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Usage of table salt and risk of all-cause and cardiovascular disease mortality among patients with diabetes: a national population-based cohort study

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Abstract

Background A lower dietary sodium intake has been associated with a reduced risk of cardiovascular disease (CVD) mortality in the general population. However, the evidence is less clear in diabetic patients. The study aims to investigate whether the usage of table salt is associated with all-cause and CVD mortality among individuals with diabetes.

Methods In this prospective cohort study, participants with diabetes from the U.S. National Health and Nutritional Examination Survey (NHANES) 2003–2018 were included. Weighted linear regression models were employed to assess the association between the usage of table salt and dietary sodium intake. Weighted Cox proportional hazards regression models were used to assess the association between the usage of table salt and all-cause and CVD mortality.

Results This cohort study included data from 6,258 participants in analysis. During 44,035 person-years of follow-up, 1,504 deaths from all-causes and 427 from CVD were documented. Not using table salt was significantly associated with lower dietary sodium intake, with a β of -192.60 (95% CI, -297.01 to -88.18) mg. A higher risk of all-cause and CVD mortality was observed in the group of participants not using table salt among patients with diabetes. Compared with participants using table salt, the hazard ratios for all-cause mortality were 1.18 (95% CI, 1.03 to 1.35), and for CVD were 1.48 (95 CI, 1.16 to 1.90) for participants not using table salt. The subgroup analysis revealed a significantly stronger link between the usage of table salt and all-cause mortality in participants with CVD (P for interaction = 0.004).

Conclusions This study indicated that not using table salt was associated with a lower dietary sodium intake, and an increased risk of all-cause and CVD mortality among individuals with diabetes. Interventional studies are needed to determine more beneficial relevant approaches to dietary management in diabetes care.

Keywords Salt, Diabetes, Mortality, NHANES

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Background

Diabetes mellitus has emerged as a global health crisis, affecting approximately 463 million adults in 2019 and projected to rise to 700 million by 2045 [1, 2]. This condition significantly elevates the risk of various complications, particularly cardiovascular diseases (CVD), which remain the leading causes of morbidity and mortality among diabetic patients, with numerous risk factors contributing to their development and progression [3].

One of the modifiable risk factors that has garnered significant attention is dietary salt intake. Excessive sodium consumption has been implicated in the pathogenesis of various chronic diseases, including hypertension, kidney disease, and CVD [4, 5]. Controlling sodium intake is a feasible way to reduce the risk of CVD and stroke in patients [6–8]. Sodium intake is higher in people with diabetes, and a correlation has been identified between sodium intake and the risk of developing type 2 diabetes [9–11]. Nevertheless, the association between the usage of table salt used by diabetics and mortality is still lacking and mainly concentrated in Asian populations [12–14].

This study aims to examine the association of the usage of table salt and all-cause and CVD mortality in the general US population with diabetes. The study used data from the National Health and Nutrition Examination Survey (NHANES), which includes mortality data from a nationally representative sample of US adults. The mean follow-up period was 7.0 years.

Methods

Study population

NHANES is a continuous, multistage, nationally representative survey of the noninstitutionalized civilian resident population of the United States. This study included 8 cycles between 2003 and 2004 and 2017–2018. Participants without data of type of table salt used were excluded. Participants aged under 18 years old were excluded. Pregnant women were excluded. Participants without history of diabetes were excluded. Participants not eligible for National Death Index were excluded. Adults with diabetes were defined as meeting one of three criteria: (1) self-reported history of diabetes, (2) receipt of oral glucose-lowering medicines or insulin, or (3) glycated hemoglobin A1c (HbA1c) level of at least 6.5%. After exclusion, a total of 6,278 participants were defined as adults with diabetes (Fig. 1).

Measurement of usage of table salt used

The usage of salt used in the diet was the primary focus of interest. Trained interviewers conducted in-home interviews to collect dietary intake data from participants. Participants were asked to participate in two 24-hour total nutrient recall interviews. The data on the type of salt used was collected from the first 24-hour recall. Four types of table salt were reported in the interview: ordinary salt, lite salt, salt substitutes, and not using or adding salt products at the table.

However, due to the limited sample size of lite salt and salt substitutes (246 and 155 participants, respectively), the participants were divided into two groups based on the type of table salt used: Group 1 consisted of individuals who either consumed ordinary salt, lite salt, or salt substitute, while Group 2 consisted of individuals who didn't use or add salt products at the table.

Covariates

The data set included sociodemographic variables, including age, sex, race, and ethnicity, which were collected using a standardized questionnaire. Self-reported race was in 6 categories, and we grouped participants into 4 mutually exclusive racial and ethnic categories: non-Hispanic Black, Hispanic, non-Hispanic White, and other (includes races other than non-Hispanic white, non-Hispanic black, or Hispanic, including multiracial). In addition, family income-poverty ratio and educational attainment were also assessed as demographic variables in the interview. The family income-to-poverty ratio, which varies depending on the size and composition of the family, was employed to ascertain the poverty status of individuals and categorize them as having an income below 1.5, between 1.5 and 3.5, or above 3.5 [15]. The participants' educational attainment was determined by their self-reported highest grade or level of education completed and categorized as having completed less than a high school graduated, high school graduated, or higher than high school graduated.

