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Association between tea, coffee and caffeine consumption and risk of female infertility: a cross-sectional study

Hanzhi Zhang[1], Sixu Qian[2], Jianlin Chen[1] and Jingfei Chen[1*]

Abstract

Objectives To explore the association between tea, coffee, and caffeine consumption and the risk of female infertility.

Methods We analyzed data from 2099 females aged 18 to 44 years, participating in the National Health and Nutrition Examination Survey (NHANES) 2013–2018. We used generalized linear models (GLM) and generalized additive model (GAM) to investigate the dose-response relationship between the tea, coffee, and caffeine consumption and infertility, adjusting for potential confounders.

Results A non-linear relationship was detected between tea consumption and infertility and the inflection point was 2 cups/day. On the right side of the inflection point, we did not detect a significant association. However, on the left side, we found a negative relationship between tea consumption and infertility (OR: 0.73; 95% CI: 0.57 to 0.93; $P=0.0122$). Meanwhile, our study found no significant association between coffee (0.96, 0.81 to 1.13, $P=0.6189$) or caffeine consumption (1.15, 0.93 to 1.42, $P=0.2148$) and female infertility.

Conclusions Tea consumption was non-linearly associated with infertility, whereas no significant associations were found between coffee, caffeine consumption and infertility.

Keywords Tea consumption, Coffee consumption, Caffeine intake, Infertility, Lifestyle, Cross-sectional study

Introduction

Infertility is defined as failure to establish a clinical pregnancy after 12 months of regular and unprotected sexual intercourse [1]. A survey covering more than 190 countries and regions shows that the prevalence of infertility is as high as 10–14% worldwide [2]. As a global health problem, it is urgent and of practical significance to find the potential risk factors of infertility.

For a long time, tea, coffee and caffeine consumption in the diet are considered to be the potential factors that affect fertility. As widely consumed beverages around the world, identifying the role of tea and coffee in female fertility would have a major public health impact. Since the initial epidemiological investigation in 1988 exploring the

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correlation between caffeine intake and female fertility, numerous subsequent studies have examined the potential impact of tea and coffee consumption on infertility. However, the findings from these studies have been inconsistent. Some studies have demonstrated a negative effect of coffee, tea, or overall caffeine consumption on female fertility [3–8], while others have found no association [9–15], or even a potential positive effect [16, 17].

Given the conflicting findings mentioned above, our study aimed to investigate the potential relationship between tea, coffee, and caffeine consumption and the risk of female infertility based on a cross-sectional study.

Methods

Study population

The study population was derived from the National Health and Nutrition Examination Survey (NHANES) database, with a total of 29,400 participants across three survey cycles conducted from 2013 to 2018. NHANES is a nationally representative cross-sectional survey in the United States that is conducted biennially and aims to assess the health and nutritional status of the American population. A total of 2099 participants were included in the present study after implementing the following exclusion criteria: (1) male; (2) age < 18 or age > 44; (3) missing main variables (infertility, tea, coffee and caffeine consumption); (4) history of bilateral oophorectomy and hysterectomy; (5) women with no sexual experience; (6) not having sexual intercourse in the past 12 months; (7) pregnant women; (8) women with infectious diseases of the reproductive system; (9) extremes values of tea and coffee consumption. The flow chart is shown in Fig. 1. This study protocol was reviewed and approved by National Center for Health Statistics (NCHS) Ethics Review Board. All study methods in NHANES were conducted in accordance with the Declaration of Helsinki and approved by National Center for Health Statistics (NCHS) Ethics Review Board. The NHANES database is publicly accessible and allows other researchers to replicate the study, so no additional ethical approval is required. The study design and data from the NHANES can be accessed at https://www.cdc.gov/nhcs/nhanes/.

Main variables

In this study, the assessment of infertility was obtained from the NHANES Reproductive Health Questionnaire (RHQ074). The questionnaire asked: "Have you ever attempted to become pregnant over a period of at least a year without becoming pregnant?". Participants will be considered infertile when they answer "yes".

