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Association of tea consumption with life expectancy in US adults

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Abstract

Objective The association of tea consumption with life expectancy in US adults remains unclear. This study aimed to evaluate the correlation between tea consumption and life expectancy among US adults.

Methods Tea consumption records and available mortality data from National Health and Nutrition Examination Survey 2001 to 2018 for adults ≥ 20 years of age were used ($n = 43,276$). Participants were grouped based on their daily tea consumption as follows: non-drinkers, < 1 cup/day, 1 to < 3 cups/day, 3 to < 5 cups/day, and ≥ 5 cups/day. Life table method was used to evaluate the association between daily tea consumption and life expectancy.

Results During a median follow-up of 8.7 years, we documented 6275 deaths out of the 43,276 participants. The estimated life expectancy at age 50 years was 30.69 years (95% confidence interval, 30.53 to 30.89), 30.77 years (29.45 to 32.19), 31.07 years (30.35 to 31.69), 32.93 years (31.24 to 34.5), and 29.68 years (27.38 to 31.97) in tea-consuming participants with non-drinker, < 1 cup/day, 1 to < 3 cups/day, 3 to < 5 cups/day, and ≥ 5 cups/day, respectively. Equivalently, participants with 3 to < 5 cups/day consumption had a life gain of average 2.24 years (0.49 to 3.85) compared with those without tea consumption. Similar years of life gained were observed in females and White individuals, but not in males, Black and Hispanic populations. Notably, obvious health benefits weren't observed in other groups of tea consumption. The addition of sugar to tea is a potential health risk factor.

Conclusions Consuming 3 to < 5 cups/day of tea may be a healthy recommendation for tea intake, and the addition of sugar to tea should be approached with caution.

Keywords Tea consumption, Life expectancy, Years of life gained, NHANES

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Introduction

The United States leads in terms of medical technology, and healthcare expenditure, remaining the largest consumer of healthcare services in the world [1]. However, its life expectancy has remained stagnant for over 10 years, and the life expectancy gap has resulted in a disastrous outcome, with a disadvantage of 7.8 years compared with leading regions (Hong Kong) in 2020 [2, 3]. The unimproved health status of chronic diseases has been the leading reason for the stalled decline in life expectancy and premature deaths, primarily attributed to unhealthy lifestyles [4, 5].

Tea, consumed by over two-thirds of the world's population, is the second most consumed beverage only after water [6]. Tea harbors elevated concentrations of flavonoids and other antioxidants, widely regarded as beneficial [6]. Numerous prior epidemiological studies have demonstrated that tea protects against numerous chronic diseases and their related mortalities [7–9]. Compared with mortality risk, life expectancy serves as a pivotal metric for assessing the holistic health of a population owing to its capacity for more straightforward communication and comprehension among the general public [10]. However, the association of tea on improving the overall lifespan of the general population has seldom been assessed, with the exception of focusing on Chinese population [11].

In this study, we investigated the association between tea consumption and both mortality risk and life expectancy among US adults using data from the National Health and Nutrition Examination Survey (NHANES). We also considered factors including sex, race and ethnicity, type of tea, and whether added sugar in tea, recognizing their potential to affect the association with life expectancy and contributing to developing more refined public health policies.

Methods

Study design and population

NHANES is a nationwide study by the National Center for Health Statistics, which assesses the health and nutrition status of the US noninstitutionalized civilian population with a complex, stratified, and multistage probability sample design. It collects interview information from the respondents at their homes, and conducts physical examinations and collects dietary information at a mobile examination center. Elaborate insights into the study framework and research methodologies are available in previous publication [12]. The study protocol was approved by the Institutional Review Board of the National Center for Health Statistics. All participants offered written informed consent.

This study included individuals aged 20 to 85, across nine survey cycles spanning from 2001 to 2002 to 2017–2018, comprising a cohort of 50,068 individuals with documented mortality data. After excluding those with incomplete tea consumption information (n=5,647) and pregnant women at the time of examination (n=1,145, because they might be restricting their tea intake based on advice from a healthcare professional.), the eligible study population consisted of 43,276 participants (Supplementary Figure S1).

Assessment of tea consumption

Dietary data were acquired through 24-h dietary recalls facilitated by adept interviewers using USDA (US Department of Agriculture) automated multi-pass methods during two distinct time periods [13, 14]. From 2001 to 2002, a singular dietary recall was conducted in person at a mobile examination center. Subsequently, from 2003 to 2018, an additional dietary recall, administered via phone, was incorporated approximately 3–10 days after the initial recall. Dietary data from the participants who underwent at least one dietary recall interview were incorporated into the current analysis. Specifically, data from the single-day participants were used as reported, whereas data from the two-day participants were averaged. We determined the tea consumption of each participant based on the USDA food codes and their descriptions. During this process, we excluded unconventional teas such as herbal tea, hibiscus tea, corn tea, chamomile tea, and chai tea. We evaluated the stability of the tea consumption pattern using two-day tea consumption data from individuals, employing weighted Pearson correlation (r=0.76; 95% confidence interval [CI]: 0.74 to 0.78). The tea consumption was categorized into five distinct subgroups: non-drinking, <1 cup/day, 1 to <3 cups/day, 3 to <5 cups/day, and ≥5 cups/day, where one cup is approximately equal to 8 US fluid ounces (236.59 milliliter). Based on the description information provided for each tea, we determined the type of tea (black, green, or unreported) and whether sugar was added to the tea (with sugar, without sugar). Detailed tea codes and description information can be found in Supplementary Table S1. Due to the limited sample size of green tea drinkers (n=1,116, 7.9%) among tea drinkers, we combined them with individuals who did not report the type of tea consumed (n=4,681, 33.13%) as 'Other tea', compared to 'Black tea'. The specific amount of sugar added to tea was determined using the nutritional information from the Food and Nutrient Database for Dietary Studies (https://www.ars.usda.gov/northeast-area/beltsville-md-bhnrc/beltsville-human-nutrition-research-center/food-surveys-research-group/docs/fndds).

