 (6.6)	37 (5.6)	10 (12.8)
Other tea consumption, n (%)					
0 cup/day	2,438 (81.3)	1,454 (86.6)	423 (73.3)	498 (74.9)	63 (80.8)
0.1–4.9 cups/day	365 (12.2)	145 (8.6)	110 (19.1)	104 (15.6)	6 (7.7)
5–9.9 cups/day	65 (2.2)	23 (1.4)	14 (2.4)	24 (3.6)	4 (5.1)
10–14.9 cups/day	41 (1.4)	13 (0.8)	9 (1.6)	19 (2.9)	0 (0.0)

Table 1 (continued)

		Coffee consumption categories			
	All participants (*n* = 3,000)	**0 cup/day (*n* = 1,680)**	**0.1–0.9 cup/day (*n* = 577)**	**1–1.9 cups/day (*n* = 665)**	**≥ 2 cups/day (*n* = 78)**
≥ 15 cups/day	91 (3.0)	45 (2.7)	21 (3.6)	20 (3.0)	5 (6.4)
Adding sugar or condensed milk to coffee or tea (yes), n (%)	1,088 (36.3)	149 (8.9)	426 (74.0)	465 (69.9)	47 (60.3)
BMI categories, n (%)					
< 18.5 kg/m^2	139 (4.6)	67 (4.0)	28 (4.9)	37 (5.6)	7 (9.0)
18.5–22.9 kg/m^2	1,344 (44.8)	794 (47.3)	227 (39.4)	289 (43.5)	34 (43.6)
23.0–24.9 kg/m^2	739 (24.6)	400 (23.8)	154 (26.7)	167 (25.1)	18 (23.1)
25.0–29.9 kg/m^2	728 (24.3)	390 (23.2)	161 (27.9)	159 (23.9)	18 (23.1)
≥ 30.0 kg/m^2	50 (1.7)	29 (1.7)	7 (1.2)	13 (2.0)	1 (1.3)
Family history of diabetes, (yes) n (%)	373 (12.4)	201 (12.0)	80 (13.9)	84 (12.6)	8 (10.3)
Hypertension (yes), n (%)	1,189 (39.6)	657 (39.1)	221 (38.3)	281 (42.3)	30 (38.5)
Dyslipidemia (yes), n (%)	1,352 (45.1)	767 (45.7)	262 (45.4)	281 (42.3)	42 (53.9)
Depressive symptoms (yes), n (%)	341 (11.4)	209 (12.4)	63 (10.9)	54 (8.1)	15 (19.2)

Abbreviations: BMI, body mass index; MET, metabolic equivalent; SD, standard deviation

1 cup is equivalent to the standard Vietnamese coffee cup (65 ml)

Table 2 Odds ratios (95% CI) of diabetes and prediabetes according to coffee consumption categories

	Coffee consumption categories					
	0 cup/day (*n* = 1,680)	**0.1–0.9 cup/day (*n* = 577)**	**1–1.9 cups/day (*n* = 665)**	**≥ 2 cups/day (*n* = 78)**	**P for trend**	**Per cup/day**
Prediabetes						
No. events	774	261	333	33		
Unadjusted Model	1.00 (reference)	1.01 (0.82–1.23)	1.21 (1.00–1.46)	0.81 (0.50–1.30)	0.23	1.05 (0.97–1.15)
Model 1	1.00 (reference)	1.03 (0.84–1.26)	1.14 (0.93–1.40)	0.75 (0.46–1.22)	0.58	0.98 (0.90–1.08)
Model 2	1.00 (reference)	1.00 (0.80–1.25)	1.16 (0.94–1.45)	0.59 (0.35–1.00)	0.78	0.96 (0.87–1.05)
Model 3	1.00 (reference)	1.02 (0.78–1.32)	1.18 (0.91–1.52)	0.60 (0.35–1.03)	0.84	0.96 (0.87–1.05)
Diabetes						
No. events	165	68	68	6		
Unadjusted Model	1.00 (reference)	1.23 (0.90–1.69)	1.16 (0.84–1.59)	0.69 (0.29–1.66)	0.57	1.04 (0.91–1.20)
Model 1	1.00 (reference)	1.31 (0.94–1.82)	1.10 (0.78–1.54)	0.65 (0.26–1.58)	0.80	0.93 (0.76–1.14)
Model 2	1.00 (reference)	1.33 (0.93–1.91)	1.10 (0.75–1.59)	0.47 (0.18–1.25)	0.96	0.87 (0.69–1.09)
Model 3	1.00 (reference)	1.74 (1.14–2.67)	1.43 (0.92–2.20)	0.59 (0.22–1.59)	0.50	0.90 (0.74–1.09)

Model 1, adjusted for age (years, continuous) and sex (men or women)