Behavioral and metabolic variables including smoking status, body mass index, and level of HbA1c were included. Individuals who had smoked more than 100 cigarettes in their lifetime were classified as smokers, while others were defined as non-smokers. Smokers were further classified as either ever smokers or current smokers. The body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. The BMI was subsequently categorized as lower than 25, 25 to 30, or 30 or higher. Individuals were divided into two groups based on HbA1c data, with a cutoff value of 6.5%. The data of serum alanine aminotransferase (ALT), aspartate aminotransferase (AST), gamma-glutamyl transferase (GGT), lactate dehydrogenase (LDH), total bilirubin, triglycerides, and creatinine were collected as continuous variables. Strict protocols were followed during blood collection and analysis, as outlined in the NHANES Laboratory/Medical Technician Protocols Manual [16]. The estimated glomerular filtration rate (eGFR) is calculated using the serum creatinine concentration [17].

Dietary data on sodium intake, potassium intake, and total energy intake were collected on the first and second

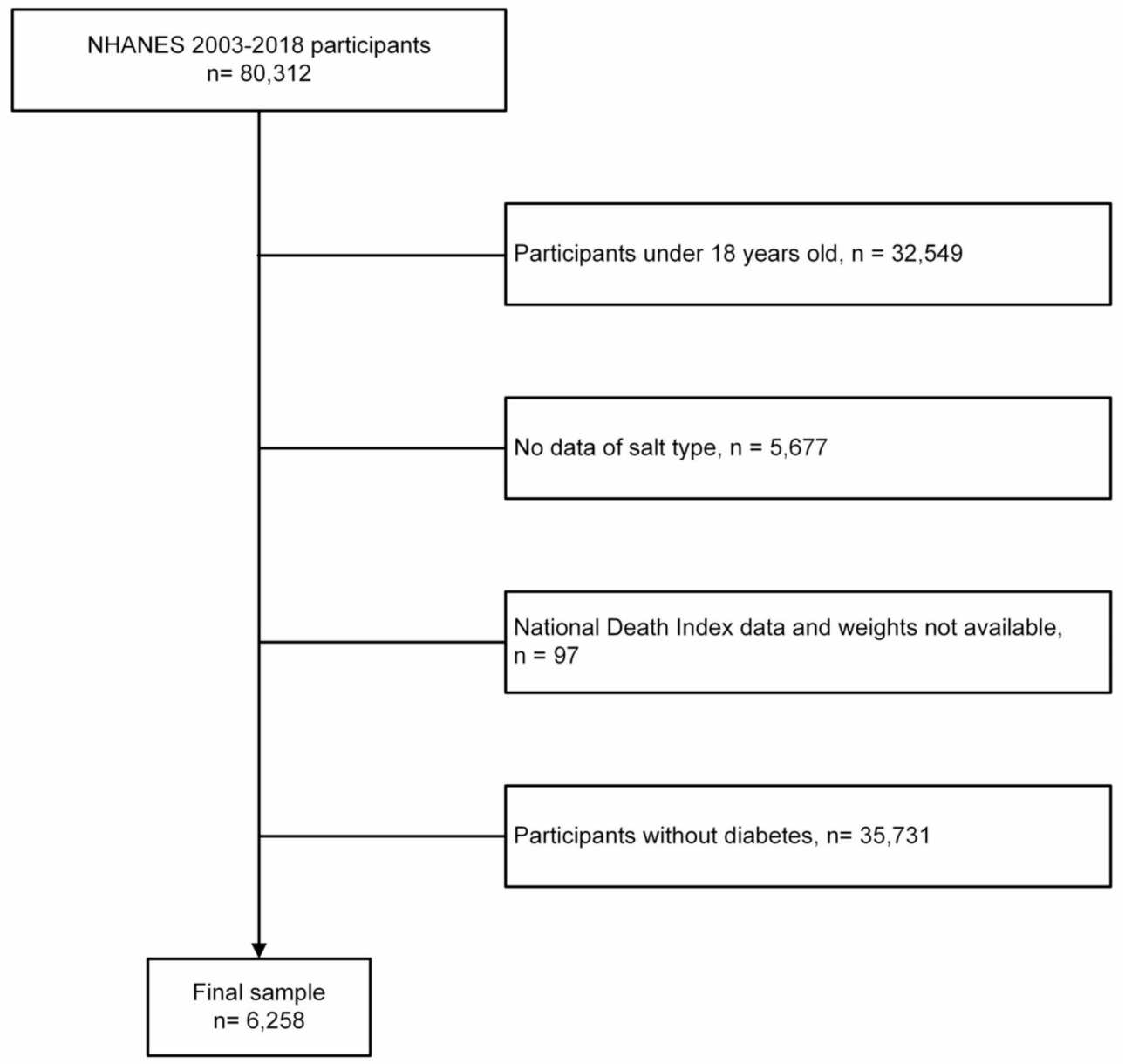

Fig. 1 Flow chart of the study. NHANES, the National Health and Nutrition Examination Survey

