Global Epidemiology 5 (2023) 100112

Contents lists available at ScienceDirect

Global Epidemiology

journal homepage: www.sciencedirect.com/journal/global-epidemiology

Research Paper

Associations of animal source foods, cardiovascular disease history, and health behaviors from the national health and nutrition examination survey: 2013–2016

Adam Eckart[a,*], Amir Bhochhibhoya[a], James Stavitz[a], Pragya Sharma Ghimire[a], Kathleen Mathieson[b]

[a] Kean University, College of Health Professions and Human Services, 1000 Morris Avenue, Union, NJ 07083, USA
[b] A.T. Still University, College of Graduate Health Studies, 5850 E. Still Circle, Mesa, AZ 85206, USA

ARTICLE INFO

Keywords:
Animal-source foods
Meat-eating
Diet
Cardiovascular disease
Lifestyle risk factors

ABSTRACT

Background: Some individuals adopt vegetarian or plant-based diets to improve their health. Observational evidence suggests diets composed of higher amounts of animal-source foods (ASFs) are associated with increased risk for disease and early mortality. In many of these studies, those who ate fewer animal-source foods reported fewer disease risk factors and unhealthy behaviors, which could indicate bias.

Purpose: This study aims to examine the relationships between ASF consumption, health behaviors, and cardiovascular disease (CVD) prevalence in a population-representative sample of U.S. civilians controlling for confounders.

Methods: Respondent data were collected from the National Health and Nutrition Examination Survey (NHANES) 2013–2016 collection years. Collected data included demographics, ASF intake, healthy lifestyle variables, body mass index, and blood lipids.

Results: There was a higher proportion of those with CVD history who consumed red meat (61.3%; C.I. 41.7%–77.8%), but the proportion was lower for white (23.3%; C.I. 12.6%–39.0%) and processed meat (15.4%; C.I. 6.5%–32.3%). When adjusted for sex, the odds of CVD history increased for red meat compared to processed meat consumption (OR 2.95; C.I. 1.14–7.66). Unhealthy lifestyle increased the odds of CVD history by nearly 8-fold (OR 7.8; C.I. 3.44–17.7). Individual factors including age, smoking history, body mass index, and blood lipids, and demographic factors, including education level, race, and income, were also associated with increased odds for CVD history. ROC analysis revealed 77.2% AUC for CVD history classified by individual factors (BMI ≥30 kg/m**2, ≤ 30 min moderate physical activity, smoker, fiber intake ≤25 g, dental visit more than two years ago, and age above 60 years). Three or more factors moderately predicted CVD history when optimized for sensitivity (73.4%) and specificity (71%). Adjusted for sex, the relationship between CVD and moderate physical activity became stronger possibly reflecting lifestyle changes. Despite evidence of lifestyle changes, modifiable risk factors persisted in the CVD group. CVD diagnosis in males was substantially delayed compared to females concerning the sex-specific age cutoff associated with higher risk. The healthy lifestyle group was characterized by earlier CVD diagnosis and fewer overall risk factors compared to the unhealthy lifestyle group.

Conclusion: CVD history was strongly associated with demographic, lifestyle, and dietary factors. Future research should focus on multidimensional models for disease risk stratification and prevention, including individual, behavioral, and sociodemographic factors.

Differing views exist on the optimal diet for disease prevention and management because of the complex nature of nutrient-disease interactions and the challenges in studying causal relationships between diet and health outcomes. Cardiovascular disease (CVD) is a global health issue, and poor nutrition is cited as a risk factor by the Centers for Disease Control and Prevention (CDC) [1]. Since there is a lack of consensus on the optimal ratios and sources of carbohydrates, fats, and proteins, consensus recommendations often refer to interventional and

* Corresponding author.
E-mail address: eckarta@kean.edu (A. Eckart).

https://doi.org/10.1016/j.gloepi.2023.100112
Received 9 March 2023; Received in revised form 5 May 2023; Accepted 17 May 2023
Available online 18 May 2023

observational evidence of specific dietary patterns associated with better health outcomes [2,3]. Although randomized controlled trials (RCTs) are considered the gold standard for evidence on the efficacy of a treatment, generalizability is a concern due to sample characteristics and highly regulated interventions that may be different from the lived experience [4]. Epidemiology researchers use observational approaches to study the effects of environmental exposures on health outcomes in a population. The results from these studies are often used to address public health issues through published recommendations and prevention initiatives [4,5]. However, confounding is a common source of bias in observational studies that create significant evidentiary gaps, making it difficult for researchers to draw inferences for a population [6–8].

There is growing interest in adopting vegetarian, plant-based, or vegan diets for health purposes [9]. Some evidence supports the health-promoting benefits of decreased overall protein intake and intake of protein and fats from plant-based sources rather than animal sources [43]. Levine et al. (2014) observed the lowest mortality risk from diabetes, but not all-cause mortality, cancer, or CVD in a U.S. population-representative sample for those consuming under 10% of total energy from protein [10]. Several studies suggest that dietary substitutions of plant protein for animal protein, plant protein for carbohydrates, or protein and monounsaturated fat for carbohydrates are associated with reduced cardiovascular disease mortality, improved blood markers of disease, or a reduced risk of developing coronary disease over a 10-year period [11–13]. Carbohydrate intakes higher than 40% but lower than 55% of total energy containing higher fiber content are associated with a longer lifespan and reduced coronary artery disease and Type 2 diabetes risk [13–15]. Red and processed meat is associated with a higher risk for colorectal, lung, esophageal, and gastric cancers and ischemic CVD, while white meat is associated with lower incidence and mortality from CVD, cancer and stroke [16–18]. In contrast to these findings, clinical trials on low-carbohydrate diets, which contain relatively higher proportions of animal source foods (ASFs), have demonstrated significant improvements in CVD and Type 2 diabetes risk factors in obese subjects and diabetics, respectively [19,20,23].