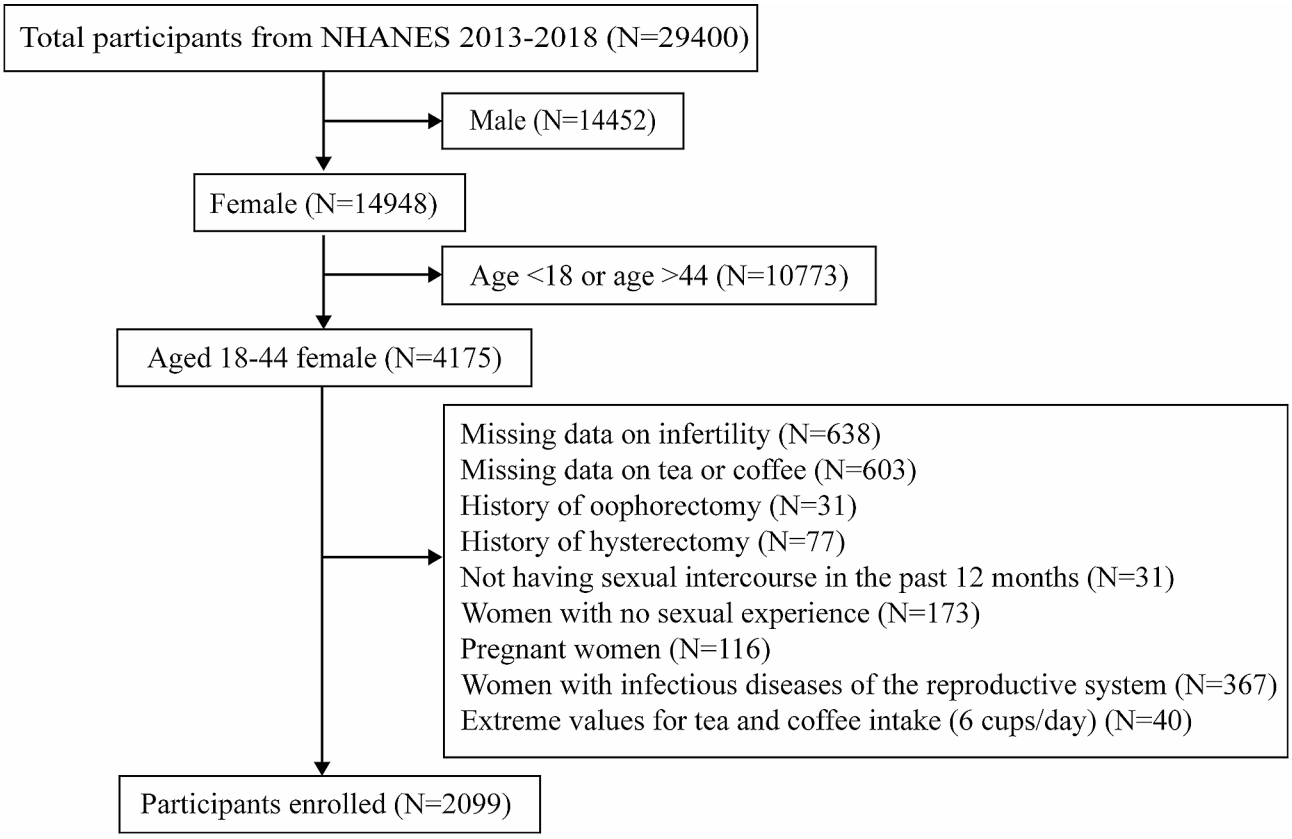

Fig. 1 Flow chart for participants recruitment of this study, NHANES 2013–2018

Information on tea, coffee, and caffeine consumption was obtained from the Dietary Data section of the NHANES. Dietary data were collected through two 24-hour dietary recall interviews, the first at the Ambulatory Examination Center (MEC) and the second by telephone 3 to 10 days later. Detailed dietary intake information will be obtained from participants at each collection. In this study, data on participants who completed two dietary conference interviews was considered complete. Referring to previous similar studies [18], we standardized tea and coffee consumption into 6 ounces per cup and categorized participants according to the number of cups consumed per day (0 cup, 0 < - ≤ 2 cups, or >2 cups) for subsequent statistical analyses. Caffeine consumption included caffeine intake from any source reported by the participants, which was transformed into milligrams using the USDA's Food and Nutrition Database for Dietary Studies. Based on the distribution in the study population, daily caffeine consumption was classified into three groups using a tertiles classification into three groups: 0.00-0.24, 0.25–0.97, and 0.98–5.92 (unit: 0.1 g/day).

Covariates

The covariates in this study were obtained primarily through self-report questionnaires and physical examination sections in the NHANES database. We extracted information on age, race, education level, poverty impact ratio (PIR), total time of physical activity, energy intake, smoking status, drinking status, marital status, menstrual regularity, history of birth control pills using, history of hypertension and diabetes from the questionnaire. BMI was extracted from physical examination data. Participants with alcohol consumed more than 0 g/week were considered drinkers. We also calculated the Healthy Eating Index (HEI), a score that measures the quality of a participant's diet, from information obtained in the dietary questionnaire. Participants with higher HEI scores had healthier dietary patterns.