days of dietary recall. The mean of the two-day data was utilized for subsequent analysis. To assess the quality of the diet, data on the Healthy Eating Index-2020 (HEI-2020) were calculated [18]. However, as the equations of the HEI were revised after 2005, only the HEI data from that point onwards were included in the analysis.

Comorbid conditions were also collected, including hypertension, cardiovascular disease, and cancer. Participants were asked if they had a history of hypertension, and if they answered "Yes," they were defined as having a history of hypertension. Participants with a self-reported history of congestive heart failure, coronary heart disease, angina, myocardial infarction, or stroke were defined as CVD survivors. Participants with a self-reported history of cancer were defined as cancer survivors.

Furthermore, data were collected on the treatment of diabetes. The participants were divided into two groups based on whether they were treated with insulin or oral medication. The number and weighted percentage of covariates were presented in Table S1.

Ascertainment of death

The National Death Index was referred to determine all-cause and CVD mortality until December 31, 2019. The causes of death were identified using ICD-10 codes [19].

Statistical analysis

All analyses were conducted following the NHIS and NHANES analytic guidelines. The data analysis took into account the major sampling units, sample weights, and strata to provide credible national estimates [20].

To determine the association between salt usage and dietary sodium intake, we employed weighted linear regression analyses to investigate the relationship between the usage of table salt and total sodium intake. Subsequently, weighted multivariable Cox proportional hazards regression models were employed to investigate the associations between the usage of table salt consumed and the risks of all-cause and CVD mortality. Schoenfeld residuals were used to test the proportional hazards assumption, and no violation was observed. Covariates with concerning collinearity observed were excluded. Two multivariable models were constructed. In Model 1, we adjusted for age, gender, and race/ethnicity. In Model 2, we additionally adjusted for educational level, BMI, family ratio of income to poverty, smoking status, treatment of diabetes, HbA1c level, and self-reported history of hypertension, CVD, and cancer. In the event of missing values, the multiple imputation method was employed to impute the variables. The Kaplan-Meier (KM) curve was utilized to visualize the relationship between the usage of table salt and all-cause and CVD mortality. Cumulative mortality rates were compared by log-rank analysis.

Further subgroup analyses were conducted according to age, gender, race/ethnicity, smoking status, BMI, HbA1c, hypertension, CVD, and cancer. A likelihood ratio test was conducted to assess the interaction between subgroups and usage of table salt used.

Various sensitivity analyses were also conducted. (1) To mitigate the potential impact of reverse causation, participants who died in the first two years of their follow-up were excluded. (2) Analyses were repeated only for participants with complete data. (3) To investigate a potential role of blood lipid levels, liver and kidney indices, or total dietary sodium, potassium, and energy intake with any of the observed associations, we further adjusted for lipid profile (including total bilirubin and triglycerides), an indicator of kidney function (eGFR), an indicator of liver function (ALT, AST, GGT, and LDH), and total dietary sodium, potassium, and energy intake. (4) In order to ascertain the potential role of specific salt types in relation to any observed associations, we repeated the main analysis on initial four groups (using ordinary salt, lite salt, salt substitutes, and not using or adding salt products at the table). (5) To ascertain the potential role of dietary quality in any observed associations, we proceeded to adjust for HEI-2020. A two-sided P-values less than 0.05 were considered statistically significant. All analyses were performed with R, version 4.3 (R Foundation for Statistical Computing) and Stata version 18.0 (Stata Corp).

Results

Among 6,258 participants with diabetes (mean age, 59.46 years; 50.33% men), the proportion of participants using table salt was 64.92%. Table 1 presents the baseline characteristics of the study participants stratified by the usage of table salt. Compared with participants who did not use table salt, those using table salt were slightly younger and had a higher proportion of males and non-Hispanic whites, while a lower percentage of non-Hispanic blacks. In terms of lifestyle factors, participants using table salt had a higher prevalence of ever and current smoking, a higher proportion of individuals with education levels higher than high school graduate, and a higher HEI-2020. The using table salt group also had a lower percentage of participants with a family income-poverty ratio < 1.5 and a higher percentage with a ratio ≥ 3.5. BMI distribution was similar between the two groups, with most participants having a BMI ≥ 30. The prevalence of CVD and hypertension was lower in the using table salt group.