Despite the differences in the methodological approaches of interventional and observational studies and the inherent weaknesses in these designs, corroboration is important for generalizability and consensus recommendations. Recently, observational studies regarding the associations between red meat, disease, and mortality have been criticized for low certainty or weak association as a basis for providing recommendations [21]. Some observational studies finding positive associations of disease and mortality with higher ASF consumption report attenuated associations after adjustment for covariates such as body mass index (BMI), blood markers of disease, and health behaviors [11,17]. In many observational studies, ASF-eaters were more likely to have more disease risk factors or unhealthy characteristics such as higher BMI, increased caloric consumption, increased smoking, increased alcohol consumption, lower physical activity, diabetes, fewer lipid-lowering drugs, and lower education [14,16,22–25]. This may be evidence of healthy lifestyle bias that confounds the causal inference that ASFs contribute to disease [8]. This notion is supported by Cramer et al. (2017), who observed healthier lifestyles in vegetarians versus non-vegetarians in a population-representative sample [9]. Other studies have found that diets higher in white meat, fish, and eggs are associated with lower disease incidence and mortality risk than processed and unprocessed meat [16–18]. Healthier overall behavior may be associated with consuming more plant foods or non-red meat sources of animal protein due to the widely-promoted recommendation to avoid excess red meat consumption, and therefore, better health outcomes than those eating higher proportions of ASFs would be expected. If this is the case, the evidence used to undergird recommendations to reduce the consumption of ASFs for the prevention and management of disease should be questioned.

Observational studies that ameliorate biases are warranted to improve evidence-based nutritional recommendations [6]. Obesity, smoking, and other health behaviors are modifiable risk factors for chronic disease often clustered within individuals increasing the likelihood of adverse health outcomes [26–31]. To check for healthy lifestyle bias and analyze other factors in conjunction with diet that contribute to health outcomes, a multifactorial causal model should be used to inform analyses of essential exposures or antecedents of certain health outcomes [8]. To the authors' knowledge, no recent studies have used U.S. population-representative data to investigate the association of ASF consumption and CVD that considers the interaction of health behaviors. First, the association between ASFs and CVD history using continuous National Health and Nutrition Examination Survey (NHANES) data will be analyzed. Next, sample characteristics and health behaviors associated with CVD history will be analyzed adjusting for confounding factors.

Methods

Survey data was extracted from the continuous NHANES (from 2013 to 2016), a population-representative survey of non-institutionalized U. S. civilians. NHANES utilizes a multistage sampling design to account for unequal selection probabilities, non-response, and reference population proportion adjustments which improve the accuracy of population estimates. Since the sample was drawn from several primary sampling units and multiple strata, using statistical analyses that assume simple random sampling would produce erroneous variances. The authors used the Complex Samples package from SPSS Statistical Software (29.0), which allows for variance adjustments from sampling units and strata using linear approximation [45]. Per NHANES guidance, a 4-year sample weight was created from the 2-year weights for each collection year [33,45]. Sample characteristics were compared across demographic groups, health behavior groups, and those with and without CVD (Appendix A).

Individual food intakes and frequencies were collected using NHANES 24-h dietary recall questionnaires administered by trained interviewers [34]. Total nutrient intakes were collected as well as calories from all ASFs which were summed for each respondent (Appendix B). Incident CVD of all types, ICD-10 codes, prescription medications, years on medication, and age of first diagnosis were collected or used to created several variables for the analysis (Appendix A & C). In addition to basic lipid values, lipid ratios including LDL-C to apolipoprotein B ratio (LDL:APOB) and total cholesterol (TC) to HDL-C ratio (TC:HDL) were computed due to their association with CVD mortality [46]. Finally, several variables related to healthy lifestyle including BMI, smoking, alcohol consumption, physical activity, dental visit frequency, fiber intake, and doctor-recommended lifestyle changes were included in the analysis.

Data analysis

All statistical analyses were conducted using IBM SPSS Statistics (29.0). Data analyses were performed using the Complex Samples function, which provided population estimates from the sample weights, masked variance pseudo-PSU, and masked variance pseudo-stratum variables. Conventionally, the mean and standard errors were used to describe variable parameters. The sample was split into quartiles (Q) of ASF calories to total calories ratio (ASF:TCAL) to check for potential dose-dependent associations. Descriptive parameter estimates were compared by sex, race/ethnicity, CVD disease status, age group, meat intake groups, and healthy lifestyle status. An unhealthy lifestyle was determined from established relationships with CVD including BMI $\geq$30 kg/m^2, $\leq$ 30 min moderate physical activity, smoking, fiber intake <25 g, dental visit more than two years ago (as a proxy for engaging in other health behaviors). Chi-square analysis was used to calculate associations of CVD history across specific risk factors, quartiles of ASF consumption, meat type intake, sex, race/ethnicity, age group, education level, and healthy lifestyle factors. A directed acyclic graph (DAG) was used to identify sex as a confounding variable for adjustment in the analysis (Fig. 1). Multinominal logistic regression was used to analyze relationships with CVD for categorical and continuous variables with and without adjustment for sex. Principle component analysis (PCA), which included all healthy lifestyle variables, was used to validate important predictors of CVD history. To test the sensitivity and specificity of these factors to predict CVD history, receiver operating characteristic (ROC) analysis was conducted.

