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A prospective cohort study of starchy and non-starchy vegetable intake and mortality risk

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Abstract

Whether starchy and non-starchy vegetables have distinct impacts on health remains unknown. We prospectively investigated the intake of starchy and non-starchy vegetables in relation to mortality risk in a nationwide cohort. Diet was assessed using 24-h dietary recalls. Deaths were identified via the record linkage to the National Death Index. Hazard ratios (HR) and 95 % CI were calculated using Cox regression. During a median follow-up of 7·8 years, 4904 deaths were documented among 40 074 participants aged 18 years or older. Compared to those with no consumption, participants with daily consumption of ≥ 1 serving of non-starchy vegetables had a lower risk of mortality (HR = 0·76, 95 % CI 0·66, 0·88, P_{trend} = 0·001). Dark-green and deep-yellow vegetables (HR = 0·79, 95 % CI 0·63, 0·99, P_{trend} = 0·023) and other non-starchy vegetables (HR = 0·80, 95 % CI 0·70, 0·92, P_{trend} = 0·004) showed similar results. Total starchy vegetable intake exhibited a marginally weak inverse association with mortality risk (HR = 0·89, 95 % CI 0·80, 1·00, P_{trend} = 0·048), while potatoes showed a null association (HR = 0·93, 95 % CI 0·82, 1·06, P_{trend} = 0·186). Restricted cubic spline analysis suggested a linear dose–response relationship between vegetable intake and death risk, with a plateau at over 300 and 200 g/d for total and non-starchy vegetables, respectively. Compared with starchy vegetables, non-starchy vegetables might be more beneficial to health, although both showed a protective association with mortality risk. The risk reduction in mortality plateaued at approximately 200 g/d for non-starchy vegetables and 300 g/d for total vegetables.

Key words: Diet: Mortality: Starchy vegetables: Non-starchy vegetables: Cohort study

In the USA, poor diet is estimated to be the leading cause of premature death, accounting for 529 299 deaths in 2016[1]. However, a high intake of vegetables has long been recommended to prevent chronic diseases, including CVD[2], cancer[3] and diabetes[4].

Growing epidemiological evidence shows that different types of vegetables may have heterogeneous health impacts. Higher intake of non-starchy vegetables is associated with weight loss, while increased intake of starchy vegetables such as potatoes is associated with weight gain[5]. Additionally, starchy vegetables, especially potatoes, may have less beneficial or detrimental effects on multiple health outcomes, including incident CVD[6], type 2 diabetes[7], chronic liver diseases[8] and cancers of the breast[9] and colon[10]. This may be partly due to the high glycaemic load[11] and poor processing or cooking methods[12] of potatoes. However, current dietary guidelines generally treat all types of vegetables equally[13–15], which necessitates investigating the possibly distinct health effects of starchy and non-starchy vegetables. To the best of our knowledge, however, only one study has separately assessed the associations

Abbreviations: HR, hazard ratio; NHANES, National Health and Nutrition Examination Survey.

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between starchy and non-starchy vegetables and the risk of mortality: the Nurses' Health Study and the Health Professionals Follow-up Study, which consisted primarily of Caucasian health professionals[16]. In addition, recommendations for vegetable intake differ globally. For example, the current recommendations for vegetable intake range from at least 200 g/d in the Netherlands[17] to 250 g/d in Finland and Norway[18], to 300 g/d in Belgium[19] and China[14], to 400–480 g/d in the USA[20] and to 600–800 g/d in Greece[15]. Nonetheless, the results from recent meta-analyses and large-scale cohort studies[16,21,22] suggested a non-linear relationship between the intake of vegetables and total mortality risk, with a plateau at approximately 3 servings of vegetables per day (approximately 240 g/d); intake above that level did not confer any additional benefits or showed a very minor risk reduction. Therefore, more evidence is needed to help guide recommendations regarding optimal vegetable intake.

Herein, we prospectively investigated the associations of the consumption of starchy and non-starchy vegetables and their subgroups with the risk of mortality in a nationally representative sample from the US National Health and Nutrition Examination Survey (NHANES). We also evaluated the dose–response relationship between vegetable intake and mortality.

Materials and methods

Study population

Participants in this study were selected from the NHANES, which is a continuous, cross-sectional survey conducted by the Centers for Disease Control and Prevention and the National Center for Health Statistics (NCHS) to monitor the health of a nationally representative sample of approximately 5000 persons in the USA every year. Data from the survey are available to the public. The NHANES interview includes demographic, socio-economic, dietary and health-related questions. Details of the NHANES study design, study protocol and data collection approaches have previously been reported[23]. Written informed consent was obtained from all participants. The NCHS Research Ethics Review Board approved the NHANES study protocols (Protocol #98-12; Protocol #2005-06; Protocol #2011-17).