As shown in Table 2, not using table salt was associated with a lower dietary sodium intake compared with using table salt among adults with diabetes. In the age-, sex-, and race/ethnicity-adjusted model (Model 1), the β was −216.78 (95% CI, -320.53 to -113.03) mg for dietary sodium intake. After further adjusting for major lifestyle risk factors and comorbidities (Model 2), the associations remained statistically significant, with a β of -192.60 (95% CI, -297.01 to -88.18) mg.

As shown in Table 3, not using table salt was associated with higher all-cause and CVD mortality compared with using table salt among adults with diabetes. In the age-, sex-, and race/ethnicity-adjusted model (Model 1), the hazard ratios (HRs) were 1.53 (95% CI,1.18 to 1.99) for CVD mortality and 1.19 (95% CI, 1.04 to 1.38) for all-cause mortality. After further adjusting for major lifestyle risk factors and comorbidities (Model 2), the associations were attenuated but remained statistically significant, with the HRs of 1.48 (95% CI, 1.16 to 1.90) for CVD mortality and 1.18 (95% CI, 1.03 to 1.35) for all-cause mortality. Kaplan-Meier survival plots indicated that participants not using table salt had significantly greater cumulative all-cause and CVD mortality than those using table salt (both p for log rank < 0.001) (Fig. 2)

In the subgroup analysis using multivariable Cox regression models, the association between the usage of table salt and CVD mortality was generally consistent across subgroups (P for interaction > 0.05) (Table 4). The increased mortality was more pronounced among participants aged less than 60 years (HR 1.85, 95% CI 0.93 to 3.68), females (HR 1.82, 95% CI 1.16 to 2.87), non-Hispanic blacks (HR 1.88, 95% CI 1.06 to 3.31), ever smokers

Table 1 Baseline characteristics of participants with diabetes by usage of table salt in NHANES 2003–2018

Variables	Usage of table salt		
	Total (*n* = 6258)	Using table salt[a](*n* = 3821)	Not using table salt (*n* = 2437)
Age, Mean (SD)	59.46 (13.77)	58.78 (13.83)	60.74 (13.57)
Gender, *n* **(%)**			
Male	3181 (50.33)	2001 (51.86)	1180 (47.49)
Female	3077 (49.67)	1820 (48.14)	1257 (52.51)
Race and ethnicity, n (%)			
Non-Hispanic white	2197 (60.18)	1455 (63.37)	742 (54.26)
Hispanic	1792 (15.38)	1146 (15.51)	646 (15.15)
Non-Hispanic black	1698 (15.86)	891 (13.53)	807 (20.16)
Other	571 (8.58)	329 (7.59)	242 (10.42)
Education level, n (%)			
Less than high school	2165 (24.40)	1281 (22.43)	884 (28.04)
High school graduate	1453 (25.69)	922 (26.67)	531 (23.90)
Higher than high school graduate	2604 (49.51)	1596 (50.43)	1008 (47.82)
Family income-poverty ratio, n (%)			
Ratio < 1.5	2325 (28.31)	1396 (26.55)	929 (31.57)
1.5 ≤ Ratio < 3.5	2010 (32.66)	1254 (33.31)	756 (31.47)
Ratio ≥ 3.5	1365 (31.78)	842 (33.39)	523 (28.81)
Body mass index			
< 25	786 (11.19)	480 (10.70)	306 (12.10)
25–30	1711 (24.60)	1068 (25.16)	643 (23.58)
≥ 30	3628 (62.51)	2197 (62.72)	1431 (62.12)
Smoke, n (%)			
Never	3110 (48.82)	1788 (45.95)	1322 (54.13)
Ever	2111 (34.50)	1311 (35.10)	800 (33.39)
Current	1015 (16.68)	705 (18.95)	310 (12.49)
CVD, n (%)			
No	4580 (73.84)	2877 (75.63)	1703 (70.52)
Yes	1678 (26.16)	944 (24.37)	734 (29.48)
Cancer, n (%)			
No	5339 (83.61)	3271 (83.37)	2068 (84.07)
Yes	882 (15.80)	521 (15.85)	361 (15.71)
Hypertension, n (%)			
No	2061 (33.39)	1383 (35.65)	678 (29.21)
Yes	4177 (66.35)	2428 (64.18)	1749 (70.39)
Diabetes treatment, n (%)			
No	2447 (38.59)	1492 (38.03)	955 (39.62)
Using oral medication or insulin	3810 (61.40)	2329 (61.97)	1481 (60.35)
Glycated hemoglobin A1c, n (%)			
< 6.5%	1760 (30.51)	1075 (30.77)	685 (30.02)
≥ 6.5%	4288 (66.88)	2644 (67.15)	1644 (66.37)
HEI-2020[b], Mean (SD)	52.04 (11.65)	51.11 (11.49)	53.73 (11.76)

Abbreviation: NHANES, National Health and Nutrition Examination Survey; HEI-2020, healthy eating index-2020. All estimates accounted for complex survey designs, and all percentages were weighted