Results

Data from 20,129 respondents were included in the analysis. The estimated proportion of respondents with CVD history was 5.4%. Overall, males had higher mean nutrient intakes, LDL-C, APOB, triglycerides, total moderate and vigorous PA, total calories from ASFs, and TC:HDL compared to females (Table S1). Females had higher mean TC, HDL-C, and slightly higher disease years. On average, those with at least one CVD condition were more than twice the age of those without CVD and had higher BMI, sedentary minutes, moderate PA minutes, TC:HDL, triglycerides, kcals/g of ASF, and cigarettes per day (Table S2). Compared to those without CVD, those with CVD had lower mean nutrient intakes, income, HDL-C, LDL-C, LDL:APOB, and vigorous PA. BMI, blood lipids except for LDL:APOB, moderate PA, TC:HDL, income, ASF:TCAL, and smoking frequency were highest in the middle two (40–49, 50–59) age groups and lower in the lowest (20-39) and highest (60 and over) age groups (Table S3). Mean values for alcohol consumption, LDL:APOB, total energy, total moderate PA, and TC:HDL were lowest in the 60 and over age group. Mean values were highest for sedentary time, disease years, total number of CVD conditions, and HDL-C in the 60 and older age group. An average of nearly 70% of total calories came from ASFs for those in Q4, with the lowest mean age of all quartiles (Table S4). Mean values were also lowest in Q4 for total energy, carbohydrate, fiber, sugar, income, HDL-C, TC, and CVD conditions. However, triglycerides, total moderate and vigorous PA, and TC:HDL were highest for those in Q4.

Compared to the healthy group, the unhealthy group had higher mean values for age, LDL-C, total energy, triglycerides, TC:HDL, and years on medication yet were lower for fiber, income, HDL-C, TC, LDL:APOB, and disease years (Table S6). No moderate PA was found for those selected to the unhealthy group. On average, males with CVD had more conditions, lower HDL-C, higher triglycerides, and higher TC:HDL than females despite similar age, substantially higher PA, and lower LDL-C, TC, and LDL:APOB (Table S8).

Compared to those consuming white and processed meat, red meat eaters were older, had more heart conditions, lower HDL-C, higher LDL-C, lower overall PA, higher TC:HDL, and smoked more, yet had the lowest number of disease years (Table S7).

Chi-square analysis showed proportional differences in demographic characteristics for those with at least one CVD condition, including age group, race/ethnicity, and education level. In the 60 and older age group, 24% (C.I. 20.6% - 27.9%) had at least one CVD condition compared to 9% (C.I. 6.1%–13.2%), 3.6% (C.I. 2.0%–6.4%), and 1.2% (C.I. 0.6%–2.3%) in the 50–59, 40–49, and 20–39 age groups, respectively (Table 1). Non-Hispanic Black (6.2%; C.I. 4.5–8.5) followed by Non-Hispanic White (5.5% C.I. 4.3%–7.0%) groups had the highest proportion with CVD history. Except for those in the 9–11 grade category, the proportion of those with CVD decreased as education level increased. Q2 of ASF intake had the highest proportion of those with CVD history at 7.4% (C.I. 5.4%–10.1%), followed by Q3 at 6.2% (C.I. 4.0%–9.5%). The odds ratio confidence intervals for all quartiles crossed 1 indicating no association (Table 2a). Adjustment for sex did not meaningfully change the relationship between quartiles of ASF:TCAL and CVD history. (See Table 2b.)

Multivariate chi-square analysis showed an association between CVD history and meat type ($\chi^2 = 8.00$ [Table S10]), yet, there was no association between unhealthy lifestyle and meat type (χ^2 = 0.32

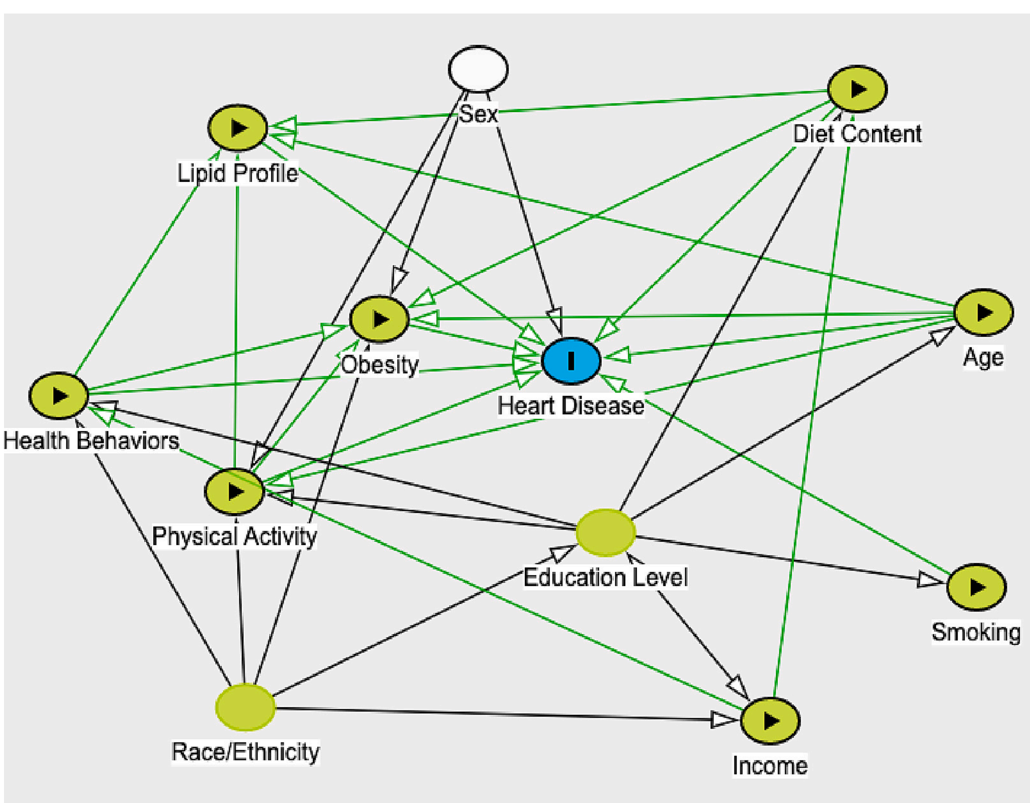

Fig. 1. Directed Acyclic Graph of Factors Associated with CVD.
Note: The directed acyclic graph shows direct and indirect relationships between exposure variables and CVD history.

Table 1
Chi-Square Analysis for Demographic Factors.