Assessments of death

Mortality information was obtained from the NHANES Linked Mortality File up to December 31, 2019. The

causes of death attributed to diseases were defined using the International Classification of Diseases, Tenth Revision (ICD-10). The follow-up period was computed from the date of the interview or examination until the date of death or until the study ended on December 31, 2019, whichever came first. Data on all-cause mortality rates for 2019 by single-year age from 50 to100 years were extracted from the National Center for Health Statistics (by sex or ethnicity, where applicable) [15]. We downloaded the specific cause-of-death (cancer, and cardiovascular and cerebrovascular diseases [CVD]) mortality data for the US population in 2019, which included mortality data for individuals aged 20 to 84 years by single-year age groups, provided by the Wide-Ranging Online Data for Epidemiologic Research database of the Centers for Disease Control and Prevention. Due to the absence of specific cause-of-death mortality data for individuals aged 85 and older, we estimated the missing data using a Poisson regression model (Supplementary Figure S2).

Assessments of covariates

To attenuate potential confounding effects, we incorporated covariates into our analytical framework when constructing Cox regression models and estimating life expectancy. Data on demographic and socioeconomic information were collected from questionnaires, including sex (male and female), age, race and ethnicity (White, Black, Hispanic, and others), educational attainment (<high school, high school, and >high school), family income (poor, moderate, and rich), marital status (married, unmarried, and others), and medical insurance (covered and not covered). Moreover, lifestyle factors, such as smoking status (never, former, or now) and dietary intake, were included. The dietary intake variables included alcohol consumption, fruit and vegetable consumption, grain consumption, dairy intake, protein food consumption, and total energy intake. Detailed insights regarding the data collection and definitions of these variables can be found in eMethod 1. Additionally, in eMethod 1, we described the definition of one grouping factor in the subgroup analysis—physical activity (insufficient; moderate or sufficient) [16].

Statistical analysis

Complex sampling design and sampling weights were considered to strengthen the reliability of our analysis with nationally representative findings. To handle missing data pertaining to covariates, we employed multiple imputation with 20 datasets and chained Eqs. [17, 18]. The association between tea consumption and mortality risk was estimated using Cox proportional hazards models, adjusting for covariates described previously. The proportional hazards assumption was appropriate, as assessed by the Kaplan-Meier and Schoenfeld residuals methods [19], with no violations detected (all $p>0.05$). Furthermore, we employed the restricted cubic spline (RCS) method to investigate whether there was a nonlinear relationship between tea consumption and all-cause mortality.

The estimated life expectancies of participants across various levels of tea consumption were calculated by life table method [20–22]. We utilized three estimates to compute the cumulative survival rates from the age of 50 years to 100 years: (1) age-specific mortality of all causes in 2019; (2) adjusted hazard ratios; and (3) age-specific distribution of tea consumption. The expected life expectancy gain from tea consumption is calculated as the cumulative sum of the survival curve difference compared to the non-tea-drinking group. To calculate the confidence intervals (CIs) for life expectancy estimates, we employed a bootstrapping simulation with 1000 iterations, reporting the 95% CI as the 25th and 975th ordered draws of the distribution. We used the all-cause mortality rate for the entire population to compute life expectancy. Further details regarding the methods employed to estimate these differences in life expectancy have been described in eMethod 2 and in a prior study [15, 22–24]. Due to the absence of mortality data for individuals of 'other' race, their life expectancy was not estimated in this study. Additionally, we employed the Arriaga decomposition method to calculate life expectancy gains attributed to different contributions from three causes of death, including cancer, CVD, and others. This methodology encompasses two essential steps: (1) decomposing the disparity in life expectancy across various age groups, and (2) within distinct age group, breaking down the difference in life expectancy by specific causes [25, 26].

We performed five sensitivity analyses to assess the robustness of our primary findings. First, we excluded participants without tea consumption to detect whether the results would be influenced by a high proportion of non-drinkers. Second, individuals lacking complete variable information were excluded from the analysis to detect the robustness of results. Third, we excluded participants who died within the first 2 years of follow-up to mitigate the potential influence of reverse causation [27]. Fourth, we included several health-related factors that may influence the relationship between tea consumption and life expectancy in our model, such as BMI, the presence of cancer, diabetes, and hypertension (described in eMethod **3**) [16]. Fifth, we classified unconventional teas as "Other types of tea" to assess the stability of the model. All statistical analyses were performed using R version 4.3.1. All statistical tests were two-sided, and a significance level of $P<0.05$ was utilized to determine statistical significance.

Results

Basic characteristics of study participants

In total, 43,276 adults were included in this study, representing an estimated 216.1 million US adults (Table 1). Among the participants, 70% (representing 148.2 million US adults) reported no tea consumption, while the proportions of individuals who consume tea at '<1 cup/day', '1 to <3 cups/day', '3 to <5 cups/day', and '≥5 cups/day' were 3.9% (representing 7.1 million US adults), 18.3% (representing 40.7 million US adults), 5% (representing 12.6 million US adults), and 2.8% (representing 7.5 million US adults), respectively (Table 1). At baseline, individuals consuming '3 to <5 cups/day' of tea tended to be males and of White ethnicity. They had higher consumption of fruits, vegetables, grains, and protein foods, and lower alcohol intake, and were non-smokers. Additionally, they had higher family incomes and greater educational attainment.