Statistical analysis

The data analysis of this study is divided into four steps. Firstly, we divided the study population into two groups based on the presence of infertility and showed the number of participants in the fertile and infertile groups out of a total of 2,099 participants. For continuous variables, data are presented in the form of "survey-weighted mean (95% confidence interval)" with *P*-value determined using survey-weighted linear regression (svyglm). For categorical variables, data are presented as "survey-weighted percentage (95% confidence interval)" with *P*-values determined using the survey-weighted Chi-square test (svytable). Secondly, we applied multiple logistic regression analyses to examine the relationship between tea, coffee and caffeine intake and infertility respectively, after adjusting covariates as follows–Model I: adjusted for age, race and energy intake; Model II: with additional adjustment for educational level, BMI, HEI, physical activity total time, marital status, menstrual regularity, history of birth control pills using, smoking status and drinking status. Adjusted confounders were selected based on other studies assessing risk factors for infertility [19–23]. It was observed that the numerical value of caffeine consumption was too large to facilitate comparison of effect sizes; therefore, we reduced it by 100 times and labeled it per 0.1 g/day. According to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [24], the results of each model are presented in the table. Thirdly, we used generalized linear models (GLM) and generalized additive models (GAM) to identify the nonlinear relationship between tea intake and infertility. Finally, we conducted subgroup analyses including age (≤30 years, 30–40 years, >40 yeas), BMI (≤25 kg/m^2, 25–30 kg/m^2, >30 kg/m^2), total exercise time (≤150 min/week, >150 min/week), marital status (widowed/divorced/separated/never married, married/living with partner), smoking status (never, former, current) and drinking status (no, yes).

Data analysis was performed using R (The R Foundation; http://www.r-project.org; version 4.2.0) and EmpowerStats (www.empowerstats.net, X&Y solutions, Inc. Boston, Massachusetts) with NHANES-provided sampling weights. A two-sided *P* value of less than 0.05 was considered as statistical significance.

Results

The selection of participates

Figure 1 illustrate the enrollment process of the study population. Women aged 18–44 years (*N*=4175) were included in the 2013–2018 NHANES survey of 29,400 participants. Women with missing data on infertility (*N*=638) and tea or coffee consumption (*N*=603), with history of bilateral oophorectomy (*N*=31) and hysterectomy (*N*=77), not having sexual experience (*N*=173), not having sexual intercourse in the past year (*N*=31), pregnant (*N*=116), with infectious diseases of the reproductive system (*N*=367) and consumed more than 6 cups per day of tea or coffee (*N*=40) were excluded. Finally, 2099 participants were included.

Baseline characteristics of participants

Table 1 presented the baseline characteristics of the study population according to infertility. There were 1863 participants in the fertile group and 236 participants in the infertile group. Compared to the fertile group, participants in the infertility group were older (33.29 vs. 30.01 years, $P<0.0001$), had larger BMI (32.12 vs. 28.54 kg/m^2, $P=0.0006$), longer physical activity total time (1474.22 vs.

Table 1 Weighted demographic characteristics of selected participants from the NHANES 2013–2018