Variable (unweighted count)	≥ 1 CVD condition	95% Confidence Interval	
	Weighted %	Lower	Upper
Sex			
Male (n = 3324)	181(5.7)	4.8	6.8
Female (n = 3216)	124(5)	3.8	6.6
Age Group			
20–39 (n = 1051)	11(1.2)	0.6	2.3
40–49 (n = 511)	23(3.6)	2	6.4
50–59(n = 459)	40(9)	6.1	13.2
60 and above (n = 869)	224(24)	20.6	27.9
Race/Ethnicity			
Mexican American (n = 1243)	25(1.8)	1.3	2.5
Other Hispanic (n = 679)	22(2.3)	1.5	3.3
Non-Hispanic White (n = 1473)	77(5.5)	4.3	7
Non-Hispanic Black (n = 1327)	72(6.2)	4.5	8.4
Non-Hispanic Asian (n = 639)	15(2.8)	1.5	5.1
Education Level Adults 20+			
Less than 9th grade (n = 371)	52(13)	9.2	18
9-11th grade (Includes 12th grade with no diploma) (n = 413)	41(9)	6.1	13.2
High school graduate/GED or equivalent (n = 622)			
Some college or AA degree(n = 847)	78(11.1)	8.2	14.7
College graduate or above(n = 655)	78(7.8)	5.6	10.7
	54(5.8)	4.4	7.8

Note: Table shows estimates of population proportions with at least one CVD condition by demographic group.

[Table S11]). The proportion of those with CVD in the red meat group was 61.3%, compared to 23.35% in the white meat group and 15.4% in the processed meat group.

Bivariate chi-square analysis showed proportional differences in individual characteristics for those with at least one CVD condition including obesity (OR 3.18; C.I. 2.11–4.8), the use of at least one prescription medication (OR 25.43; C.I. 13.28–48.68), engaging in 30 min of physical activity at a moderate intensity, (OR 0.169; C.I. 0.034–0.834) at least one dental visit within the past two years (OR 0.38; C.I. 0.26–0.551), being told by their doctor to change lifestyle (OR 5.20; C.I. 3.85–7.02), and consuming at least 25 g fiber per day (OR 0.48; C.I. 0.275–0.848)(Table 3). There was no association between sex and CVD history (OR 0.87C.I. 0.608–1.24). Of those selected for unhealthy lifestyle, 44.1% were on medication at the time of the survey (OR 3.004; C.I. 1.5–6.0)(Table S9). The percentage of males (82.3%) with CVD on medication was lower than females (87.7%). There was no association between current smoking and CVD history (OR 0.63; C.I. 0.375–1.05). However, former smokers were over 3 times as likely to have a history of CVD (OR 3.30; C.I. 2.15–5.07).

Univariate logistic regression showed noteworthy relationships for predictors of CVD history include age (10-year increase, OR 2.31; C.I. 2.09–2.55), education level less than 9th grade (OR 2.40C.I. 1.44–4.01), a high school graduate/GED or equivalent (2.007; C.I. 1.31–3.08), Black (OR 3.51; C.I. 2.2–5.58) and White (OR 3.09; C.I. 1.94–4.9) race/ethnicity, and poverty level index between 1.3 and 1.85 (OR 2.05; C.I. 1.29–3.27) (Table 4).

Adjusted for sex, associations of CVD decreased for age (10-year increase; OR 0.43; C.I. 0.38–0.48), increased for total moderate PA (90-min increase; OR 1.51; C.I. 1.12–2.03), and attenuated for minimum moderate physical activity (OR 0.40; C.I. 0.161–1.001) (Table 5). Compared to processed meat, the relationship between red meat and CVD became meaningful after adjustment for sex (OR 2.950; C.I. 1.14–7.66). There was no association between meat type intake and sex (χ^2 = 2.63 [Table S12]).

Principle component analysis showed CVD factors loaded onto three components (Tables 6a-c). For component 1, the highest factor loadings were dental visits (r = 0.645) and smoking status (r = 0.802). This component may represent overall health behaviors. For the second principal component, the variable with the highest factor loading was obesity status (r = 0.843). This component may represent body composition or weight-related factors. For the third principal component, the variable with the highest factor loading was minimum moderate PA to be considered active (r = 0.718). This component may represent physical activity levels. (See Tables 6b and 6c.)

ROC analysis revealed an area under the curve of 77.2% [C.I. 75% -

Table 2b
Chi-Square Analysis for Quartiles of ASF Kcal Ratio.

	≥ 1 CVD condition	95% Confidence Interval	
Variable (unweighted count)	Weighted %	Lower	Upper
Quartiles ASF Kcal ratio			
1 (n = 944)	42(4.6)	2.8	7.3
2 (n = 881)	62(7.4)	5.4	10.1
3 (n = 847)	46(6.2)	4	9.5
4 (n = 1134)	35(4.1)	4.5	7

Note: Table shows estimates of population proportions with at least one CVD condition by quartile of ASF:TCAL.

Table 3
Chi-Square Analysis for CVD Characteristic Factors.

			95% Confidence Interval	
Variable (unweighted count)	Weighted %	OR	Lower	Upper
Current smoker (n = 170)	39.2	0.63	0.375	1.05
Former smoker (n = 305)	29.2	3.30	2.15	5.07
Obese (n = 305)	50.9	3.18	2.11	4.8
≥ 1 Rx (n = 147)	84.7	25.43	13.28	48.68
Males (n = 70)	82.3			
Females (n = 55)	87.7			
Told by dr. to change lifestyle (n = 305)	64.4	5.197	3.85	7.02
Unhealthy lifestyle		7.808	3.44	17.7
(n = 54)	28.1			
Males (n = 10)	28.8			
Females (n = 5)	27.0			
Minimum moderate PA (n = 305)	1.0	0.169	0.034	0.834
Female (n = 124)	45.5	0.87	0.608	1.24
Dental visit within last 2 yrs. (n = 271)	45.9	0.38	0.26	0.551
≥ 25 g/day fiber (n = 303)	4.0	0.48	0.275	0.848

Note: Table shows the percentages and odds ratios of those with at least one CVD condition selected for each factor.