Because the most recent mortality data were collected through 2015, we selected participants who completed at least the first 24-h dietary recall in the NHANES from 1999 to 2014. We excluded participants if they were younger than 18 years (*n* 34 735), had missing dietary data (*n* 5132) or implausible energy intake[24] (< 2510 or > 14 644 kJ/d for women and < 3347 or > 17 573 kJ/d for men, *n* 2100) or had no linked mortality data (*n* 50). A total of 40 074 eligible participants (20 984 women and 19 090 men) were included in the final analysis (online Supplementary Fig. 1).

Dietary assessment

Dietary data were collected using 24-h dietary recall. We used a multiple-pass method to enhance complete and accurate data collection and decrease the respondent burden[25]. From 1999 to 2002 only, single 24-h dietary recall was performed in person at the NHANES Mobile Examination Center (MEC). After 2003, participants had two 24-h dietary recalls, with the second 24-h (Day 2) recall being performed by telephone 3–10 d after the first (Day 1) recall to obtain a more complete picture of the usual dietary habits. We used Day 1 dietary sampling weights to overcome the limitations, including the dietary interview-specific non-response, day of the week for dietary recalls, unequal probability of selection and oversampling[25].

The definitions of total vegetables and subgroups were based on the US Department of Agriculture Food and Nutrition Database for Dietary Studies (online Supplementary Table 1). Total non-starchy vegetables include dark-green vegetables (e.g. raw or cooked broccoli, romaine, and collards), deep-yellow vegetables (e.g. carrot, pumpkin, and winter squash) and other non-starchy vegetables (e.g. tomatoes and lettuce). Starchy vegetables included white potatoes (e.g. baked, boiled, mashed, scalloped and fried potatoes and potato chips) and other starchy vegetables (e.g. immature peas, lima beans and maize).

Assessments of covariates

Information on demographic and lifestyle factors, including age, sex, race/ethnicity, educational level, marital status, family income, physical activity and smoking, was collected using standardised questionnaires during household interviews. Body weight, height and alcohol intake were obtained in the MEC. The ratio of family income to poverty was used to measure family income. This ratio divides family income by the poverty thresholds accounting for family size and annual inflation. BMI was calculated as weight in kilograms divided by the square of the height in metres (kg/m^2). Physical activity was expressed in metabolic equivalent tasks-hours/week. Healthy Eating Index-2015 (HEI-2015) scores were also calculated[26]. Histories of cancer, hypertension, diabetes and other CVD (excluding hypertension) were defined if individuals reported that they had ever been told by a healthcare professional that they had such diseases and/or took prescribed medications due to the diseases. Diabetes (a fasting plasma glucose level ≥ 126 mg/dl) and hypertension (a systolic blood pressure ≥ 140 mmHg or a diastolic blood pressure ≥ 90 mmHg) were also identified through laboratory test or physical examination in the MEC[27].

Ascertainment of deaths

Deaths and causes of death were identified via record linkage to the National Death Index (NDI) through 31 December 2015. NDI has been proven to be a reliable and efficient utility for ascertainment of deaths in large epidemiological studies; over 98 % of deaths can be identified by this method[28,29].

Ethical approval

The NCHS approved the NHANES study protocol and written informed consent was obtained from all participants. The Institutional Review Board at Anhui Medical University determined that this analysis used a public dataset, so human subjects' approval was waived.

Statistical analysis

We calculated person-years from the date of the first diet assessment to the date of death or the end of follow-up (31 December

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2015), whichever came first. Based on previous studies, we defined the standard serving size for all types of vegetables as 80 g and divided vegetable intake into three groups (i.e. 0, 0–1 and ≥ 1 servings/d)[16,30]. Cox proportional hazards regression was used to estimate hazard ratios (HR) and 95 % CI for deaths associated with intake of different types of vegetables, treating 0 servings/d as the reference group. The proportional hazards assumption was tested by including the interaction term between the intake of each vegetable and the follow-up time in the model. We also used plots of Schoenfeld residuals (data not shown) and found no evidence for violation of this assumption. Model 1 was adjusted for age, sex and total energy intake. Model 2 was further adjusted for race/ethnicity, education, marital status, ratio of family income to poverty, physical activity, smoking, alcohol drinking, BMI, diabetes, HEI-2015 and histories of hypertension, other CVD and cancer at baseline. Of note, starchy and non-starchy vegetables were mutually adjusted, dark-green and deep-yellow vegetables and other non-starchy vegetables were mutually adjusted and potatoes and other non-starchy vegetables were mutually adjusted in Model 2. To avoid overadjustment, the intake component of vegetables was removed from the HEI-2015. A missing-value indicator was created for the covariates with missing values in the models. A linear trend test was conducted by treating each exposure as a continuous variable in the models. We used restricted cubic splines with three knots at fixed percentiles (i.e. 5, 50 and 95 %) to evaluate the potential non-linear relationships between vegetable intake and death risk.