	Fertile	Infertile	*P*-value
Numbers of participants	1863	236	
Age (years)	30.01 (29.38, 30.65)	33.29 (32.39, 34.20)	< 0.0001
Race (%)			0.2263
Non-Hispanic Black	14.62 (11.75, 18.06)	11.59 (8.01, 16.49)	
Non-Hispanic White	51.19 (45.57, 56.78)	56.87 (48.69, 64.69)	
Mexican American	14.16 (10.80, 18.35)	15.70 (9.98, 23.84)	
Others	20.03 (17.11, 23.30)	15.83 (10.75, 22.70)	
BMI (kg/m^2)	28.54 (27.87, 29.22)	32.12 (30.32, 33.93)	0.0006
Educational level (%)			0.9792
Less than 9th grade	2.81 (1.91, 4.13)	2.72 (0.94, 7.58)	
High school or equivalent	27.71 (23.88, 31.89)	28.54 (20.36, 38.43)	
College or over	69.48 (64.94, 73.67)	68.74 (58.99, 77.07)	
PIR	2.59 (2.43, 2.75)	2.84 (2.59, 3.09)	0.0538
HEI	52.97 (51.68, 54.27)	51.87 (48.85, 54.90)	0.4901
Physical activity total time (min/week)	1083.55 (1005.98, 1161.11)	1474.22 (1108.18, 1840.26)	0.0365
Energy intake (kcal/day)	1842.44 (1806.40, 1878.49)	1816.78 (1700.69, 1932.86)	0.6813
Smoking status (%)			0.2852
Never	75.37 (71.95, 78.50)	69.18 (62.21, 75.37)	
Former	10.56 (8.43, 13.15)	12.82 (8.09, 19.73)	
Current	14.07 (11.54, 17.04)	18.00 (12.59, 25.08)	
Drinking status (%)			0.3960
No	79.86 (77.04, 82.42)	75.78 (64.31, 84.45)	
Yes	20.14 (17.58, 22.96)	24.22 (15.55, 35.69)	
Marital status (%)			< 0.0001
Widowed/Divorced/Separated/Never Married	41.59 (37.98, 45.29)	21.39 (15.04, 29.49)	
Married/Living with Partner	58.41 (54.71, 62.02)	78.61 (70.51, 84.96)	
Age at menarche (years)	12.66 (12.55, 12.77)	12.24 (11.92, 12.56)	0.0188
Menstrual regularity (%)			0.2858
No	6.17 (4.68, 8.09)	8.58 (4.84, 14.77)	
Yes	93.83 (91.91, 95.32)	91.42 (85.23, 95.16)	
History of birth control pills use (%)			0.4291
No	30.06 (26.66, 33.69)	27.05 (20.70, 34.50)	
Yes	69.94 (66.31, 73.34)	72.95 (65.50, 79.30)	
Hypertension (%)			0.0176
No	90.13 (88.17, 91.80)	83.11 (75.69, 88.61)	
Yes	9.87 (8.20, 11.83)	16.89 (11.39, 24.31)	
DM (%)			< 0.0001
No	97.41 (96.58, 98.04)	91.87 (87.13, 94.96)	
Yes	2.59 (1.96, 3.42)	8.13 (5.04, 12.87)	
Tea consumption (cups/day)	0.63 (0.56, 0.70)	0.60 (0.37, 0.83)	0.8324
Coffee consumption (cups/day)	0.91 (0.81, 1.02)	1.02 (0.80, 1.25)	0.3999
Caffeine intake (0.1 g/day)	0.98 (0.90, 1.06)	1.29 (1.04, 1.54)	0.0379

Data in the table: "Numbers of participants" shows the count of participants in the fertile and infertile groups out of a total of 2,099 participants. For the continuous variables: survey-weighted mean (95% confidence interval), *P*-values were calculated using survey-weighted linear regression (svyglm). For the categorical variables: survey-weighted percentage (95% confidence interval), *P*-values were calculated using survey-weighted Chi-square test (svytable)

BMI, body mass index; DM, Diabetes mellitus; HEI, healthy eating index; PIR, poverty impact ratio

1083.55 min/week, $P=0.0365$), earlier onset of menarche (12.24 vs. 12.66 years, $P=0.0188$) and higher caffeine consumption (129.03 vs. 98.32 mg/day, $P=0.0379$). There were more patients with hypertension (16.89% vs. 9.87%, $P=0.0176$) and diabetes (8.13% vs. 2.59%, $P<0.0001$) in the infertility group. Interestingly, more subjects in the infertile group were married and living with partner than those in the fertile group (78.61% vs. 58.41%, $P<0.0001$).

The association of tea, coffee and caffeine consumption with infertility

In order to explore the association of tea, coffee and caffeine consumption with infertility, univariable and multivariable logistic regression models were applied. As depicted in Table 2, we identified a significant negative association between tea consumption and infertility. Specifically, women who consumed less than two cups of tea per day had significantly lower odds for infertility, with a reduction of 45% (95% CI: 11–67%, $P=0.0234$), which remained consistent across various models. However, no significant association was found between coffee, caffeine consumption and infertility. Because menarche age and PIR were significantly different between the two groups in Table 1, we also included them in the adjusted variables for analysis, and the results showed that including these variables improved the result, reducing the risk of infertility by 47% instead of 45% (Supplementary Table 1).

The analyses of non-linear relationship between tea consumption and infertility

We further analyzed the relationship between tea consumption and infertility using smooth curve fitting (Fig. 2). We observed a non-linear connection between tea consumption and infertility (after adjusting age, race, energy intake, educational level, BMI, HEI, physical activity total time, marital status, menstrual regularity, history of birth control pills use, smoking status; drinking status and coffee consumption). By using a two-piecewise linear regression model, we identified the inflection point value was 2 (Table 3). On the right side of the inflection point, we did not observe a significant association between tea consumption and infertility (OR: 1.28; 95% CI: 0.93 to 1.76; $P=0.1351$). However, on the left side of the inflection point, we found a negative relationship between tea consumption and infertility. Within this range, each additional cup of tea consumed was associated with a 27% reduction in the risk of infertility (95% CI: 0.57 to 0.93, $P=0.0122$).