[a] Using table salt including using regular iodized salt, sea salt, seasoning salts made with regular salt, lite salt, and salt substitute

[b] Only the HEI-2020 data from 2005 to 2006 to 2017–2018 cycle were included

(HR 1.77, 95% CI 1.04 to 3.01), those with higher family income-to-poverty ratio (family income to-poverty ratio ≥ 3.5, HR 2.08, 95% CI 1.08 to 4.02), obese participants (BMI ≥ 30 kg/m2, HR 1.85, 95% CI 1.33 to 2.58), those without hypertension (HR 1.80, 95% CI 1.13 to 2.86), those with CVD (HR 1.66, 95% CI 1.17 to 2.36), those receiving diabetes treatment (HR 1.70, 95% CI 1.18 to 2.44), and those with higher glycated hemoglobin A1c (glycated hemoglobin A1c ≥ 6.5%, HR 1.56, 95% CI 1.12 to 2.18), although the P values for interaction did not reach statistical significance (All P for interaction > 0.05)

The association between the usage of table salt and all-cause mortality was generally consistent across subgroups (P for interaction > 0.05), with a few exceptions

Table 2 Weighted multivariable Linear regression models examining the association of usage of table salt with total dietary sodium intake among adults with diabetes in NHANES 2003–2018

Model	β (95% CI)	
	Usage of Table salt	
	Model 1 [b]	Model 2 [c]
Dietary sodium intake, mg		
Using table salt[a]	1 [Reference]	1 [Reference]
Not using table salt	-216.78(-320.53, -113.03)	-192.60(-297.01, -88.18)

Abbreviations: CVD, cardiovascular disease; NHANES, National Health and Nutrition Examination Survey

[a] Using table salt including using regular iodized salt, sea salt, seasoning salts made with regular salt, lite salt, and salt substitute

[b] Model 1 was adjusted for age(continuous), sex (male or female), and race/ethnicities (non-Hispanic White, non-Hispanic Black, Hispanic, or other)

[c] Model 2 was further adjusted for body mass index (calculated as weight in kilograms divided by height in meters squared; <25.0, 25.0-29.9, or 30.0), educational level (<high school, high school graduated or equivalent, or >high school graduated), family income-poverty ratio (<1.5, 1.5–3.5, or ≥3.5), smoking status (never, ever, or current), diabetes medication use (none or using oral medication or insulin), glycated hemoglobin A1c (<6.5% or ≥6.5%), self-reported cancer (yes or no), self-reported hypertension (yes or no), and self-reported cardiovascular disease (yes or no)

Table 3 Weighted multivariable COX regression models examining the association of usage of table salt with all-cause and cardiovascular disease mortality among adults with diabetes in NHANES 2003–2018

Model	Hazard ratio (95% CI)		
	Usage of Table salt		
	Using table salt [1]	Not using table salt	
CVD mortality			*P*-value
Deaths, No./total No.	224/3821	203/2437	
Model 1[2]	1 [Reference]	1.53(1.18,1.99)	0.002
Model 2[3]	1 [Reference]	1.48(1.16,1.90)	0.005
All-cause mortality			
Deaths, No./total No.	862/3821	642/2437	
Model 1[2]	1 [Reference]	1.19(1.04,1.38)	0.015
Model 2[3]	1 [Reference]	1.18(1.03,1.35)	0.017

Data are presented as HR (95% CI). Abbreviations: CVD, cardiovascular disease; NHANES, National Health and Nutrition Examination Survey

[1] Using table salt including using regular iodized salt, sea salt, seasoning salts made with regular salt, lite salt, and salt substitute

[2] Model 1 was adjusted for age(continuous), sex (male or female), and race/ethnicities (non-Hispanic White, non-Hispanic Black, Hispanic, or other)

[3] Model 2 was further adjusted for body mass index (calculated as weight in kilograms divided by height in meters squared; <25.0, 25.0-29.9, or 30.0), educational level (<high school, high school graduated or equivalent, or >high school graduated), family income-poverty ratio (<1.5, 1.5–3.5, or ≥3.5), smoking status (never, ever, or current), diabetes medication use (none or using oral medication or insulin), glycated hemoglobin A1c (<6.5% or ≥6.5%), self-reported cancer (yes or no), self-reported hypertension (yes or no), and self-reported cardiovascular disease (yes or no)

(Table S2). The association was more pronounced among participants with CVD at baseline (HR 1.58, 95% CI 1.26 to 1.98) compared to those without CVD (HR 0.96, 95% CI, 0.76 to 1.21) (P for interaction=0.004). The increased mortality was also slightly stronger among participants aged under 60 years (HR 1.36, 95% CI 0.91 to 2.03 for age<60), females (HR 1.41, 95% CI 1.13 to 1.75), and obese participants (BMI≥30 kg/m2, HR 1.47, 95% CI 1.15 to 1.88), although the P values for interaction did not reach statistical significance (P for interaction>0.05 for all).