Subgroup analysis was conducted by age, sex, race/ethnicity, education, ratio of family income to poverty, smoking, marital status, alcohol drinking, physical activity, BMI and diabetes. To test the possible effect modification, we used the Wald test to examine whether the cross-product terms among these variables and exposures were statistically significant. In the secondary analysis, to minimise reverse causation from existing health conditions, we conducted a sensitivity analysis by excluding participants who died within 3 years after diet assessment. We also repeated the analyses after excluding participants with CVD, cancer or diabetes at baseline. All P values are two-sided at a type I error rate of 0·05. All statistical analyses were performed using SAS version 9.4 (SAS Institute Inc.).

Results

Characteristics of participants

After a median follow-up of 7·8 years among 40 074 participants aged 18–85 years (mean age, 47·3 years, (SD 19·4) years), we documented 4904 deaths. Potato and other non-starchy vegetable intakes contribute substantially to total vegetable intake, with proportions of energy from vegetables being 59 % for white potatoes, 29 % for other non-starchy vegetables, 9 % for other starchy vegetables and 3 % for both dark-green and deep-yellow vegetables (online Supplementary Fig. 2). Participants with higher consumption of starchy vegetables were more likely to be non-Hispanic black and have a history of other CVD. These trends were reversed for the non-starchy vegetables (Table 1). In addition, participants with higher consumption of total non-starchy vegetables were older and had higher income, education and physical activity and were more likely to be married and never smoke.

Vegetable consumption and mortality risk

Compared to those with no consumption, participants with daily consumption of 1 serving or more of total non-starchy vegetables had a lower mortality risk (HR = 0·76, 95 % CI 0·66, 0·88, P_{trend} = 0·001) in the adjusted model (Table 2). For the same comparison, we observed similar inverse associations for dark-green and deep-yellow vegetables (HR = 0·79, 95 % CI 0·63, 0·99, P_{trend} = 0·023) and other non-starchy vegetables (HR = 0·80, 95 % CI 0·70, 0·92, P_{trend} = 0·004). There was a weak inverse association between total starchy vegetable intake and death risk with borderline significance (HR = 0·89, 95 % CI 0·80, 1·00, P_{trend} = 0·048), whereas potato intake was not associated with the risk of mortality (HR = 0·93, 95 % CI 0·82, 1·06, P_{trend} = 0·186).

Restricted cubic spline analysis did not support a non-linear association of intake of starchy or non-starchy vegetables with mortality risk (all $_{non\text{-}linearity}$ > 0·05). There seemed to be a plateau in the dose–response relationship between total vegetable intake and death risk, with a minimal risk of mortality observed at above 300 g for daily total vegetable intake. Similarly, participants would gain no further apparent benefit from increasing non-starchy vegetables over 200 g/d (Fig. 1).

Secondary analysis

In the subgroup analysis, the inverse association between non-starchy vegetable intake and the risk of overall mortality appeared stronger in individuals under 65 years of age (HR per 1-SD increase = 0·84, 95 % CI 0·75, 0·93) than in those aged 65 years or older (HR per 1-SD increase = 0·96, 95 % CI 0·89, 1·03, $P_{interaction}$ = 0·028, Fig. 2). We did not find any differential associations by sex, race/ethnicity, education, ratio of family income to poverty, marital status, smoking, alcohol drinking, physical activity, BMI or history of diabetes.

In the sensitivity analysis, the results were essentially unchanged after excluding participants who had a history of diabetes (n 636, 1·59 %), cancer (n 3018, 7·53 %) or major CVD (n 3156, 7·88 %) at baseline or excluding individuals (n 1308, 3·3 %) who died within 3 years after the baseline survey (online Supplementary Table 2).

Discussion

In this large prospective cohort study, we found that higher intakes of total non-starchy vegetables and their subgroups (i.e. dark-green and deep-yellow vegetables and other non-starchy vegetables) were associated with a lower risk of overall mortality among US adults. Intake of starchy vegetables, not including potato intake, showed a weak inverse association with the risk of mortality. In addition, the risk reduction in mortality plateaued at approximately 200 g/d for non-starchy vegetables and 300 g/d for total vegetable intake.