Table 2 Relationship between tea, coffee, caffeine consumption and infertility in different models

Exposure	Crude Model		Model I		Model II	
	OR (95%CI)	*P* value	OR (95%CI)	*P* value	OR (95%CI)	*P* value
Tea (cups/day)						
(continuous)	0.97 (0.76, 1.25)	0.8360	0.94 (0.73, 1.22)	0.6637	0.92 (0.72, 1.18)	0.5294
(categorical)						
0	Ref.		Ref.		Ref.	
0 < - ≤ 2	0.55 (0.34, 0.88)	0.0158	0.55 (0.34, 0.88)	0.0173	0.55 (0.33, 0.89)	0.0234
> 2	0.95 (0.48, 1.89)	0.8863	0.88 (0.42, 1.81)	0.7222	0.82 (0.40, 1.69)	0.6034
P for trend	0.84 (0.60, 1.17)	0.3064	0.81 (0.57, 1.15)	0.2493	0.79 (0.56, 1.12)	0.1955
Coffee (cups/day)						
(continuous)	1.07 (0.92, 1.25)	0.3839	0.95 (0.80, 1.13)	0.5886	0.96 (0.81, 1.13)	0.6189
(categorical)						
0	Ref.		Ref.		Ref.	
0 < - ≤ 2	0.96 (0.63, 1.46)	0.8483	0.81 (0.52, 1.28)	0.3742	0.75 (0.47, 1.20)	0.2436
> 2	1.25 (0.78, 2.00)	0.3532	0.84 (0.50, 1.42)	0.5243	0.89 (0.53, 1.51)	0.6690
P for trend	1.09 (0.87, 1.38)	0.4548	0.90 (0.70, 1.16)	0.4304	0.91 (0.70, 1.18)	0.4946
Caffeine (0.1 g/day)						
(continuous)	1.26 (1.50, 1.51)	0.0167	1.17 (0.96, 1.43)	0.1296	1.15 (0.93, 1.42)	0.2148
(tertiles)						
T1 (0.00-0.24)	Ref.		Ref.		Ref.	
T2 (0.25–0.97)	0.80 (0.48, 1.34)	0.4096	0.72 (0.43, 1.20)	0.2111	0.65 (0.39, 1.10)	0.1217
T3 (0.98–5.92)	1.26 (0.79, 2.00)	0.3386	0.95 (0.59,1.53)	0.8261	0.84 (0.51,1.36)	0.4738
P for trend	1.15 (0.90, 1.48)	0.2655	1.00 (0.77, 1.28)	0.9725	0.94 (0.72, 1.21)	0.6244

Model I adjusted for age, race and energy intake

Model II further adjusted for educational level, BMI, HEI, physical activity total time, marital status, menstrual regularity, history of birth control pills use, smoking status and drinking status. Tea consumption (for the coffee model), coffee consumption (for the tea model)

BMI, body mass index; CI, confidence interval; HEI, healthy eating index; OR, odds radio; Ref., reference