In sensitivity analyses, the positive association of usage of table salt with all-cause and CVD mortality was not materially changed when participants who died within first 2 years of follow-up were excluded (Table S3). In the analyses of participants with complete data only, the results remained largely unchanged (Table S4). Similar results were observed when further adjusting for lipid profile (including total bilirubin and triglycerides), eGFR, indicators of liver function (alanine aminotransferase, aspartate transferase, gamma-glutamyl transferase, and lactate dehydrogenase), total energy intake, and total sodium and potassium intake (Table S5). In analysis on initial four groups of table salt, no added salt was associated with higher all-cause and CVD mortality compared with using ordinary salt. In contrast, the use of lite salt and salt substitute was not significantly associated with either CVD or all-cause mortality in both models, except for the lite salt group and CVD mortality in Model 1. However, following further adjustments in Model 2, this association was no longer significant. The notable difference in HRs and the extensive 95% confidence interval for lite salt and salt substitute can be attributed to the unequal distribution and the limited number of participants in these groups (246 participants for lite salt, and 155 for salt substitute) (Table S6). After further adjusting for HEI, the results remained stable (Table S7).

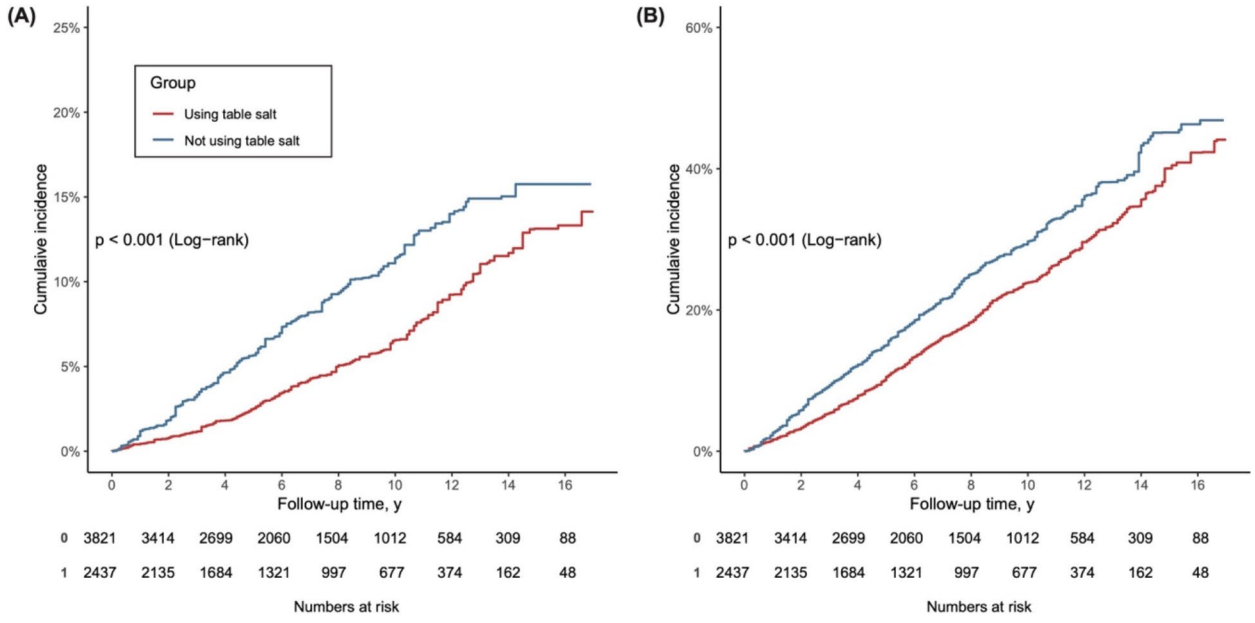

Fig. 2 Cumulative incidence of mortality by usage of table salt. (**a**) Cardiovascular disease mortality; (**b**)All-cause mortality

Discussion

In this large, nationally representative study, we demonstrated that among adults with diabetes, those who did not use table salt had a lower dietary sodium intake and significantly higher all-cause and CVD mortality compared with those who used table salt. This association was independent of traditional risk factors, including sociographic, metabolic and lifestyle factors, diabetes treatment status, and glycated hemoglobin A1c levels. Stratified and sensitivity analyses were conducted and demonstrated the robustness of our findings. However, a more pronounced association between usage of table salt and all-cause mortality was found in the subgroup with CVD.

Accurately measuring dietary sodium intake is crucial in individual and public health, but obtaining an unbiased measurement of sodium intake is challenging. NHANES and other large-scale dietary surveys have used dietary assessment tools such as questionnaires and food recalls, and 24-hour urinary sodium excretion has been considered the gold standard.