Our findings suggest that higher non-starchy vegetable intake was associated with a lower risk of mortality, which is in line with previous cohort studies[16,31]. A prospective study consisting of

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Table 1. Age-adjusted characteristics of participants according to individual vegetable intake in NHANES (1999–2014)*
(Mean values and standard deviations; numbers)

Characteristic	Total starchy vegetables									Total non-starchy vegetables								
	0 servings/d			< 1 serving/d			≥ 1 servings/d			0 servings/d			< 1 serving/d			≥ 1 servings/d		
	%	Mean	SD	%	Mean	SD	%	Mean	SD	%	Mean	SD	%	Mean	SD	%	Mean	SD
Female, %	51·9			57·4			47·2			49·4			51·9			53·7		
Age, years		47·2	19·3		46·7	19·3		48·3	19·8		44·6	19·8		44·9	19·4		50·3	18·9
BMI, kg/m^2		28·4	6·5		28·7	6·8		28·7	6·9		28·7	6·9		28·8	6·8		28·4	6·5
Energy intake, kcal/d		1901·9	725·5		1972·0	696·2		2211·4	747·1		1880·2	742·0		1976·8	720·4		2085·2	733·3
Race/ethnicity, %																		
Non-Hispanic white	42·6			45·6			52·0			42·0			43·8			49·5		
Non-Hispanic black	17·8			22·6			23·4			25·3			23·1			17·0		
Hispanic	7·8			7·4			6·4			9·3			7·2			6·6		
Other	31·8			24·4			18·2			23·4			25·9			26·9		
Education, %																		
≤ 12th grade	33·1			26·5			25·5			38·5			31·5			23·3		
High school graduate	21·7			24·3			26·7			26·6			25·5			21·4		
More than high school	45·0			49·1			47·7			34·7			42·9			55·2		
Ratio of family income to poverty																		
< 1·3	30·6			28·3			28·2			37·4			31·6			24·0		
1·3–3·5	33·7			34·4			35·4			33·6			35·8			33·6		
≥ 3·5	26·8			29·9			29·3			20·1			24·7			34·7		
Marital status, %																		
Married	52·0			53·0			52·6			46·8			50·6			56·8		
Widowed, separated or divorced	26·0			25·7			27·1			28·8			27·6			23·6		
Never married	18·0			17·5			16·7			19·5			17·6			16·7		
Smoking status, %																		
Never smokers	50·8			51·3			48·3			44·0			48·6			54·5		
Former smokers	23·1			23·5			24·1			20·7			22·3			25·7		
Current smokers	19·6			18·6			20·1			26·4			21·5			15·0		
Physical activity, METS-h/week																		
< 8·3	41·6			40·5			39·2			46·1			42·8			37·1		
8·3–16·7	12·1			12·5			12·1			11·3			12·1			12·7		
> 16·7	45·8			46·6			48·3			42·2			44·7			50·0		
Drinking																		
Never drinking	27·1			27·1			25·3			27·5			26·8			26·1		
Low to moderate drinking	26·6			26·4			26·3			24·8			25·5			28·1		
Heavy drinking	34·7			35·3			36·6			33·5			36·1			35·7		
Diabetes, %	12·2			12·4			12·4			12·3			12·7			12·0		
Hypertension, %	34·5			36·0			36·2			35·9			35·6			35·2		
Other CVD, %	10·1			10·3			10·5			11·3			10·7			9·6		
Cancer, %	8·1			8·6			9·1			7·4			8·4			9·0		
HEI-2015		52·3	13·7		52·6	12·9		52·7	12·1		48·1	12·1		50·1	12·3		56·2	12·9

METS, metabolic equivalent tasks; NHANES, National Health and Nutrition Examination Survey.
* Variables were adjusted for age except for age. Continuous variables were expressed as the mean (SD) if normally distributed. Categorical variables were expressed as proportions (%).

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Table 2. All-cause mortality according to starchy and non-starchy vegetable intake in NHANES (1999–2014)
(Hazard ratios and 95 % confidence intervals)