Table 1 Characteristics of participants at baseline by tea consumption

Variable	All	Tea consumption					
		Non-drinking	< 1 cup/day	1 to < 3 cups/day	3 to < 5 cups/day	≥ 5 cups/day	*P* value
N (%)	43,276(100%)	30,307(70%)	1697(3.9%)	7912(18.3%)	2169(5%)	1191(2.8%)	< 0.0001
Age (years, SE)	47.4(0.2)	46.4(0.2)	50.5(0.6)	50.3(0.3)	47.7(0.4)	47.1(0.5)	< 0.0001
Coffee (cups/d, SE)	1.4(0.0)	1.5(0.0)	1.2(0.1)	1.3(0.0)	1.3(0.1)	1.4(0.1)	< 0.0001
Alcohol (drinks/d, SE)	0.7(0.0)	0.8(0.0)	0.4(0.0)	0.5(0.0)	0.6(0.1)	0.6(0.1)	< 0.0001
Fruit (cups/d, SE)	3.6(0.0)	3.6(0.0)	3.2(0.1)	3.6(0.0)	3.8(0.1)	3.9(0.1)	< 0.0001
Vegetables (cups/d, SE)	1.6(0.0)	1.6(0.0)	1.6(0.0)	1.7(0.0)	1.7(0.0)	1.8(0.1)	< 0.0001
Grain (oz/d, SE)	6.5(0.0)	6.5(0.0)	6.1(0.1)	6.3(0.1)	6.8(0.1)	6.9(0.1)	< 0.0001
Dairy (cups/d, SE)	1.6(0.0)	1.6(0.0)	1.3(0.0)	1.4(0.0)	1.5(0.0)	1.7(0.1)	< 0.0001
Protein food (oz/d, SE)	1.7(0.0)	1.7(0.0)	1.2(0.1)	1.6(0.0)	2.0(0.1)	2.3(0.1)	< 0.0001
Energy (kcal, SE)	2159.9(7.4)	2166.8(8.6)	1872.8(23.4)	2067.9(17.5)	2318.2(34.7)	2534.7(38.3)	< 0.0001
Sex, %							< 0.0001
Male	21,496	15,537(50.7)	618(34.7)	3477(41.4)	1150(52.8)	714(58.1)	
Female	21,780	14,770(49.3)	1079(65.3)	4435(58.6)	1019(47.2)	477(41.9)	
Race and ethnicity, %							< 0.0001
White	19,471	13,123(67.1)	600(57.8)	3811(70.2)	1155(75.5)	782(83.8)	
Black	9177	6505(11.7)	346(11.5)	1750(11.0)	414(9.0)	162(5.7)	
Mexican-Hispanic	10,722	8382(15.1)	367(13.7)	1414(9.7)	405(9.5)	154(6.0)	
Other	3906	2297(6.1)	384(17.0)	937(9.0)	195(6.0)	93(4.5)	
Education, %							< 0.0001
< High school	11,121	8514(17.8)	450(18.5)	1553(12.8)	398(12.2)	206(12.6)	
High school	10,141	7111(24.2)	329(21.1)	1816(22.8)	562(26.4)	323(27.8)	
> High school	22,014	14,682(58.0)	918(60.4)	4543(64.4)	1209(61.4)	662(59.6)	
Smoke, %							< 0.0001
Never	23,315	15,934(52.5)	1109(62.7)	4564(56.9)	1129(51.7)	579(51.0)	
Former	10,785	7556(24.8)	397(22.9)	2018(25.7)	541(26.0)	273(21.9)	
Now	9176	6817(22.7)	191(14.4)	1330(17.4)	499(22.3)	339(27.1)	
Marriage, %							< 0.0001
Married	25,808	17,827(61.1)	1061(66.3)	4804(63.9)	1347(65.2)	769(66.0)	
Unmarried	7630	5599(19.9)	242(15.6)	1199(15.3)	403(18.0)	187(16.0)	
Other	9838	6881(18.9)	394(18.1)	1909(20.8)	419(16.8)	235(18.0)	
Family Income, %							< 0.0001
Poor	13,008	9639(22.9)	510(23.7)	1996(18.0)	558(17.8)	305(17.4)	
Moderate	17,028	11,989(36.7)	640(34.7)	3132(36.9)	822(33.4)	445(33.8)	
Rich	13,240	8679(40.4)	547(41.6)	2784(45.1)	789(48.8)	441(48.8)	
Medical Insurance, %							< 0.0001
Covered	34,094	23,392(81.2)	1389(83.8)	6621(85.6)	1742(82.9)	950(82.2)	
Not Covered	9042	6808(18.8)	298(16.2)	1269(14.4)	427(17.1)	240(17.8)	

Data are mean (SE) or counts (percentages). Tea consumption was categorized into 5 levels (non-drinking, <1 cup/day, 1 to <3 cups/day, 3 to <5 cups/day, ≥5 per day). A cup of tea is about 240 mL. Fruit: total intact or cut fruits and fruit juices (cup eq.); Vegetables: Total dark green, red and orange, starchy, and other vegetables, excludes legumes (cup eq.); Grain: Total whole and refined grains (oz. eq.); Dairy: Total milk, yogurt, cheese, and whey (cup eq.); Protein foods: Total meat, poultry, seafood, organ meats, cured meat, eggs, soy, and nuts and seeds; excludes legumes (oz. eq.). kcal: kilocalorie; oz: ounce equivalents; d: day. Medical insurance encompasses both government-backed and private insurance policies. Income was quantified as the ratio of family income to the official poverty threshold, and this ratio was further categorized as follows: <1.3 (Poverty), ≥1.3 and <3.5 (Moderate), and ≥3.5 (Rich)

Association of the tea consumption with mortality risk

Over a median follow-up period of 8.7 years, 6,275 deaths occurred out of the 43,276 participants, including 1,943 deaths from CVD, and 1,420 from cancer (Table 2). '3 to <5 cups/day' of tea consumption was significantly associated with reduced risks of all-cause mortality. Compared with participants who did not consume tea, those with '3 to <5 cups/day' of tea consumption had a 21% lower risk of total mortality (Hazard ratio [HR], 0.79; 95% CI, 0.67 to 0.94). Regarding specific mortality, '3 to <5 cups/day' of tea consumption was linked to a 25% reduction in cancer mortality (HR, 0.75; 95% CI, 0.53 to 1.06) and a 30% reduction in other causes of mortality (HR, 0.7; 95% CI, 0.55 to 0.89), with no apparent benefit in reducing CVD mortality. Conversely, no significant association was observed among the participants with other cups of tea consumption. Similar results were observed in the RCS analysis adjusted covariates described previously (Supplementary Figure S3A). However, after additional adjustment for added sugar in tea, consuming '≥5 cups/day' of tea still corresponded to HRs less than 1, although the results were not statistically significant (Supplementary Figure S3B).