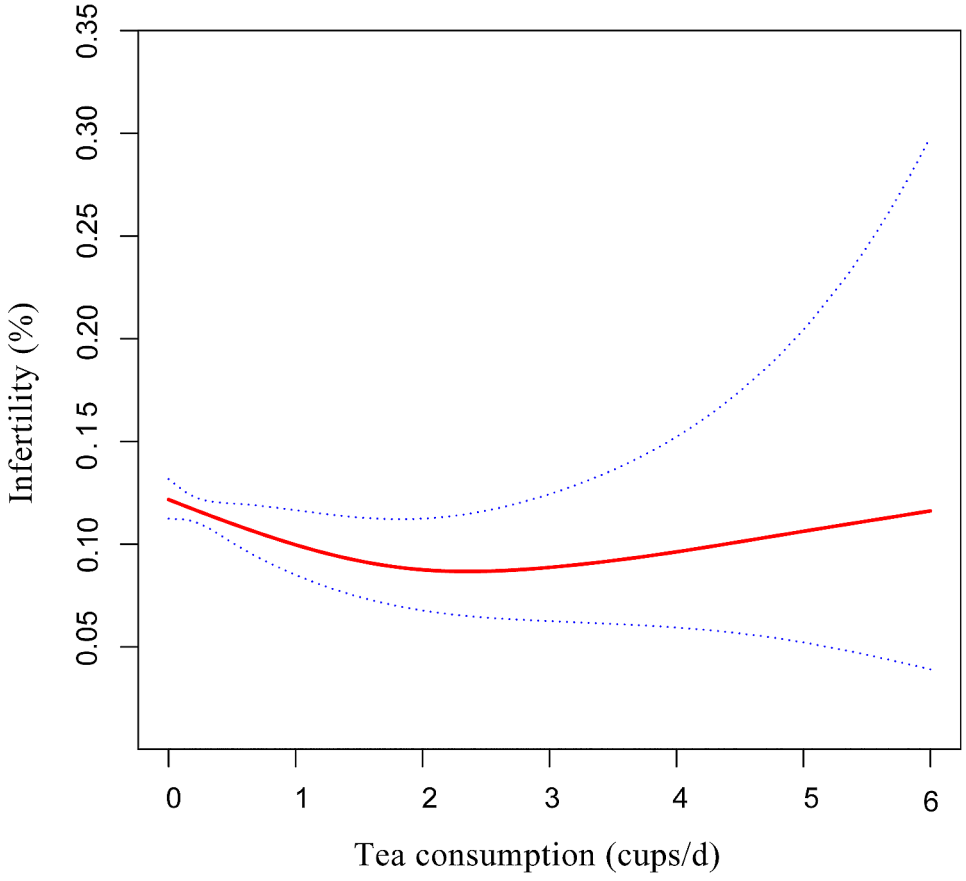

Fig. 2 Adjusted associations of tea consumption with infertility. A non-linear relationship between tea consumption and infertility was found in generalized additive models (GAM). Adjusted: age; race; energy intake; educational level, BMI, HEI, physical activity total time, marital status, menstrual regularity, history of birth control pills use, smoking status; drinking status and coffee consumption. BMI, body mass index; HEI, healthy eating index

Table 3 Threshold effect analysis of tea consumption and infertility using two-piecewise linear regression

Inflection point of tea consumption (cups/day)	Effect size (OR)	95%CI	*P* value
< 2	0.73	0.57 to 0.93	0.0122
≥ 2	1.28	0.93 to 1.76	0.1351

Adjusted: age, race, energy intake, educational level, BMI, HEI, physical activity total time, marital status, menstrual regularity, history of birth control pills use, smoking status; drinking status and coffee consumption

BMI, body mass index; CI, confidence interval; HEI, healthy eating index; OR, odds radio

The results of subgroup analyses

To further test the stability of the results, we performed subgroup analyses of tea, coffee and caffeine consumption separately, and the results are presented in Fig. 3. After adjusting age, race, energy intake, educational level, BMI, HEI, physical activity total time, marital status, menstrual regularity, history of birth control pills using, smoking status and drinking status, tea consumption (for the coffee model) and coffee consumption (for the tea model), the test for interactions were not significant in each subgroup (*P* values for interactions were larger than 0.05).

Discussion

In the present study, we used GLM and GAM to elucidate the relationship between tea, coffee and caffeine consumption and risk of female infertility. The results obtained from GAM and two-piecewise linear regression model showed that the relationship between tea consumption and infertility was non-linear, and the association were different on the left and right side of the inflection point. We found tea consumption was negatively associated with infertility on the left of the inflection point, but tea consumption was not statistically significant on the right side of the inflection point. However, in the present study, we did not find a correlation between coffee and caffeine consumption and infertility.

To date, a large number of studies have investigated the association between tea, coffee or total caffeine consumption and female fertility, and the conclusions of different studies have been highly inconsistent.

Regarding the relationship between tea consumption and infertility, our study found a significant negative association when individuals consumed more than 0 cups but less than 2 cups of tea. Within this range, each additional cup of tea consumed was associated with a 27%