	0 servings/d	< 1 serving/d		≥ 1 servings/d		P_{trend}‡
		HR	95 % CI	HR	95 % CI	
Total vegetables						
No. of deaths/person-years	598/33363	1093/79668		3213/212874		
Model 1*	1 (Reference)	0·73	0·59, 0·90	0·57	0·48, 0·67	< 0·001
Model 2†	1 (Reference)	0·84	0·70, 1·00	0·74	0·64, 0·85	< 0·001
Total starchy vegetables						
No. of deaths/person-years	2154/137567	1327/97362		1423/90976		
Model 1*	1 (Reference)	0·92	0·78, 1·07	0·92	0·80, 1·05	0·183
Model 2†	1 (Reference)	0·95	0·83, 1·09	0·89	0·80, 1·00	0·048
Potatoes						
No. of deaths/person-years	2545/160476	1239/93386		1120/72043		
Model 1*	1 (Reference)	0·91	0·79, 1·06	1·00	0·85, 1·17	0·797
Model 2†	1 (Reference)	0·91	0·80, 1·04	0·93	0·82, 1·06	0·186
Other starchy vegetables						
No. of deaths/person-years	4006/274168	577/32143		321/19594		
Model 1*	1 (Reference)	1·00	0·88, 1·14	0·75	0·61, 0·93	0·030
Model 2†	1 (Reference)	1·08	0·96, 1·22	0·79	0·65, 0·96	0·268
Total non-starchy vegetables						
No. of deaths/person-years	1048/62627	1574/115566		2282/147713		
Model 1*	1 (Reference)	0·75	0·63, 0·90	0·58	0·50, 0·68	< 0·001
Model 2†	1 (Reference)	0·84	0·72, 0·98	0·76	0·66, 0·88	0·001
Dark-green and deep-yellow vegetables						
No. of deaths/person-years	3680/242481	879/60299		345/23125		
Model 1*	1 (Reference)	0·71	0·63, 0·79	0·71	0·57, 0·87	< 0·001
Model 2†	1 (Reference)	0·93	0·84, 1·04	0·79	0·63, 0·99	0·023
Other non-starchy vegetables						
No. of deaths/person-years	1238/71918	1706/125745		1960/128242		
Model 1*	1 (Reference)	0·76	0·64, 0·89	0·60	0·52, 0·70	< 0·001
Model 2†	1 (Reference)	0·87	0·75, 1·00	0·80	0·70, 0·92	0·004

GED, general educational development; HR, hazard ratio; METS, metabolic equivalent tasks; NHANES, National Health and Nutrition Examination Survey.
* Model 1 was adjusted for sex (male, female), age (18–45, 46–65, ≥ 66 years) and total energy intake (kcal/d, tertile).
† Model 2 was further adjusted for race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic or other races), education (≤ 12th grade, high school graduate/GED or equivalent or more than high school), marital status (married, widowed/divorced/separated or never married), ratio of family income to poverty (< 1·30, 1·30–3·49 or ≥ 3·50), physical activity (< 8·3, 8·3–16·7 or > 16·7 METS-h/week), smoking (never smokers, former smokers or current smokers), drinking (never drinking, low to moderate drinking, heavy drinking), BMI (< 18·5, 18·5–24·9, 25·0–29·9 and ≥ 30·0), diabetes (no, yes), hypertension (no, yes), other CVD (no, yes), cancer (no, yes) and HEI-2015 (tertile). Of note, starchy and non-starchy vegetables were mutually adjusted, dark-green and deep-yellow vegetables and other non-starchy vegetables were mutually adjusted and potatoes and other non-starchy vegetables were mutually adjusted.
‡ Linear trend test was conducted by treating each exposure as a continuous variable in the models.

US health professionals reported that non-starchy vegetable intake was inversely associated with overall mortality, but a null association of starchy vegetables with mortality was found[16]. In another cohort study of Japanese participants, higher non-starchy vegetable intake was associated with a lower risk of all-cause mortality[31]. Several biological mechanisms might explain the beneficial effects of non-starchy vegetables on human health. First, dietary fibre in non-starchy vegetables has been described as promoting the production of SCFA, improving insulin resistance and assisting in lowering cholesterol[32]. In addition, dietary fibre has been shown to be beneficial to human health through its physiological effects in the gut, including acting as a prebiotic to selectively enrich beneficial gut bacteria[33]. Second, non-starchy vegetables can reduce oxidative stress because they contain several antioxidant compounds and vitamins that may reduce the risk of vascular disease and cancer by scavenging reactive oxygen species and other free radicals and preventing the oxidation of DNA and lipids in arterial tissue[34]. Additionally, most antioxidant phytochemicals in starchy vegetables have also been found to have anti-inflammatory properties, such as resveratrol, anthocyanin and curcumin[35]. Third, obesity is associated with low-grade systemic inflammation, significant adipose inflammation and insulin resistance, which may increase the risk of mortality and chronic diseases[36]. However, a long-term follow-up cohort study in the USA revealed that increased consumption of non-starchy vegetables was inversely associated with weight change[37].

We found a weak inverse association between total starchy vegetable intake and death risk, possibly because starchy vegetables provide important nutrients and bioactive compounds[38] such as carbohydrates, K, dietary fibre, vitamins, polyphenols and flavonoids. In accordance with our results, a recent study in Costa Rican adults found a significant inverse association between the consumption of starchy vegetables and fasting blood glucose[39]; higher consumption of starchy vegetables during reproductive years decreased the risk of gestational diabetes mellitus during pregnancy among Tehranian women[40]. Similarly, moderate starchy vegetable intake was inversely associated with all-cause mortality in the China Health and Nutrition Survey[41].