In the subgroup analyses, this association remained consistent in females but was insignificant in males (Supplementary Table S2; $P_{\text{for trend}} = 0.024$ for females, and $P_{\text{for trend}} = 0.878$ for male in supplementary Table S3). Moreover, the consumption of '≥5 cups/day' of tea may be associated with a potential adverse effect in males (HR, 1.35; 95% CI, 1.00 to 1.82) (Supplementary Table S2). White individuals appeared to benefit from consuming '3 to <5 cups/day' of tea, showing a 23% lower risk of total mortality (HR, 0.77; 95% CI, 0.62 to 0.95) (Supplementary Table S3). However, no such benefit was observed in the Black, Hispanic, and other populations. '3 to <5 cups/day' of tea consumption without added sugar was linked to a 28% reduction in mortality (HR, 0.72; 95% CI, 0.59 to 0.88), whereas the association of tea with added sugar yielded a 20% risk decrease with an insignificant confidence interval (HR, 0.8; 95% CI, 0.63 to 1.01). Furthermore, for '3 to <5 cups/day' of tea consumption, both black tea (HR, 0.79; 95% CI, 0.65 to 0.97) and other tea (HR, 0.75; 95% CI, 0.6 to 0.94; including green tea and not specifically reported teas) were found to be beneficial for drinkers.

Association of tea consumption with estimated life expectancy

At age 50, the estimated life expectancy was 30.69 years (95% CI, 30.53 to 30.89) for non-drinkers, 30.77 years (29.45 to 32.19) for '<1 cups/day' of tea consumers, 31.07 years (30.35 to 31.69) for '1 to <3 cups/day' of tea consumers, 32.93 years (31.24 to 34.5) for '3 to <5 cups/day' of tea consumers, and 29.68 years (27.38 to 31.97) for '≥5 cups/day' of tea consumers (Fig. 1A). Compared with that of non-drinkers, the average life gain was 2.24 years longer (0.49 to 3.85) among participants aged 50 with '3 to <5 cups/day' of tea consumption (Fig. 1A and B). Potential life gain effect from '3 to <5 cups/day' of tea consumption remained consistent across all sensitivity analyses (Supplementary Table S4). In the Arriaga decomposition analysis, it was observed that for '3 to <5 cups/day' of tea consumption, the years of life gained compared with non-drinkers were attributed to decreases in deaths from CVD (29.82%), cancer (24.85%), and other causes (45.33%) (Fig. 1C). Although our study found a small effect (2%; HR: 0.98 [95% CI, 0.72 to 1.33]) of consuming '3 to <5 cups/day' of tea on reducing the risk of death from CVD, its contribution accounted for a relatively high proportion due to the heavy burden of CVD.

Table 2 Hazard ratios and 95% CI for category of tea consumption with the hazard of mortality

Cause of death	Indicators	Tea consumption					P for trend
		Non-drinking	< 1 cup/day	1 to < 3 cups/day	3 to < 5 cups/day	≥ 5 cups/day	
All-cause mortality	HR(95% CI)†	1(reference)	0.99 (0.84,1.15)	0.96 (0.88,1.04)	0.79 (0.67,0.94)	1.11 (0.88,1.41)	0.33
	Cases(total)*	4404(30307)	270(1697)	1244(7912)	233(2169)	124(1191)	-
CVD mortality	HR(95% CI)†	1(reference)	1.14 (0.85,1.52)	0.94 (0.81,1.09)	0.98 (0.72,1.33)	1.16 (0.68,1.98)	0.98
	Cases(total)*	1355(30307)	88(1697)	383(7912)	80(2169)	37(1191)	-
Cancer mortality	HR(95% CI)†	1(reference)	1 (0.67,1.49)	1.09 (0.91,1.3)	0.75 (0.53,1.06)	1.06 (0.73,1.53)	0.72
	Cases(total)*	985(30307)	56(1697)	292(7912)	51(2169)	36(1191)	-
Other mortality	HR(95% CI)†	1(reference)	0.87 (0.69,1.11)	0.91 (0.82,1.03)	0.7 (0.55,0.89)	1.12 (0.78,1.61)	0.2
	Cases(total)*	2064(30307)	126(1697)	569(7912)	102(2169)	51(1191)	-

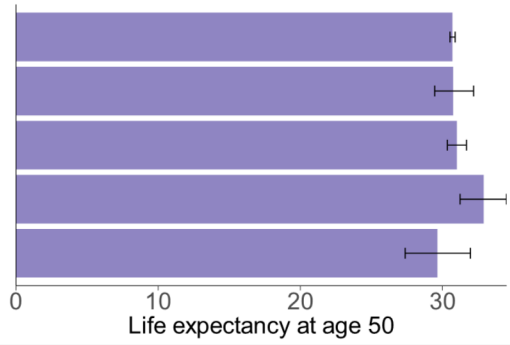
HR: Hazard ratio; CI: Confidence interval, CVD: Cardiovascular disease. HR is expressed as its estimation (95% CI). All hazard ratios (HRs) were estimated with weighting and adjustment for sex (male and female), race and ethnicity (White, Black, Hispanic and other), age, education (< high school, high school and > high school), marital status(married, unmarried and other), family income (poverty, moderate, and rich), smoking status(never, former, and now), and dietary intake (coffee, alcohol, fruits, vegetables, grains, dairy, protein foods, and energy intake) and medical insurance (covered and not covered)