Table 2a
Logistic Regression Analysis With & Without Adjustment for Sex.

	–	Without adjustment	95% Confidence Interval		With adjustment	95% Confidence Interval	
		Odds Ratio	Lower	Upper	Odds Ratio	Lower	Upper
	1	1.114	0.541	2.296	1.122	0.545	2.311
	2	1.863	0.983	3.531	1.871	0.986	3.548
Quartiles of ASF:TCAL ratio†	3	1.540	0.783	3.030	1.543	0.782	3.043

Note: Table shows odd ratios for CVD history in each quartile of ASF:TCAL intake. † reference category = Q4.

Table 4
Logistic Regression Analysis Without Adjustment for Sex.

Variable	Units of Change	Odds Ratio	95% Confidence Interval	
			Lower	Upper
Age in years at screening	10	2.306	2.086	2.549
Smoking years	10	1.58	1.262	1.984
Body Mass Index (kg/m**2)	1	1.071	1.053	1.089
Total moderate PA (mins/day)	10	1.046	1.016	1.078
Avg # alcoholic drinks/day - past 12 mos	1	0.862	0.678	1.096
≥30 mins/day, mod intensity	Not selected †	0.169	0.034	0.834
Minutes sedentary activity	90	1.106	1.014	1.205
Direct HDL-Cholesterol (mg/dL)	10	0.850	0.743	0.974
Triglyceride (mg/dL)	10	1.029	1.008	1.050
LDL-cholesterol (mg/dL)	10	0.882	0.804	0.969
Food Types	red meat vs. white meat†	1.979	0.895	4.375
	processed meat† vs. white meat	0.677	0.246	1.860
≤ 25 g/day fiber	Not selected†	2.070	1.179	3.636
Unhealthy lifestyle	Not selected †	7.808	3.444	17.700
Education Level Adults 20+	Less than 9th grade	2.404	1.440	4.013
	9-11th grade	1.598	0.924	2.764
	High school graduate/GED or equivalent	2.007	1.307	3.081
	Some college or AA degree	1.368	0.852	2.195
Race/Ethnicity	Other Hispanic	1.235	0.718	2.123
	Non-Hispanic White	3.087	1.941	4.908
	Non-Hispanic Black	3.505	2.201	5.582
	Non-Hispanic Asian	1.526	0.694	3.357
Family monthly poverty level category	≤ 1.30 vs. > 1.85†	1.312	0.885	1.944
	1.30 ≤ 1.85† vs. > 1.85†	2.054	1.292	3.266

Note: † indicates reference category. Odds ratios for the dependent variable: ≥ *1 CVD condition*. Reference categories: education level = college graduate or above; race/ethnicity = Mexican American.

Table 5
Logistic Regression Analysis With Adjustment for Sex.

Units of Change		Odds Ratio	95% Confidence Interval	
			Lower	Upper
Age in years at screening	10	0.429	0.384	0.478
Total moderate PA (mins/day)	90	1.509	1.121	2.032
≥30 mins/day, mod intensity	Not selected †	0.402	0.161	1.001
Food Types	red meat vs. processed meat†	2.950	1.136	7.662

Note: † indicates reference category. Odds ratios for the dependent variable: ≥ *1 CVD condition*. Gender was fixed at female.

80%] for the number of characteristic factors classifying CVD (Fig. 2; Table 7). Optimized for sensitivity (73.4%) and specificity (71%), any combination of 3 factors predicted CVD status.

Discussion

There were two main objectives of this study. The first objective was to determine the

association between ASFs and CVD in a population-representative sample of non-institutionalized U.S. civilians controlling for confounding factors. The second objective was analyzing the relationship

Table 6a
Component Matrix.

	Component		
	1	2	3
Dental Visits ≤ 2 years	0.645	−0.179	0.346
Normal BMI	−0.065	0.843	0.226
Non Smoker	0.802	−0.106	0.058
<60 yrs. old	−0.652	−0.490	0.136
Fiber >25 g/day	−0.035	0.334	−0.599
Min mod PA to be considered active	−0.260	0.201	0.718

Note: Extraction method: principal component analysis; only cases for ≥*1 CVD condition* are used in the analysis phase. Table values refer to the correlation coefficient between each CVD factor and each component.

between sample characteristics, health behaviors, and CVD history. The analysis showed that age, race, education, smoking history, and income was associated with CVD history, which aligns with previous studies and well-established health determinants [11,17,25,40,42,44].

Quartiles of ASF were not associated with CVD history. However, in contrast to previous studies, red meat consumption was associated with CVD history only when adjusted for sex [11,14,16,17,22–24]. Given that the largest proportion of the sample was in the red meat category, it is plausible that this category would also contain the highest proportion of those with CVD. Furthermore, characteristic profiles of those selected to the unhealthy category and the red meat category were similar. The analysis also showed that an unhealthy lifestyle was associated with an 8-fold increase in odds for CVD history and that 3 or more factors predicted CVD history with moderately high sensitivity, albeit relatively low specificity.

Remarkably, when adjustments for sex were made, odds for CVD history increased for each 90-min increase in moderate PA, which suggests implementation of secondary prevention efforts. These changes in odds with adjustment may be explained by marked differences in the CVD profiles between males and females [41]. Males had lower mean years on medication and mean male age at first CVD diagnosis was 55.1 years compared to the cutoff of 45 years associated with increased CVD risk [47]. In contrast, the mean age at first CVD diagnosis in females was 53.8 years compared to the risk cutoff of 55 years. This speaks to possible latent CVD or advanced disease progression before treatment in males.