Our results showed a null association between mortality and potato intake, which is consistent with the few existing

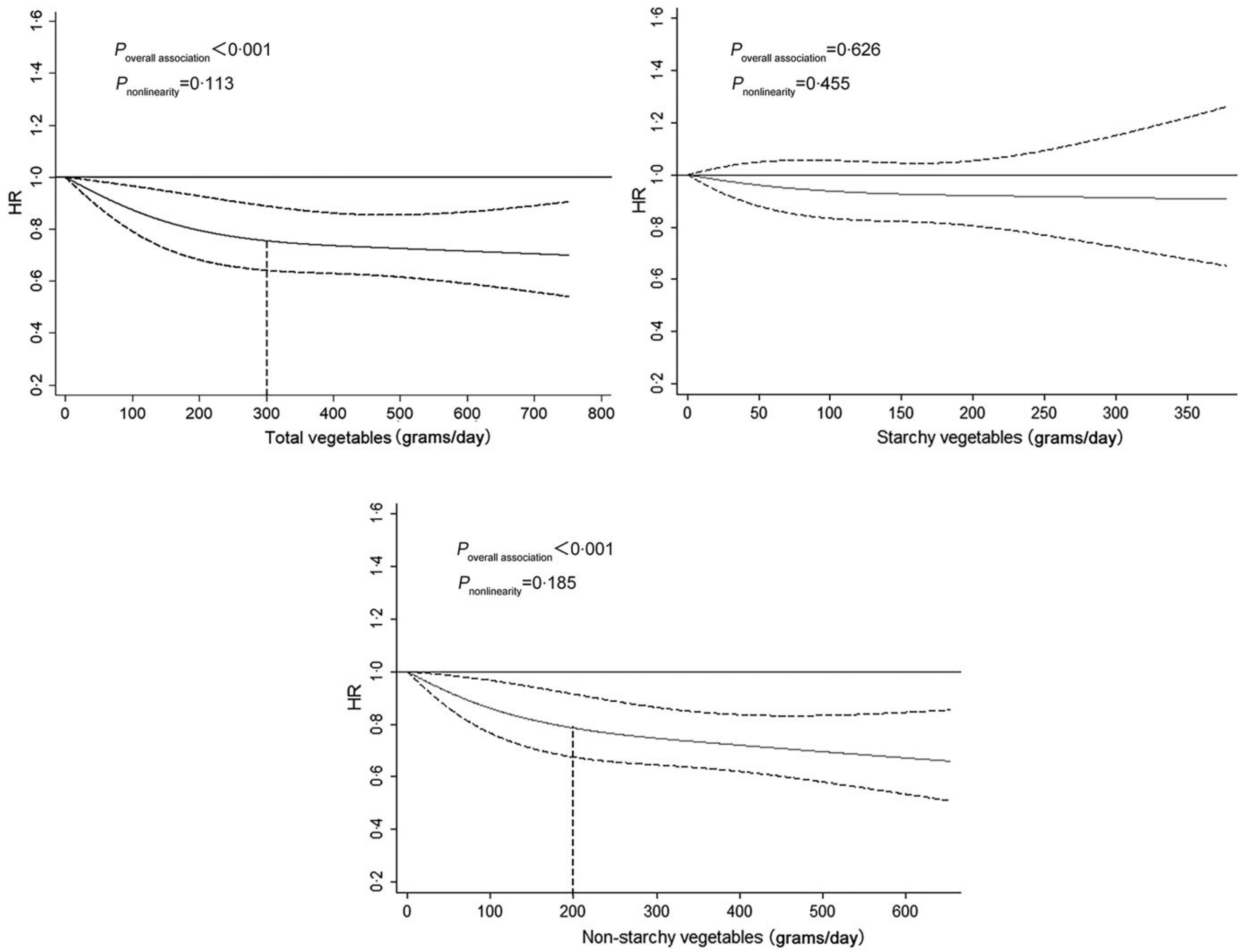

Fig. 1. Dose–response relationship between total vegetables, total starchy vegetables, total non-starchy vegetables and all-cause mortality in NHANES (1999–2014)[a]. HR, hazard ratio; NHANES, National Health and Nutrition Examination Survey. [a] Adjusted for sex (male, female), age (18–45, 46–65, ≥ 66 years), total energy intake (kcal/d, tertile), race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic or other race), education (≤ 12th grade, high school graduate/GED or equivalent or more than high school), marital status (married, widowed/divorced/separated or never married), ratio of family income to poverty (< 1·30, 1·30–3·49 or ≥ 3·50), physical activity (< 8·3, 8·3–16·7 or > 16·7 METS-h/week), smoking (never smokers, former smokers or current smokers), drinking (never drinking, low to moderate drinking, heavy drinking), BMI (< 18·5, 18·5–24·9, 25·0–29·9 and ≥ 30·0), diabetes (no, yes), hypertension (no, yes), other CVD (no, yes), cancer (no, yes), HEI-2015 (tertile) and starchy and non-starchy vegetables were mutually adjusted. Of note, the dotted line represents the 95 % CI.