However, these methods can only reflect sodium intake over a short period of time and can be subject to significant day-to-day variability in an individual's diet [21, 22]. In our study, we also observed this phenomenon. The difference in dietary sodium intake between day 1 and day 2 of dietary recall in NHANES was 50.091 (IQR, -947.212, 1017.575) mg. Even the data for two days of dietary sodium intake from food recalls demonstrated a significant discrepancy. Therefore, these methods may not accurately represent an individual's habitual sodium intake.

In comparison to dietary recalls or 24-hour urinary sodium excretion, our study chose to use the usage of table salt as an intervention. Our analyses indicated that participants who did not use table salt had lower sodium intake in the days of dietary recalls. Furthermore, as a dietary habit, usage of table salt used may better capture the long-term sodium intake of individuals, minimizing the variability caused by short-term dietary changes. Concurrently, there is a need to find better ways to assess long-term dietary sodium intake.

Although a substantial body of literature has addressed the impact of table salt on mortality risk, the majority of these studies have focused on populations in Asia, with the prevailing conclusion being that salt reduction reduces mortality risk [12, 14]. Additionally, there are only a few studies on diabetic populations. This study examined the impact of salt usage on the risk of mortality in diabetic patients using nationally representative data from the NHANES database for the United States. Although the findings differed from those observed in the general population (low salt intake was associated with a reduction in mortality), they were consistent with those of studies conducted in diabetic populations in Europe and Australia (low salt intake was associated with an increase in mortality) [23, 24]. This highlights the fact that a low-sodium diet may not be universally beneficial for diabetic patients and that further research is required to identify more beneficial approaches to dietary management in diabetes care.

However, evidence was also observed indicating the benefit of salt reduction in diabetic populations, including significant reductions in blood pressure and urinary

Table 4 Stratified analyses of the associations between usage of table salt and cardiovascular disease mortality among adults with diabetes in NHANES 2003–2018

	Usage of Table Salt		
Characteristics	**Using table salt [1]**	**Not using table salt**	**P for interaction**
Age			0.334
< 60	1 (ref)	1.85 (0.93, 3.68)	
≥ 60	1 (ref)	1.34 (1.02, 1.77)	
Gender			0.197
Male	1 (ref)	1.24 (0.88, 1.74)	
Female	1 (ref)	1.82 (1.16, 2.87)	
Race and ethnicity			0.193
Non-Hispanic white	1 (ref)	1.49 (1.06, 2.08)	
Hispanic	1 (ref)	0.77 (0.38, 1.57)	
Non-Hispanic black	1 (ref)	1.88 (1.06, 3.31)	
Other	1 (ref)	1.33 (0.44, 4.02)	
Smoke			0.719
Never	1 (ref)	1.30 (0.89, 1.89)	
Ever	1 (ref)	1.77 (1.04, 3.01)	
Current		1.22 (0.62, 2.42)	
Education level			0.852
Less than high school	1 (ref)	1.57 (1.06, 2.31)	
High school graduate	1 (ref)	1.78 (0.96, 3.27)	
Higher than high school graduate	1 (ref)	1.37 (0.91, 2.07)	
Family income-poverty ratio			0.235
Ratio < 1.5	1 (ref)	1.17 (0.72, 1.89)	
1.5 ≤ Ratio < 3.5	1 (ref)	1.38 (0.93, 2.04)	
Ratio ≥ 3.5	1 (ref)	2.08 (1.08, 4.02)	
Body mass index			0.053
< 25	1 (ref)	1.33 (0.78, 2.27)	
25–30	1 (ref)	0.90 (0.53, 1.54)	
≥ 30	1 (ref)	1.85 (1.33, 2.58)	
CVD			0.359
No	1 (ref)	1.27 (0.74, 2.18)	
Yes	1 (ref)	1.66 (1.17, 2.36)	
Cancer			0.974
No	1 (ref)	1.47 (1.12, 1.93)	
Yes	1 (ref)	1.48 (0.82, 2.68)	
Hypertension			0.372
No	1 (ref)	1.80 (1.13, 2.86)	
Yes	1 (ref)	1.39 (1.05, 1.85)	
Diabetes treatment			0.238
No	1 (ref)	1.14 (0.76, 1.70)	
Using oral medication or insulin	1 (ref)	1.70 (1.18, 2.44)	
Glycated hemoglobin A1c			0.409
< 6.5%	1 (ref)	1.38 (0.84, 2.28)	
≥ 6.5%	1 (ref)	1.56 (1.12, 2.18)	

Data are presented as HR (95% CI)

[1] Using table salt including using regular iodized salt, sea salt and seasoning salts made with regular salt, lite salt, and salt substitute

Adjusted for age(continuous), sex (male or female), and race/ethnicities (non-Hispanic White, non-Hispanic Black, Hispanic, or other), body mass index (calculated as weight in kilograms divided by height in meters squared; <25.0, 25.0-29.9, or 30.0), educational level (<high school, high school graduated or equivalent, or >high school graduated), family income-poverty ratio (<1.5, 1.5–3.5, or ≥3.5), smoking status (never, ever, or current), diabetes medication use (none or using oral medication or insulin), glycated hemoglobin A1c (<6.5% or ≥6.5%), self-reported cancer (yes or no), self-reported hypertension (yes or no), and self-reported cardiovascular disease (yes or no). The strata variable was not included in the model when stratifying by itself

albumin excretion, although no notable changes in glucose control were observed [25–27]. These conflicting results underscore the complexity of salt restriction in diabetic care and suggest that while it may offer benefits in hypertensive control, the effects on mortality and other metabolic outcomes warrant further investigation.