Model 2, further adjusted for marital status (married/cohabiting or not), education (less than primary school, primary school, secondary school, or high school or higher), job (government employee, non-government employee, self-employed, farmer or fisherman, houseworker, other, or not working), income (low, middle, or high), smoking status (never, former, or current), alcohol consumption (0, 0.1–0.9, 1–1.9, or ≥ 2 drinks/day), physical activity (< 600, 600–1,199, or ≥ 1,200 MET-minutes/week), sleep duration (< 6, 6–6.9, 7–7.9, 8–8.9, or ≥ 9 h/day), fruit consumption (0, 0.1–0.9, 1–1.9, or ≥ 2 servings/day), vegetable consumption (0, 0.1–0.9, 1–1.9, 2–2.9, or ≥ 3 servings/day), red meat consumption (0, 0.1–99, 100–199, or ≥ 200 g/day), rice consumption (< 2, 2–2.9, 3–3.9, 4–5.9, 6–7.9, or ≥ 8 bowls/day), rice noodle consumption (0, 0.1–1.9, 2–3.9, 4–6.9, or ≥ 7 bowls/week), green tea consumption (0, 0.1–4.9, 5–9.9, 10–14.9, or ≥ 15 cups/day), other tea consumption (0, 0.1–4.9, 5–9.9, 10–14.9, or ≥ 15 cups/day), family history of diabetes (yes, no, or unknown), BMI (< 18.5, 18.5–22.9, 23.0–24.9, 25.0–29.9, or ≥ 30.0 kg/m^2), hypertension (yes or no), dyslipidemia (yes or no), and depressive symptoms (yes or no)

Model 3, further adjusted for use of additives (yes or no)

1 cup is equivalent to the standard Vietnamese coffee cup (65 ml)

studies reporting significant findings. Despite the lack of a strong statistical association, individuals consuming ≥ 2 Vietnamese coffee cups per day had 0.59 times the odds of diabetes compared to non-coffee drinkers, indicating a possible protective trend. These findings highlight the need for further studies in rural Vietnam to better understand the complex association between coffee consumption, drinking habit, and prediabetes/diabetes.

When the associations were examined and compared before and after accounting for the additives, no significant changes were observed in this study. This finding was in line with some previous studies, which also incorporated use of additives. For example, Fuhrman et al. [28] showed an inverse association among Puerto Rican middle-aged men even after adjustment for additives (milk and sugar intakes). These results suggest that the potential effects of coffee consumption on diabetes may not be substantially altered by the addition of sugar or condensed milk commonly practiced in certain populations, such as Vietnamese population. However, as the

Table 3 Geometric means (95% CI) of HOMA-IR and HOMA-β according to coffee consumption categories

	Coffee consumption categories				
	0 cup/day (*n* = 1,680)	**0.1–0.9 cup/day (*n* = 577)**	**1–1.9 cups/day (*n* = 665)**	**≥ 2 cups/day (*n* = 78)**	**P for trend**
HOMA-IR					
Unadjusted Model	1.81 (1.75–1.87)	1.77 (1.67–1.88)	1.62 (1.53–1.71)	1.43 (1.22–1.67)	< 0.001
Model 1	1.65 (1.59–1.71)	1.75 (1.65–1.85)	1.70 (1.61–1.79)	1.56 (1.34–1.82)	0.51
Model 2	1.82 (1.58–2.08)	1.86 (1.62–2.14)	1.88 (1.64–2.15)	1.74 (1.45–2.10)	0.41
Model 3	1.80 (1.57–2.07)	1.87 (1.63–2.15)	1.89 (1.64–2.16)	1.75 (1.45–2.10)	0.41
HOMA-β					
Unadjusted Model	85.32 (82.66–88.06)	78.70 (74.57–83.06)	71.22 (67.73–74.89)	67.15 (57.99–77.77)	< 0.001
Model 1	76.31 (73.88–78.82)	76.56 (72.74–80.57)	75.96 (72.40–79.70)	75.47 (65.65–86.77)	0.87
Model 2	78.67 (68.45–90.41)	77.08 (66.92–88.79)	77.69 (67.63–89.25)	77.02 (64.02–92.68)	0.58
Model 3	79.41 (68.96–91.44)	76.68 (66.53–88.39)	77.31 (67.26–88.87)	76.80 (63.82–92.42)	0.44

Abbreviations: HOMA-IR, Homeostatic model assessment of insulin resistance; HOMA-β, Homeostatic model assessment of β-cell function

Model 1, adjusted for age (years, continuous) and sex (men or women)