studies[42,43]. Although potatoes are rich in fibre, niacin, folate, vitamins and minerals, including K, Mg and Fe[44], their high glycaemic load may raise glucose levels faster than non-starchy vegetables, leading to disruption of insulin homoeostasis and promotion of fat deposition[45], all potentially important mechanisms in the development of major chronic diseases[11,46]. In this context, it is possible that the beneficial compounds in potatoes may compensate for the detrimental effect of high carbohydrate intake and therefore a higher glycaemic index[47]. On the other hand, different preparation methods of potatoes can lead to different health effects. For example, consumption of boiled potatoes was not associated with all-cause or CVD mortality in Norway[43], whereas two epidemiological studies reported that the consumption of fried potatoes was associated with a higher risk for CVD[12] and overall mortality[42], which might be due to the harmful chemical contaminants generated during heat processing[41]. Unfortunately, potatoes are eaten mainly in the form of French fries, potato chips and mashed potatoes in the USA[48], which are also part of the Western dietary pattern.

Restricted cubic spline analysis suggested that the risk reduction in mortality plateaued at approximately 200 g/d for non-starchy vegetables and 300 g/d for total vegetable intake. These results were partly consistent with the three meta-analyses[16,21,22] showing a plateau at 3 servings/d (approximately 240 g/d) of total vegetable intake; intake above that level was not associated with further risk reductions[16,22] or showed a very minor risk reduction in mortality[21]. Similarly, the 2020–2025 Dietary Guidelines for Americans recommend that adults consume 2–3 cup equivalents of vegetables per day[49]. However, several dietary guidelines recommend higher daily intake levels. The Dietary Guidelines for Germany[13] and the Food Guide Pagoda for Chinese Residents[14] recommend 400 g of total vegetable intake per day. The recommended daily intake of vegetables in the Dietary Guide for Adults in Greece[15] is higher than 400 g.

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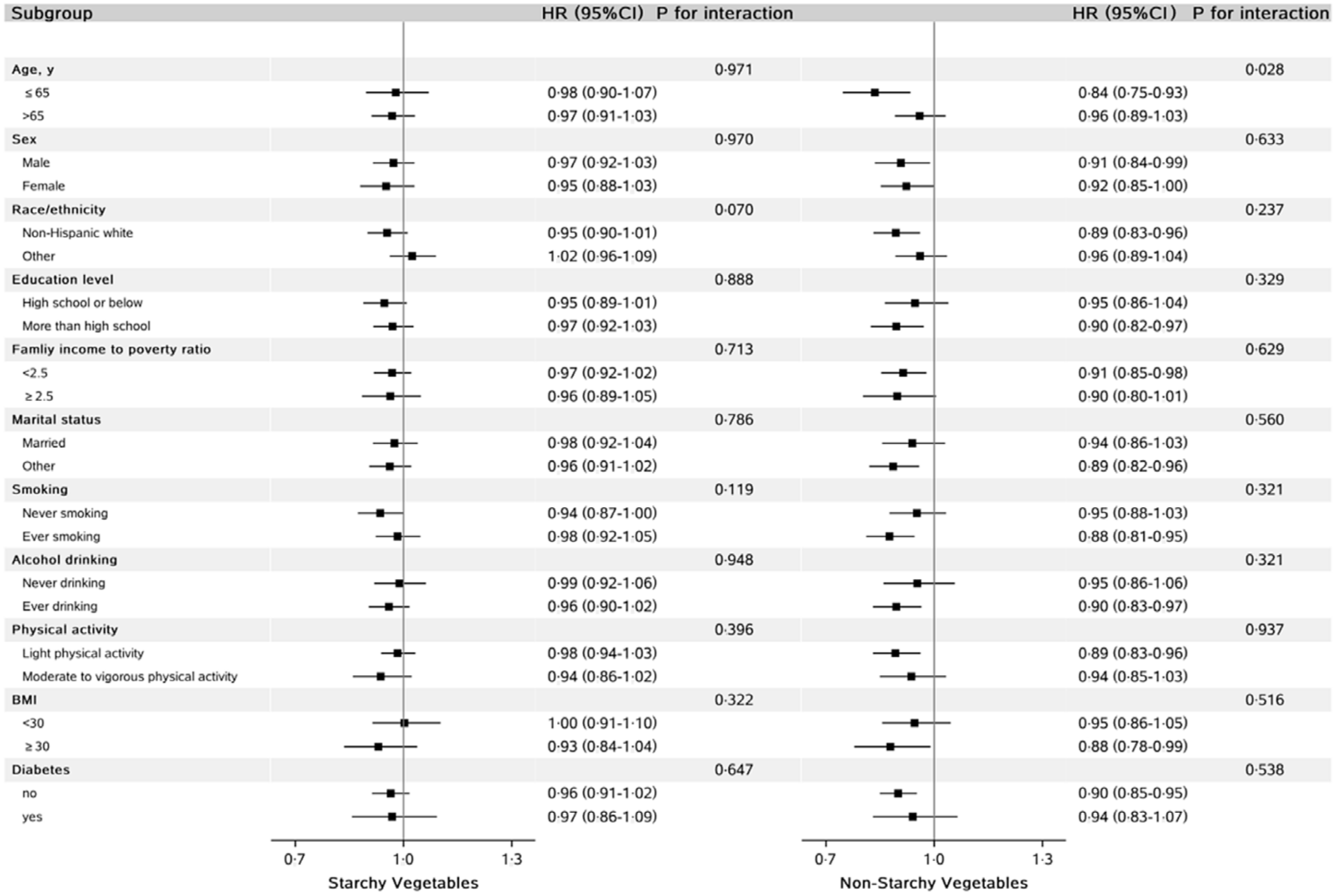