There are some tangential observations worth noting. First, some variable estimates associated with CVD history or unhealthy lifestyle were paradoxical. For example, lipid concentrations, moderate physical activity, and total nutrient intakes were improved in the CVD group. This is likely due to a high proportion of CVD patients reporting taking prescription medication related to cardiovascular or metabolic conditions (84.7%) and getting recommendations from their doctor to change their lifestyle (64.4%), in addition to possible self-motivated lifestyle changes. However, despite lifestyle changes and medication, markers associated with increased CVD risk, including higher TC:HDL, higher triglycerides, and lower HDL-C persisted despite lower TC, lower LDL-C, and lower LDL:APOB.

Also notable, current smoker status was not associated with CVD history, yet, former smoker status was associated with an over 3-fold increase in odds for CVD history. Sinha et al. reported residual confounding evidenced by higher CVD mortality risk for higher white meat intake in former smokers but lower risk for processed meat intake in never smokers [25]. Coincidentally, the proportion of those with CVD was lowest in the processed meat category, likely due to common CVD recommendations including avoiding processed meat. Q2 of ASF:TCAL had the highest proportion of those with CVD history (7.4%). Comparative descriptive analysis of Q2 showed mean age was highest, lipid profiles were reflective of higher risk, physical activity was lowest, and smoking frequency was highest. Revealingly, the mean number of disease years was lower in the unhealthy group (7.94 yrs. vs. 10.76 yrs.)

Table 6b
Total Variance Explained.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	1.557	25.957	25.957	1.557	25.957	25.957	1.543
2	1.145	19.083	45.040	1.145	19.083	45.040	1.143
3	1.067	17.783	62.823	1.067	17.783	62.823	1.093
4	0.945	15.747	78.570				
5	0.717	11.945	90.515				
6	0.569	9.485	100.000				

Note: Only cases for ≥*1 CVD condition* were used in the analysis.

Table 6c
PCA Correlation Matrix.

	Min mod PA to be considered active	Normal BMI	< 60 yrs	Non- Smoker	Dental Visits ≤ 2 years	Fiber ≥25 g/day
Min mod PA to be considered active	1.000	0.098	0.110	−0.092	0.010	−0.022
Normal BMI	0.098	1.000	−0.158	−0.096	−0.057	0.014
< 60 yrs. old	0.110	−0.158	1.000	−0.315	−0.146	−0.058
Non-Smoker	−0.092	−0.096	−0.315	1.000	0.326	−0.036
Dental Visit ≤ 2 years	0.010	−0.057	−0.146	0.326	1.000	−0.051
Fiber ≥25 g/day	−0.022	0.014	−0.058	−0.036	−0.051	1.000

Note: Only cases for ≥*1 CVD condition* were included in the analysis. Table values refer to the correlation coefficient between each CVD factor.

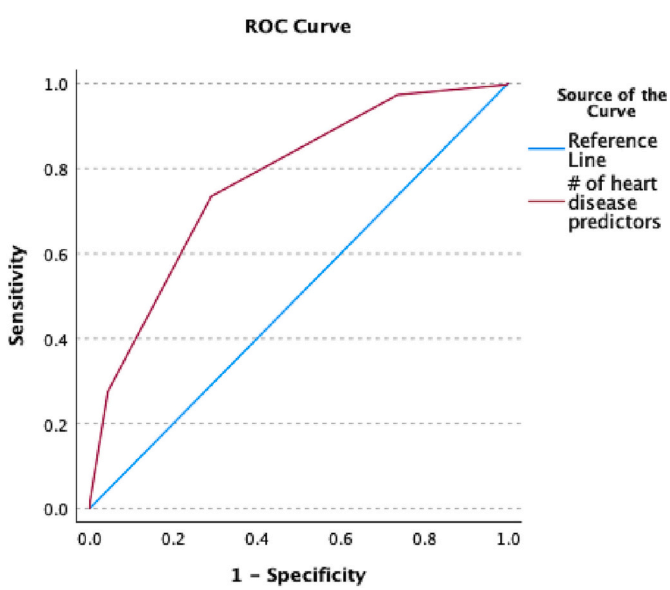

Fig. 2. ROC Curve of CVD Conditions By the Number of Predictors.

Table 7
Area Under the ROC Curve.

	Area	Std. Error	Asymptotic 95% Confidence Interval	
Unweighted n			Lower Bound	Upper Bound
305	0.772	0.013	0.746	0.798

Test Result Variable(s): # of CVD predictors.
Note: Table shows AUC for the number of CVD factors and selection to the ≥*1 CVD condition* group. CVD predictors included BMI ≥30 kg/m**2, ≤ 30 min moderate physical activity, smoker, fiber intake <25 g, dental visit >2 years ago, and age above 60 years.

despite higher mean age and more years on medication than the healthy group (4.7 yrs. vs. 5.8 yrs.). This may be due to better disease management via earlier diagnosis, compliance with doctor-recommended changes, or otherwise beneficial lifestyle changes for those in the healthy group.

Supporting our claim regarding methodological issues in dietary studies, Vega-López and Lichtenstein (2005) noted the inconsistencies between the findings of interventional and observational studies comparing the effects of plant-based protein and animal-based protein on plasma lipids and lipoprotein markers [35]. The authors concluded that based on interventional studies, plant-based protein offered no additional benefit on blood markers. In light of this, the protective effect of plant-based protein reported in observational studies was not understood. Some observational studies report changes in disease risk with isocaloric substitutions of one nutrient type for another. This statistical procedure is problematic because it only considers nutrient values, decoupling lifestyle characteristics from risk estimates.

Some evidence suggests saturated fatty acid intake is cardioprotective. In a randomized crossover intervention in overweight post-menopausal women, isocaloric substitutions of carbohydrates with cheese and meat were associated with higher HDL-C and lower atherogenic blood lipid concentrations [37]. In Japan, a proposed cause for decreased cerebrovascular disease is the gradual increase in ASFs intake resulting in higher saturated fat intake [38]. Nilsson et al. (2012) observed reduced CVD mortality in diabetic men on a low carbohydrate high protein diet composed of mostly animal protein and animal fats compared to low carbohydrate diets with higher plant protein after adjustment for BMI, smoking, education, sedentary lifestyle, alcohol intake, total energy, and saturated fat [36]. However, the results were not similar in women with diabetes.