Model 2, further adjusted for marital status (married/cohabiting or not), education (less than primary school, primary school, secondary school, or high school or higher), job (government employee, non-government employee, self-employed, farmer or fisherman, houseworker, other, or not working), income (low, middle, or high), smoking status (never, former, or current), alcohol consumption (0, 0.1–0.9, 1–1.9, or ≥ 2 drinks/day), physical activity (< 600, 600–1,199, or ≥ 1,200 MET-minutes/week), sleep duration (< 6, 6–6.9, 7–7.9, 8–8.9, or ≥ 9 h/day), fruit consumption (0, 0.1–0.9, 1–1.9, or ≥ 2 servings/day), vegetable consumption (0, 0.1–0.9, 1–1.9, 2–2.9, or ≥ 3 servings/day), red meat consumption (0, 0.1–99, 100–199, or ≥ 200 g/day), rice consumption (< 2, 2–2.9, 3–3.9, 4–5.9, 6–7.9, or ≥ 8 bowls/day), rice noodle consumption (0, 0.1–1.9, 2–3.9, 4–6.9, or ≥ 7 bowls/week), green tea consumption (0, 0.1–4.9, 5–9.9, 10–14.9, or ≥ 15 cups/day), other tea consumption (0, 0.1–4.9, 5–9.9, 10–14.9, or ≥ 15 cups/day), family history of diabetes (yes, no, or unknown), BMI (< 18.5, 18.5–22.9, 23.0–24.9, 25.0–29.9, or ≥ 30.0 kg/m2), hypertension (yes or no), dyslipidemia (yes or no), and depressive symptoms (yes or no)

Model 3, further adjusted for use of additives (yes or no)

1 cup is equivalent to the standard Vietnamese coffee cup (65 ml)

amount of additives was not accounted for and some of coffee drinkers might have unintentionally consumed additives in commercially available coffee beverages, further investigation into the actual additive quantities and types of such beverages is warranted to confirm the role of additives on the association between coffee consumption and prediabetes/diabetes.

The present study found no evidence of statistically significant association of coffee consumption with HOMA-IR and HOMA-β. While evidence is limited on this subject, a few previous studies showed an inverse association between coffee consumption and insulin resistance assessed by HOMA-IR [29–32]; for example, Rebello et al. [29] showed that higher coffee consumption (consumption variation from never/rarely to ≥ 3 cups/day) was associated with a lower level of HOMA-IR among multi-ethnic Asian population in Singapore, and another study by Pham et al. [31] found the inverse association between coffee consumption (consumption variation from < 1 cup/day to ≥ 4 cups/day) and HOMA-IR among Japanese adults. It is noteworthy that the level of HOMA-IR was the lowest in the highest category of coffee consumption (≥ 2 cups/day) in the present study, which was in line with the above-mentioned studies. As regards HOMA-β, the null finding observed in the present study was in line with the above mentioned previous studies by Pham et al. [31] and Rebello et al. [29]. The current evidence from the present and these previous studies suggests that coffee consumption may not be involved in dysfunction of insulin secretion assessed by HOMA-β.

The present study had several limitations that should be acknowledged. First, the cross-sectional design of the study precludes the ability to assess the causality of the association between coffee consumption and prediabetes/diabetes or markers of glucose metabolism. Second, the specific types of coffee consumed, such as traditional brewed coffee or instant coffee, and the preparation methods, including the amounts of sugar or condensed milk added, were not assessed. These factors could introduce variability in the effects of coffee consumption and potentially confound the present results. Future studies should consider collecting detailed data on coffee types and preparation methods to better understand the associations. Finally, this study was conducted among middle-aged adults in rural communes in one province in Vietnam, which may limit the generalizability of our findings to the broader Vietnamese population, particularly urban areas. Coffee consumption patterns, as well as other lifestyle and dietary factors, may differ significantly between rural and urban populations due to socioeconomic, cultural, and environmental differences. Thus, the findings should be interpreted with caution.

In conclusion, this study did not show a clear association of coffee consumption with prediabetes, diabetes, or markers of glucose metabolism among middle-aged residents in rural Khánh Hòa province, Vietnam. Further context-specific research, particularly in Vietnam, is necessary to clarify these associations and guide public health recommendations in the country.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-025-22346-7.

Supplementary Material 1

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Author contributions
All authors contributed to the conception, design and interpretation of the data. A.F. contributed to the data analysis. A.F. drafted the manuscript. M.J., T.M., and Y.I. contributed to the critical revision of the manuscript. T.T.P.P., C.Q.N., D.V.Ho., D.C.P., H.X.L. and H.T.D. contributed to the acquisition of data. T.V.P. conducted the biochemical measurement. A.F. had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. All authors reviewed the manuscript and approved the final version.

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Data availability
The data are not publicly available but are available upon reasonable request to the last author (yosuke.yoshi.yosky@gmail.com).

Declarations

Ethics approval and consent to participate
This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving research study participants were approved by the Research Ethics Committee at National Center for Global Health and Medicine (NCGM), Tokyo, Japan (approval number: NCGM-G-003172) and Pasteur Institute in Nha Trang, Vietnam (approval number: 02/2019/HĐĐĐ-IPN), and the Research Ethics Committee at the University of Tokyo, Tokyo, Japan (approval number: 2021007NI). Written informed consent was obtained from all the participants. Their participation was voluntary, and their confidentiality was secured.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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