Fig. 2. HR of all-cause mortality per 1-SD increase in total starchy vegetables and non-starchy vegetables by subgroups in NHANES (1999–2014)[a]. HR, hazard ratios; METS, metabolic equivalent tasks; NHANES, National Health and Nutrition Examination Survey. [a] Adjusted for sex (male, female), age (18–45, 46–65, ≥ 66 years), total energy intake (kcal/d, tertile), race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic or other race), education (≤ 12th grade, high school graduate/GED or equivalent, or more than high school), marital status (married, widowed/divorced/separated, or never married), ratio of family income to poverty (< 1·30, 1·30–3·49 or ≥ 3·50), physical activity (< 8·3, 8·3–16·7 or > 16·7 METS-h/week), smoking (never smokers, former smokers or current smokers), drinking (never drinking, low to moderate drinking, heavy drinking), BMI (< 18·5, 18·5–24·9, 25·0–29·9, and ≥ 30·0), diabetes (no, yes), hypertension (no, yes), other CVD (no, yes), cancer (no, yes), HEI-2015 (tertile) and starchy and non-starchy vegetables were mutually adjusted. Of note, each stratified variable was removed from the corresponding model. Light physical activity was defined as participants with physical activity less than 8·3 METS-h per week, and moderate and vigorous activity was defined as participants who had physical activity of 8·3 METS-h per week or more.

We found that age may significantly modify the inverse association between non-starchy vegetable intake and the risk of overall mortality, with a stronger inverse association being observed among younger participants (i.e. under 65 years of age). The reasons for such significant effect modification remain unclear. A possible explanation is that ageing of the human body leads to a decrease in the number of nerve cells in the myenteric plexus, which affects digestive absorption, and degeneration of the small intestine villi in the elderly also leads to blunting of nutrient absorption[50]. Alternatively, the results might be due to chance. Further studies are warranted to validate these findings and to elucidate the underlying mechanisms.

The strengths of our study include the use of a nationally representative sample of US adults, the large sample size and the prospective cohort design. However, several limitations should be noted. First, self-reported diet and other lifestyle factors from questionnaires have measurement errors, although we used several methods[25], including dietary sampling weight and a multiple-pass method, to reduce measurement error and to improve estimates of usual intake. In addition, dietary information was collected based on a single measurement at baseline, and participants may have changed their dietary habits during the follow-up. Second, although we adjusted for a wide range of risk factors, such as demographics, smoking and physical activity, the possibility of residual confounding cannot be totally ruled out. In addition, we were unable to consider cooking methods in the analysis, which may also lead to confounding bias. Third, despite a nationally representative sample in the current study, the findings may not be generalisable to other populations, such as Asian populations, given the differences in food composition and cooking/preparation methods across regions or countries.

In conclusion, a higher intake of non-starchy vegetables might be more beneficial to health than starchy vegetables, although both showed an inverse association with mortality risk. Our results do not support that potato intake is associated with a lower risk of death. The risk reduction in mortality plateaued at approximately 200 g/d for non-starchy vegetables and 300 g/d for total vegetable intake. These findings should be interpreted

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with caution and need to be validated in well-designed cohorts, given the single diet measurement using 24-h recalls.

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The authors disclose no conflicts.

Supplementary material

For supplementary material referred to in this article, please visit https://doi.org/10.1017/S0007114522003518

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