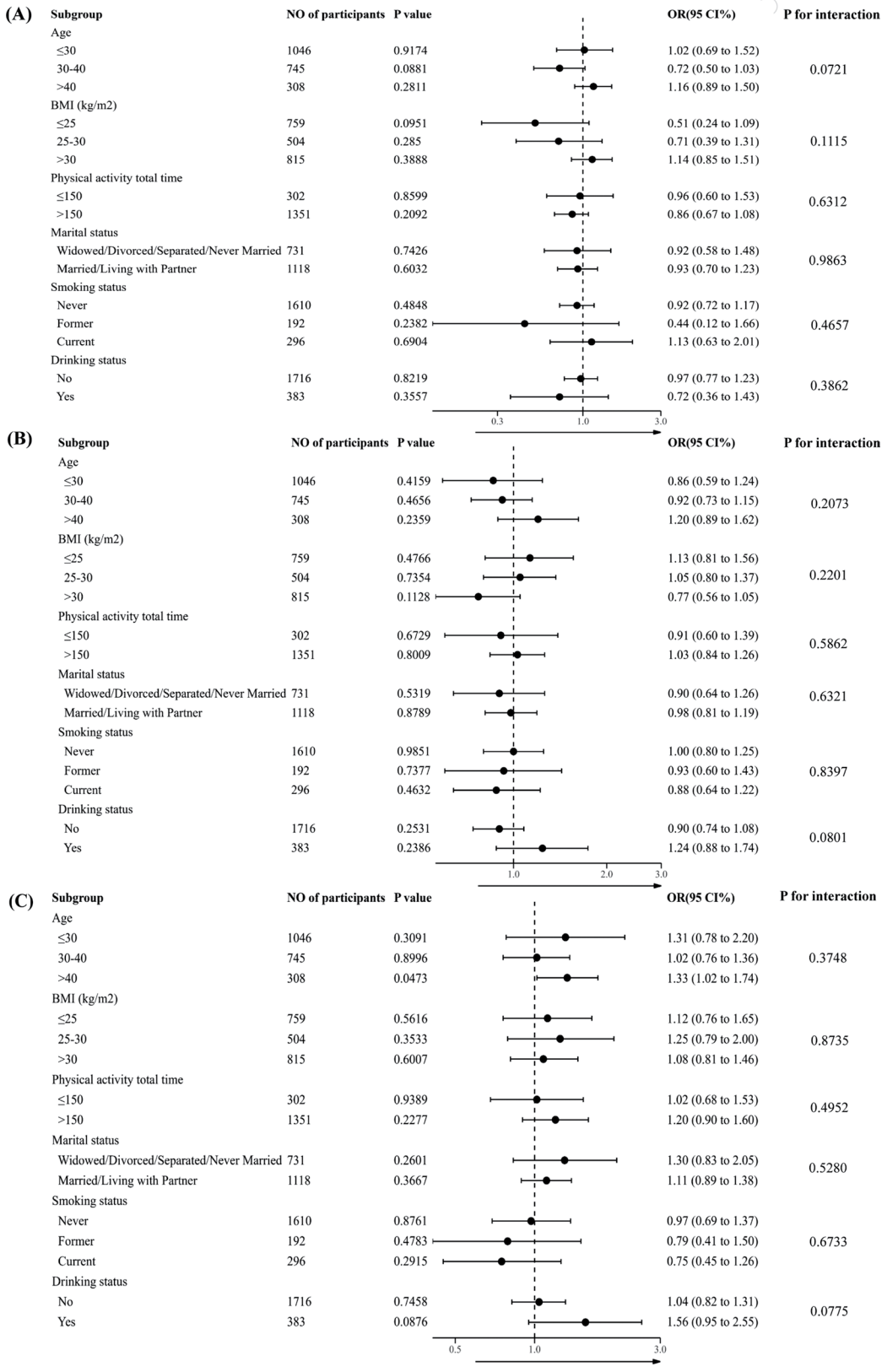

Fig. 3 Effect size of tea (**A**), coffee (**B**) and caffeine (**C**) consumption on infertility in subgroups analysis. Adjusted: age, race, energy intake, educational level, BMI, HEI, physical activity total time, marital status, menstrual regularity, history of birth control pills use, smoking status, drinking status and coffee consumption. In each case, the model is not adjusted for the stratification variable. BMI, body mass index; CI, confidence interval; HEI, healthy eating index; OR, odds radio

decrease in the risk of infertility. A previous cohort study conducted in the United States involving 187 women of reproductive age reached a similar conclusion to our current study [25]. Tea consumption of more than half a cup per day was significantly associated with an increase in fertility (OR: 2.05; 95% CI: 1.09 to 3.88). In that study, participants were informed during recruitment that the purpose was to examine the relationship between diet and fertility, which could have influenced the accuracy of the collected dietary information. However, a prospective cohort study conducted in Denmark involving 3,628 women treated tea and coffee intake as 250 ml per serving. The study assessed the relationship between caffeine, coffee, tea, and sodas with time to pregnancy and found no significant association between tea consumption and female fertility (fecundability ratios: 1.27, 95% CI: 0.98 to 1.64) [14]. The reason for obtaining a negative result may be due to the small sample size, with only 11% of participants providing information on tea consumption, which is significantly smaller than the sample size in our study with 2,099 participants. Additionally, we conducted subgroup analyses to assess the consistency of our findings across different population subgroups. These analyses demonstrated consistent results, reinforcing the reliability of our findings. Notably, compared to previous studies, we innovatively found the relationship between tea consumption and infertility was nonlinear.