Interestingly, the current study found that males and females with CVD had similar macronutrient intake ratios despite females having higher TC and LDL-C but higher HDL-C and lower TC:HDL than males. Men had suboptimal HDL-C and triglycerides, which may be due to higher alcohol consumption [48]. Supporting low-carbohydrate interventional studies, the healthy group consumed relatively more protein (+3%) and fewer carbohydrates despite a similar percentage of calories from fat (~36%). Levine et al. (2014) reported lower mortality in respondents over age 65 that consumed relatively more protein, which may indicate a protective effect [10].

Clinical relevance

The American College of Sports Medicine, American College of Cardiology, and the American Heart Association have made commendable efforts to develop evidence-based practice guidelines for reducing CVD risk. These efforts have brought much-needed attention to the vital role of lifestyle choices in achieving this aim [2,50]. Given the profound effect of health behaviors on CVD history, clinical prevention efforts should continue to focus on PA, weight management, smoking cessation, and preventive care. In the current study, over 64% of CVD patients were counseled to make lifestyle changes by their doctor relating to PA and diet. Despite this, those with long-standing CVD were obese with suboptimal lipid profiles. Studies on the efficacy of lifestyle counseling by clinicians cite several barriers including a lack of PA counseling training, time barriers, and lack of reimbursement [51]. Likewise, patient barriers such as lack of time, resources, and social support hinder health behavior adherence. Therefore, counseling strategies should be customized to individual characteristics and specific milieu. However, socioeconomic and demographic factors such as income, sex, and education have a differential effect on health behavior adherence which may be more challenging to address at the interpersonal level of influence [52].

Limitations

There are several limitations to this study. First, due to the observational design of this study, causal inferences about the relationship between ASFs and CVD could not be made. The most important limitation is using data from a 24-h dietary recall as a proxy for long-term dietary habits. Since only nutrient intake values from one day were used, it is uncertain whether respondents' habitual dietary intake was adequately reflected. However, associations between meat type and CVD were similar to previous studies. Next, the estimated population proportion of those with CVD history should not be taken as a true estimate of CVD prevalence because physician diagnoses were self-reported.

The current analysis is different from the many prospective analyses mentioned in the literature review due to our retrospective analysis of NHANES data. Conventionally, prospective analyses are used to prevent reverse causality attribution. However, this study demonstrated an inexorable link between unhealthy lifestyle and CVD history. Although it could be argued that consumption of certain food types for the years preceding CVD diagnosis may have been causal, it would be impossible to isolate the effects of individual nutrients/foods on CVD. Moreover, it would be inappropriate to disregard other health factors, given their strong associations with CVD. Another major limitation of this study is the lack of genetic predisposing factors, which substantially raise risk [49]. Future research should focus on the interactions of predisposing genetic, sex, demographic, and behavioral risk factors to differentiate CVD risk in the population.

Conclusion

It appears red meat consumption but not overall ASF consumption is a plausible surrogate for an unhealthy lifestyle and that certain risk factors remain prevalent in those with CVD, despite evidence of lifestyle change. More research is needed on the dietary, genetic, sex, and socioeconomic determinants of CVD and on training for healthcare professionals related to health behavior counseling.

Author contribution

Adam Eckart is the primary author responsible for manuscript write up and study conceptualization. Amir Bhochhibhoya provided statistical and study design support. Pragya Sharma Ghimire and James Stavitz provided content and copyediting support. Kathleen Mathieson provided copyediting and statistical support.

Funding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Institutional review board

This research was protocol was deemed an exempt human research study per Code of Federal Regulations 45 CFR §46.104(d) [4] by the A.T. Still University Institutional Review Board (protocol number: 2020–099).

Declaration of Competing Interest

None.

Appendix A. Variables included in analysis

Variable Type	Variable Label
Demographics	Education level - Adults 20+
	Family monthly poverty level category
	Ratio of family income to poverty
	Gender
	Age in years at screening
	Race/Hispanic origin w/ NH Asian
Body Measures	Body Mass Index (kg/m**2)
	Obese BMI*
Animal source foods	USDA food code
	Carbohydrate (gm)
	Dietary fiber (gm)
	Energy (kcal)
	Protein (gm)
	Total sugars (gm)
	Total fat (gm)
	Total kcals from animal foods*
	Total grams from animal foods*
	Ratio of total kcals from ASF to total daily kcals*
	Quartile of ASF kcals to total daily kcals*
	Kcals per gram of ASF*
	Food type groups*
Blood Lipids	Direct HDL-Cholesterol (mg/dl)
	LDL-cholesterol (mg/dl)
	Apolipoprotein (B) (mg/dl)

(continued on next page)

(*continued*)

Variable Type	Variable Label
	Total Cholesterol (mg/dl)
	Triglyceride (mg/dl)
	LDL/Apo b ratio*
	Total cholesterol to HDL ratio*
Health Behaviors	≥ 25 g/day fiber*
	Dr. recommended lifestyle change*
	Avg # alcoholic drinks/day - past 12 mos
	Minutes vigorous-intensity work
	Minutes moderate-intensity work
	Minutes walk/bicycle for transportation
	Minutes vigorous recreational activities
	Minutes moderate recreational activities
	Total moderate PA*
	Total vigorous PA*
	Min moderate PA to be considered active*
	Min vigorous PA to be considered active*
	Minimum of moderate PA to be considered active*
	When did you last visit a dentist
	Dental visit within the last 2 years
	Do you now smoke cigarettes
	Avg # cigarettes/day during past 30 days
	Selected for healthy lifestyle (BMI ≥30 kg/m**2, ≤ 30 min moderate physical activity, smoker, fiber intake ≤25 g, dental visit >2 years ago)*
Medical History	Ever told had congestive heart failure
	Ever told you had coronary heart disease
	Ever told you had angina/angina pectoris
	Ever told you had heart attack
	Ever told you had a stroke
	Age when told you had heart failure
	Age when told had coronary heart disease
	Age when told you had angina pectoris
	Age when told you had heart attack
	Age when told you had a stroke
	Any Rx for metabolic diseases*
	Years on medication*
	Disease years*
	Age when diagnosed with first CVD condition*
	Selected for heart disease factors (BMI ≥30 kg/m**2, ≤30 min moderate physical activity, smoker, fiber intake ≤25 g, dental visit >2 years ago, and age above 60 years.)*
	# of heart disease factors*

Note: *indicates ad-hoc variable.