Major guidelines recommend a low-sodium diet, limiting daily sodium intake to less than 2–2.4 g (5–6 g of salt) for most adults and recommending further reductions for at-risk populations [28–32]. Nevertheless, despite the controversy surrounding this topic, some studies have indicated the existence of a J-curve relationship, whereby a negative association is observed between low sodium intake and the occurrence of cardiovascular events [33–36].

Although methodological errors may be a contributing factor for the J-curve relationship, the physiologic function of sodium ions may also be a potential cause. Sodium ions regulate the osmolarity of extracellular fluid and the volume of extracellular fluid [37]. Moderate decreases in sodium do not affect the nervous system or metabolism. However, greater decreases result in significant activation of the sympathetic nervous system and renin-angiotensin-aldosterone system, significant increases in serum lipids, and hyponatremia, which can cause further damage to the cardiovascular system [38, 39].

Distinguished from the general population, due to hyperglycemia-induced osmotic fluid shifts, osmotic diuresis, diabetic nephropathy, and certain diabetes medications, individuals with diabetes are at increased risk of electrolyte imbalances, particularly low levels of sodium, magnesium, and calcium [40, 41]. These reasons may contribute to the higher all-cause and CVD mortality among diabetic participants who do not use common salt. Previous studies have also demonstrated that low sodium intake is associated with higher mortality in both type I and type II diabetics [23, 24].

Given that individuals with diabetes frequently exhibit multiple comorbidities, including diabetic kidney disease, dyslipidemia, and hypertension, we proceeded to adjust covariates, including eGFR, lipid profile, and history of hypertension. The results remained statistically significant. Additionally, we adjusted covariates including BMI, total energy intake on the day of dietary recall, and HEI. The results remained consistent.

Clinically, these results suggest that long-term low sodium diets may not be universally beneficial for diabetic patients. Individualized sodium recommendations that balance the need to control blood pressure without inducing sodium deficiency might be a more effective approach to dietary management in diabetes care.

The study was subject to certain limitations. Despite the large sample size and long follow-up period, the observational study design does not allow for the establishment of causality. Secondly, the NHANES only contains a single record of the type of table salt consumed, which may not accurately reflect long-term preferences regarding table salt. Third, because of using usage of table salt as the intervention, we were unable to quantify the relationship between sodium intake and mortality rates. However, we performed multiple linear regression modeling and demonstrated that not using table salt was significantly associated with lower sodium intake on the days of dietary recall. Fourthly, we cannot distinguish between different types of diabetes from NHANES data. Nevertheless, the inclusion of participants aged 18 years or older may have resulted in findings that are more representative of type 2 diabetes. Finally, despite the inclusion of various potential covariates in the study, residual confounding could not be fully controlled for.

Conclusions

In the prospective cohort study, we found that not using table salt was associated with increased all-cause and CVD mortality among individuals with diabetes. It is necessary to conduct clinical trials to ascertain the potential effects of table salt among participants with diabetes and to determine the optimal amount of sodium intake.

Abbreviations

CVD	Cardiovascular disease
NHANES	National Health and Nutritional Examination Survey
HbA1c	Glycated hemoglobin A1c
ALT	Alanine aminotransferase
AST	Aspartate aminotransferase
GGT	Gamma-glutamyl transferase
LDH	Lactate dehydrogenase
eGFR	estimated glomerular filtration rate
HEI	Healthy Eating Index
HRs	Hazard ratios
CIs	Confidence intervals
KM	Kaplan-Meier

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13098-024-01511-9.

Supplementary Material 1

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None.

Author contributions

H.C. and Y.W. proposed and designed the study. Y.W. conducted the statistical analysis. Y.W. completed the literature search and data extraction. Y.W. and H.C. drafted the first version of the manuscript. Y.W. and H.C. participated in the critical revision of the manuscript. All authors contributed to the article and approved the submitted version.

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Data availability
The datasets analyzed during the current study are available in the NHANES, https://www.cdc.gov/nchs/nhanes/index.htm.

Declarations

Ethics approval and consent to participate
The portions of this study involving human participants, human materials, or human data were conducted in accordance with the Declaration of Helsinki and were approved by the National Center for Health Statistics Research Ethics Review Board. Written informed consent was obtained from all adult participants.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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