*Unweighted number of participants

†Sampling weights were considered in analyses

A

Tea consumption	Life expectancy at age 50	Years of life gained
Non-drinking	30.69(30.53, 30.89)	Reference
<1 cup/day	30.77(29.45, 32.19)	0.09(-1.34, 1.53)
1 to <3 cups/day	31.07(30.35, 31.69)	0.38(-0.52, 1.14)
3 to <5 cups/day	32.93(31.24, 34.5)	2.24(0.49, 3.85)
≥5 cups/day	29.68(27.38, 31.97)	-1.01(-3.34, 1.31)



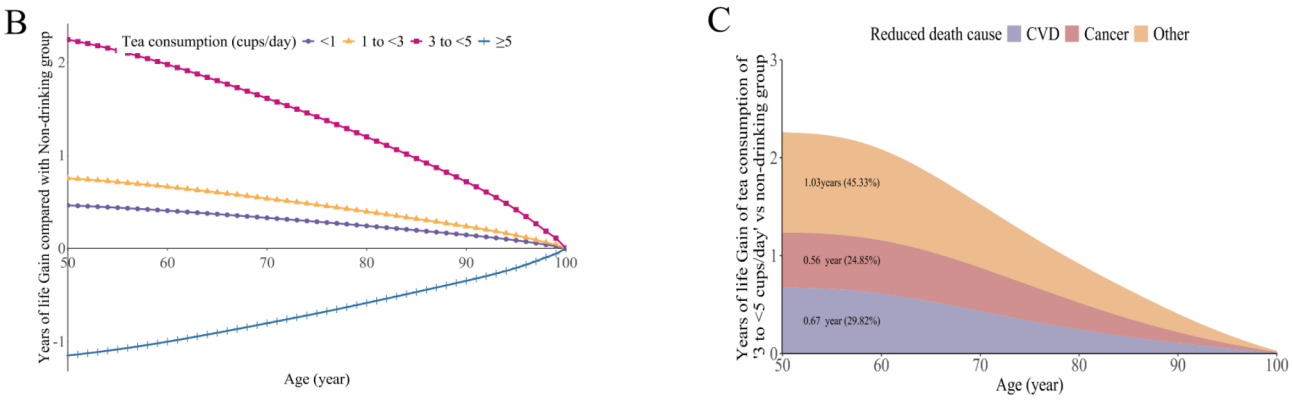


Fig. 1 Estimates of participants' cumulative survival time of total participants from the age of 50 and beyond, considering various levels of tea consumption. (**A**) Life expectancy according to tea consumption levels. (**B**) Years of life gained from'<1 cup/day','1 to < 3 cups/day','3 to < 5 cups/day'and'≥5 cups/day' versus non-drinking group from 50 to 100 years of age. (**C**) Estimated proportion of life gain from '3 to < 5 cups/day' of tea consumption versus non-drinking attributable to reduced death from cancer, cardiovascular and cerebrovascular diseases (CVD) and other causes. All results were estimated with weighting and adjustment for sex (male and female), race and ethnicity (White, Black, Hispanic and other), age, education (< high school, high school and > high school), marital status (married, unmarried and other), family income (poverty, moderate, and rich), smoking status (never, former, and now), dietary intake (coffee, alcohol, fruits, vegetables, grains, dairy, protein foods, and energy intake) and medical insurance (covered and not covered)

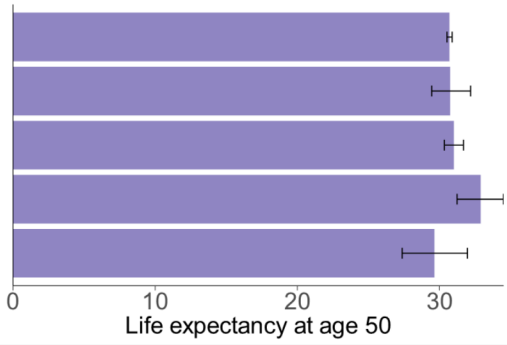
Associations of tea consumption with estimated life expectancy by subgroups

'3 to <5 cups/day' of tea consumption was related to a longer life expectancy in both males (30.83 VS 28.94 years) and females (35.53 VS 32.28 years) than in non-drinkers (Fig. 2A-B). In females, participants with '3 to <5 cups/day' of tea consumption had an estimated additional 3.25 years (95% CI, 0.48 to 5.38) of life expectancy at the age of 50 (Fig. 2C). In males, the estimation was 1.89 years (-0.55 to 4.12) (Fig. 2D). Possibly due to limitations in sample size, there was considerable variation in the estimated years of life gained for the '≥5 cups/day' tea consumption group between males (-1.92 years, 95% CI: -5.3 to 1.03) and females (1.74 years, 95% CI: -1.82 to 4.94), although estimates both did not reach statistical significance. The patterns of attribution proportion were similar to that in the overall population (Fig. 2E-F).