Our study found no significant association between coffee or caffeine consumption and infertility. Some studies have suggested an association between coffee or caffeine intake and decreased female fertility [3–8]. A multicenter cohort study of 3187 women from Europe evaluated the impact of caffeine intake on delayed conception and concluded that women with an intake exceeding 500 mg/day experienced delayed conception [8]. However, there are also studies that have suggested that coffee and caffeine intake are favorable factors for female fertility [16, 17]. A cohort study conducted on 259 non-medical female hospital workers who were planning to become pregnant found that moderate caffeine consumption (400-700 mg/day) was associated with higher fertility compared to lower intake levels [16]. Reduced statistical power caused by the smaller sample sizes of participants with higher caffeine consumption may account for the different results. Nonetheless, consistent with our results, the majority of studies on caffeine consumption and fertility showed no association [9–15].

Interestingly, our study found a significant correlation between tea consumption, rather than coffee or caffeine, and infertility. This suggests that apart from caffeine, other components in tea may play a role in the negative association between tea consumption and infertility. Tea is derived from the camellia plant and is a widely consumed beverage worldwide. Except for caffeine, tea contains green tea polyphenols (GrTPs). GrTPs, especially epigallocatechin gallate (EGCG) have significant antioxidant properties. In addition, tea also contains many other ingredients, such as vitamin C, carotenoids and tocopherols, which may enhance the antioxidant activity of GrTPs [26]. The antioxidant properties of polyphenols include scavenging and destroying free radicals, enhancing egg viability and reducing cellular damage in reproductive organs; however, they can exert opposite effects at higher concentrations [27]. This may be the potential mechanism behind the conclusion of this study that only moderate tea consumption (less than 2 cups/day) is negatively associated with infertility risk.

Our study contains several advantages. Firstly, we utilized data from the NHANES database derived from a large-scale national normative survey in the United States. Secondly, our study provides new evidence to explore the association between tea, coffee, caffeine consumption and infertility. We found a non-linear relationship between tea consumption and infertility, with an inflection point of 2 cups/day, while there was no significant association between coffee consumption, caffeine intake and infertility. Thirdly, threshold effect analysis was used to determine the effective range of the negative association between tea consumption and infertility. Finally, in order to demonstrate the stability of the results, we conducted a detailed subgroup analysis to confirm that the results of this study are generally valid in different subgroups of people.

However, our study also has certain limitations. First, this study was cross-sectional, which allowed it to demonstrate an association between exposure and outcome, but not to establish causality. Second, the dataset was derived from a nationwide survey in the United States, and it remains to be tested whether the findings are generalizable to populations of other ethnicities. Third, due to the lack of data on the specific amount of water used to brew tea in the NHANES database, we cannot exclude the possibility that the quantity of water used for brewing tea may affect the relationship between tea consumption and infertility. Further research is needed to investigate this aspect more comprehensively. Finally, information on diet was collected primarily from self-reports but was fairly representative of the dietary habits of the participants when information from two recall surveys was combined from the NHANES database.

Conclusions

In conclusion, in this population-based cross-sectional study, we found a negative association between daily tea consumption ranging from more than 0 cups to less than 2 cups and infertility. Within this range, each additional cup of tea consumed was associated with a 27% reduction in the risk of infertility. However, our findings did

not indicate any significant impact of coffee or total caffeine intake on the risk of infertility.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12958-024-01261-3.

Supplementary Material 1

Author contributions

Hanzhi Zhang wrote the main manuscript text and analysis. Sixu Qian prepared Figs. 1, 2 and 3. Jianlin Chen prepared Tables 1, 2 and 3. Jingfei Chen have drafted the work or substantively revised it. All authors reviewed the manuscript.

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Data availability

The datasets presented in this study can be found in online repositories and the NHANES data releasing for public use. The names of the repository/repositories and accession number(s) can be found below: https://www.cdc.gov/nchs/nhanes/index.html.

Declarations

Ethical approval

All data obtained from NHANES, which was reviewed and approved by National Center for Health Statistics (NCHS) Ethics Review Board and all subjects agreed on the survey and signed written consent. The NHANES was conducted in accordance with local legislation and institutional requirements. Because the NHANES database is publicly accessible, no additional ethical approvals are required.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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