By race and ethnicity, '3 to <5 cups/day' of tea consumption provided a longer estimated life expectancy in white individuals (33.03 years; 95% CI, 31.17 to 34.93) than in black individuals (28.71 years; 95% CI, 25.44 to 32.3) (Fig. 3A and C). White participants consuming '3 to <5 cups/day' of tea had an estimated additional 2.5 years (95% CI, 0.48 to 4.51) of life gained (Fig. 3A and B), whereas other doses of tea consumption and participants of other races (Black, and Hispanic) did not show a significant difference (Fig. 3C-F). Because specific cause-of-death data were incomplete within racial groups, we did not perform cause-specific decomposition analysis in this subgroup analysis. By adding tea sugar, the expected life expectancy and the effect of prolonging life expectancy

A

Tea consumption	Life expectancy at age 50	Years of life gained
Non-drinking	30.69(30.53, 30.89)	Reference
<1 cup/day	30.77(29.45, 32.19)	0.09(-1.34, 1.53)
1 to <3 cups/day	31.07(30.35, 31.69)	0.38(-0.52, 1.14)
3 to <5 cups/day	32.93(31.24, 34.5)	2.24(0.49, 3.85)
≥5 cups/day	29.68(27.38, 31.97)	-1.01(-3.34, 1.31)



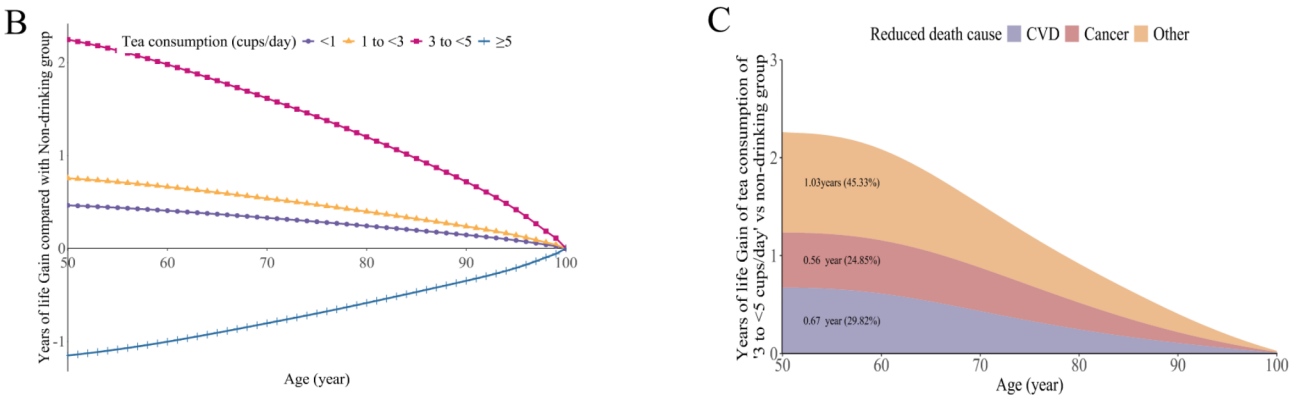


Fig. 2 Estimates of participants' cumulative survival time from the age of 50 and beyond, considering various levels of tea consumption, in males and females. A and B, Life expectancy according to tea consumption levels in males (**A**) or females (**B**). C and D, Years of life gained from '<1 cup/day', '1 to < 3 cups/day', '3 to < 5 cups/day' and '≥5 cups/day' versus non-drinking group from 50 to 100 years of age, in males (**B**) or females (**D**). E and F, estimated proportion of life gained from '3 to < 5 cups/day' of tea consumption versus non-drinking attributable to reduced death from cancer, cardiovascular and cerebrovascular diseases (CVD) and other causes, in males (**E**) or females (**F**). All results were estimated with weighting and adjustment for race and ethnicity (White, Black, Hispanic and other), age, education (< high school, high school and > high school), marital status (married, unmarried and other), family income (poverty, moderate, and rich), smoking status (never, former, and now), dietary intake (coffee, alcohol, fruits, vegetables, grains, dairy, protein foods, and energy intake) and medical insurance (covered and not covered)

of unsweetened tea were slightly higher than those of sweetened tea across all groups (Supplementary Figure S4). By tea type, individuals with '3 to <5 cups/day' of tea consumption of black tea were estimated to gain an additional 1.68 (-0.75 to 4.38) years of life expectancy at the age of 50 and a 2.53 (0.2 to 5.33) years increase in those consuming other tea types (including green tea and not specifically reported teas) (Supplementary Figure S5). By physical activity, individuals consuming '3 to <5 cups/day' of tea who had insufficient physical activity were estimated to have an insignificant gain in life expectancy (1.49 years; 95% CI: -0.68 to 3.02). In contrast, participants with moderate or sufficient physical activity showed a significant increase in life expectancy (3.98 years; 95% CI: 0.66 to 7.41) (Supplementary Figure S6).

Comparison of sugary tea consumption between subpopulations

We calculated the proportion and amount of sugar added among different subpopulations (by sex and by race and ethnicity) to explore whether sugar addition is a potential factor contributing to differences in life expectancy between these groups. We found that Black individuals preferred adding sugar to their tea (Supplementary Table S5). Specifically, in the group that consumed '3 to <5' cups/day of tea, the proportion of sugary tea in the Black population was 69.87% (95% CI, 65.00 to 74.75), whereas in the White population, it was 46.91% (43.96 to 49.86) ($P<0.0001$). Similarly, females were likely to consume less sugary tea than males. Moreover, the amount of sugar added was lower in subpopulations with longer

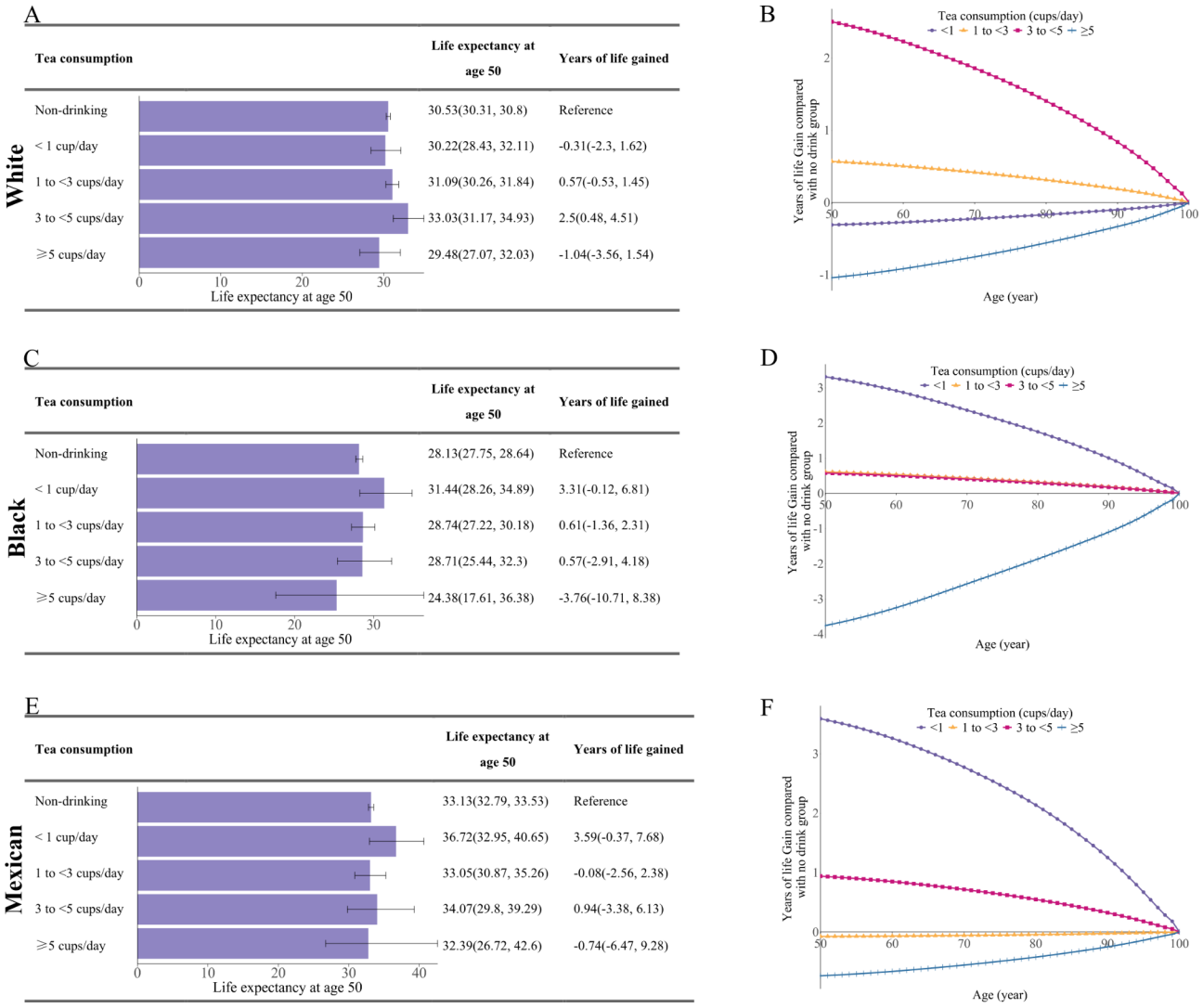


Fig. 3 Estimates of participants' cumulative survival time from the age of 50 and beyond, considering various levels of tea consumption, in White, Black and Mexican participants. A, C and E, Life expectancy at age 50 according to tea consumption levels in White (**A**), Black (**C**), or in Mexican (**E**). B, D and F, years of life gained from '<1 cup/day', '1 to < 3 cups/day', '3 to < 5 cups/day' and '≥5 cups/day' versus non-drinking group from 50 to 100 years of age, in White (**B**), Black (**D**) or Mexican (**D**). All results were estimated with weighting and adjustment for sex (male and female), age, education (< high school, high school and > high school), marital status (married, unmarried and other), family income (poverty, moderate, and rich), smoking status (never, former, and now), dietary intake (coffee, alcohol, fruits, vegetables, grains, dairy, protein foods, and energy intake) and medical insurance (covered and not covered). Due to the lack of mortality rate data for other races, their corresponding results were not estimated

life expectancy, such as females and Whites, compared to those with shorter life expectancy, such as males and Blacks (Supplementary Figure S7).

Discussion

Based on a nationally representative cohort, we observed a positive correlation between tea consumption and increased life expectancy among American adults who consume '3 to <5 cups/day' of tea. Those enjoy an additional 2.24 years of life expectancy compared to non-drinkers. In 2019, the life expectancy for 50-year-old adults in the United States was 31.8 years. In our study, individuals who consume '3 to <5 cups/day' of tea have an estimated life expectancy of 32.93 years, while non-drinkers have an estimated life expectancy of only 30.69 years.

The life expectancy of Americans increased from 76.8 years in 2000 to 78.8 years in 2014 [28, 29]. However, it remained stagnant until 2019, positioning the United States close to the bottom among its peer developed nations [30]. Tea has been extensively investigated concerning a wide range of chronic conditions, including type 2 diabetes mellitus, cardiovascular diseases, cancer, and overall mortality, as well as risks associated with specific causes of death [31–34]. Based on a meta-analysis, raising daily tea consumption by 3 cups lowers the risk

of coronary heart disease by 27%, cardiac disease by 26%, stroke by 18%, and total mortality by 24% [35]. Similarly, our findings suggest that consuming '3 to <5 cups/day' of tea consumption is a favorable choice, associated with the greatest increase in life expectancy. Another study revealed reduced overall and CVD mortality for British individuals who even consumed 10 or more cups of tea daily [33], while our analysis showed no benefits beyond 5 cups per day [36]. First, this could be due to misclassifications in tea exposure, varying tea quantity or volume, and effective intake of compounds such as catechins, which depend on factors such as tea type, steeping time, and temperature [37]. Secondly, it may also be influenced by changes in people's tea-drinking habits. Third, due to the relatively low propensity for tea consumption in the US population, our study, based on nationally representative survey data, faces challenges related to limited sample sizes in the tea-drinking subgroups, resulting in potentially larger estimation errors. All suggest the need for further comprehensive investigations into the implications of tea consumption for reducing mortality risk and prolonging life expectancy among Americans.

Limited research exists on the association between tea consumption and life expectancy, with just a single Chinese study on this topic [11]. Given the obvious differences in tea consumption patterns and population composition between China and the US, it is essential to explore the effects of tea consumption on the US population. Regarding research on factors influencing life expectancy in the American population, several studies have already explored various aspects, including lifestyle factors and Life's Essential 8 scores [21, 22]. In the first study, it was found that five ideal factors—diet, smoking, physical activity, alcohol consumption, and body mass index—could collectively increase life expectancy by more than 12.2 years [21]. In the second study, the healthiest participants experienced an increase in life expectancy of 8.9 years, attributed to eight essential factors, including diet, lifestyle, and physiological indicators [22]. However, simultaneously considering multiple factors would complicate public understanding and increases the complexity of public health practices. Our study employs the simplest and most intuitive indicator to make the public aware of the potential value of tea consumption for their health. '3 to <5 cups/day' of tea consumption could contribute to a great expansion in life expectancy (2.24 years), which would be highly valuable on a population scale. To enhance life expectancy among the US population, simple yet effective public health measures, including tea consumption, need to be further explored and validated in higher-quality studies. However, the present lack of adequate investment in public health, with only approximately 1.5% of healthcare costs allocated to public health, underscores the urgent need for reform [38].

In stratified analysis, we found that tea drinkers who consumed unsweetened tea tend to have a longer life expectancy. The years of life gained among those who consume tea without added sugar were also higher than among those who consume tea with added sugar. Furthermore, subpopulations with shorter life expectancy tend to consume more sugar in tea. Therefore, it can be speculated that adding sugar may be a potential influencing factor to health when consuming tea, which still need more study in future. A meta study found that each additional daily cup of sugary beverage increased the risk of obesity by 12%, type 2 diabetes by 27%, coronary heart disease by 17%, and both cancer-specific and total mortality by 4% [39]. With respect to addition of sugar to tea, it has been reported that unsweetened tea lowers mortality risk, while sweetened tea does not provide the same benefits [36]. In future public health initiatives promoting health tea consumption or other beneficial lifestyle factors, stricter control of sugar intake should be considered. In the analysis of tea types, we merged green tea and unreported tea types into the 'Other tea' group. In this scenario, we found that the years of life gained in the group containing green tea was higher than that in the black tea group by approximately one year. Many studies have reported greater health benefits of green tea compared to black tea [40, 41]. Therefore, such differences in life expectancy may be partly attributed to the benefits of green tea. Although our study did not directly analyze the association between green tea consumption and life expectancy due to sample size limitations, the clues provided can still contribute positively to enhancing people's awareness of the health benefits of tea and green tea and researchers' interests. It is also important to recognize that additives in tea, such as lemon, may be potential key factors in prolonging average life expectancy. Further detailed studies on tea types are needed to accurately assess the life expectancy benefits of green tea. We found '3 to <5 cups/day' of tea consumption only extended the life expectancy of the white population. For the black population, further research is also needed to explore additional avenues that can effectively address their life expectancy disparities. Additionally, our study found that individuals with different levels of physical activity experienced significant variations in years of life gained, further indicating that physical activity is a potentially important factor influencing the effects of tea consumption.

We do recognize several study limitations. Firstly, estimating tea intake based on one or two days may not fully represent the participants' drinking habits. Although the correlation between tea consumption over two days is relatively high, future studies will still need to collect

information on tea-drinking habits based on Food Frequency Questionnaire. Secondly, our evaluation relied solely on the baseline data and did not consider potential shifts of tea consumption habits during follow-up. Thirdly, sample size constraints may introduce bias in life expectancy estimations, especially for individuals consuming '≥5 cups/day' of tea and specific subgroups. Fourthly, self-reporting of variables such as tea consumption and dietary intake may introduce measurement inaccuracies. Finally, due to limitations in data completeness, we were unable to conduct a detailed analysis of different types of tea and additional additives, such as lemon. Future studies should address these limitations.

Conclusions

Our study revealed a positive association between '3 to <5 cups/day' of tea consumption and life expectancy in US adults. Further detailed investigations into tea consumption, involving larger populations, are still needed. Adding sugar to tea is a potential unhealthy lifestyle, an important factor that should not be overlooked in future research and public health practice. Our research holds significant implications for enhancing the life expectancy of the general population and offers valuable insights into future public health practices and policy formulation.

Abbreviations

CI	Confidence interval
CVD	Cardiovascular and cerebrovascular diseases
HR	Hazard ratio
ICD	10-International Classification of Diseases, Tenth Revision
RCS	Restricted cubic spline

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12937-024-01054-9.

Supplementary Material 1

Acknowledgements

The NHANES study was approved by the research ethics review board of the National Center for Health Statistics. All NHANES participants provided their written informed consent. We are grateful to the participants and staff of the US NHANES.

Author contributions

Ms. G. Yan and Dr. Tian played a pivotal role throughout various stages of the study, responsible for research design and data collection. Analysis, visualization, or interpretation of data: All authors. Drafting of the manuscript: Tian. Paper's revisions: G. Yan. Funding: Zhao. Administration: Zhao and G. Yan. All authors were responsible for the decision to submit the manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethical approval

The NHANES study was approved by the research ethics review board of the National Center for Health Statistics. All NHANES participants provided their written informed consent. Because NHANES data are de-identified and publicly available, the analysis presented here was exempt.

Competing interests

The authors declare no competing interests.

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