Appendix B. Food categories & groups

WWEIA Food Category	Food Description	Food Group
2002	Beef, excludes ground	Red meat
2004	Ground beef	
2006	Pork	
2008	Lamb, goat, game	
2010	Liver and organ meats	
2602	Cold cuts and cured meats	Processed meat
2604	Bacon	
2606	Frankfurters	
2608	Sausages	
2202	Chicken, whole pieces	White meat
2204	Chicken patties, nuggets and tenders	
2206	Turkey, duck, other poultry	
2402	Fish	
2404	Shellfish	

Appendix C. ICD-10 codes selected/present associated with prescription medications

Prevent blood clots
Hypothyroidism, unspecified
Autoimmune thyroiditis
Disorder of thyroid, unspecified
Type 1 diabetes mellitus
Type 2 diabetes mellitus
Type 2 diabetes mellitus with kidney complications
Type 2 diabetes mellitus with neurological complications
Pure hypercholesterolemia

(*continued on next page*)

(*continued*)

Prevent high cholesterol
Pure hyperglyceridemia
Essential (primary) hypertension
Prevent hypertension
Angina pectoris, unspecified
ST elevation (STEMI) and non-ST elevation (NSTEMI) myocardial infarction
Prevent heart attack/myocardial infarction
Pulmonary embolism
Unspecified atrial fibrillation and atrial flutter
Cardiac arrhythmia, unspecified
Heart failure, unspecified
Heart disease, unspecified
Prevent heart disease
Cerebral infarction
Prevent stroke
Atherosclerosis
Phlebitis and thrombophlebitis of lower extremities, unspecified
Unspecified disorder of circulatory system
Abnormalities of heart beat
Chest pain, unspecified
Other specified symptoms and signs involving the circulatory and respiratory systems
Elevated blood glucose level
Presence of cardiac and vascular implants and grafts
Prevent diabetic kidney disease
Prevent diabetes
Hyperglycemia, unspecified
Long term (current) use of antithrombotics/antiplatelets

Note: Table includes ICD-10 codes present in the total dataset of those that were preselected.

Appendix D. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gloepi.2023.100112.

References

[1] Centers for Disease Control and Prevention. Prevent heart disease. https://www.cdc.gov/heartdisease/prevention.htm (accessed 01 March 2020).

[2] Eckel RH, Jakicic JM, Ard JD, de Jesus JM, Miller NH, Hubbard, et al. 2013 AHA/ACC guideline on lifestyle management to reduce cardiovascular risk: A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol 2014;63(25 Part B):2960–84. https://doi.org/10.1161/01.cir.0000437740.48606.d1.

[3] Evert AB, Dennison M, Gardner CD, Garvey WT, Lau KHK, MacLeod J, et al. Nutrition therapy for adults with diabetes or prediabetes: a consensus report. Diabetes Care 2019;42(5):731–54. https://doi.org/10.2337/dci19-0014.

[4] Hariton E, Locascio JJ. Randomised controlled trials - the gold standard for effectiveness research: study design: randomised controlled trials. BJOG 2018;125(13):1716. https://doi.org/10.1111/1471-0528.15199.

[5] Austin PC, Stuart EA. Moving towards best practice when using inverse probability of treatment weighting (IPTW) using the propensity score to estimate causal treatment effects in observational studies. Stat Med 2015;34(28):3661–79. https://doi.org/10.1002/sim.6607.

[6] Bero L, Chartres N, Diong J, Fabbri A, Ghersi D, Lam J, et al. The risk of bias in observational studies of exposures (ROBINS-E) tool: concerns arising from application to observational studies of exposures. Syst Rev 2018;7(1):242. https://doi.org/10.1186/s13643-018-0915-2.

[7] Hammer GP, du Prel JB, Blettner M. Avoiding bias in observational studies: part 8 in a series of articles on evaluation of scientific publications. Dtsch Arztebl Int 2009;106(41):664–8. https://doi.org/10.3238/arztebl.2009.0664.

[8] Shrank WH, Patrick AR, Brookhart MA. Healthy user and related biases in observational studies of preventive interventions: a primer for physicians. J Gen Intern Med 2011;26(5):546–50. https://doi.org/10.1007/s11606-010-1609-1.

[9] Cramer H, Kessler CS, Sundberg T, Leach MJ, Schumann D, Adams J, et al. Characteristics of Americans choosing vegetarian and vegan diets for health reasons. J Nutr Educ Behav 2017;49(7):561–7. https://doi.org/10.1016/j.jneb.2017.04.011.

[10] Levine ME, Suarez JA, Brandhorst S, Balasubramanian P, Cheng CW, Madia F, et al. Low protein intake is associated with a major reduction in IGF-1, cancer, and overall mortality in the 65 and younger but not older population. Cell Metab 2014;19(3):407–17. https://doi.org/10.1016/j.cmet.2014.02.006.

[11] Song M, Fung TT, Hu FB, Willett WC, Longo VD, Chan AT, et al. (2016). Association of animal and plant protein intake with all-cause and cause-specific mortality. JAMA Intern Med 2016;176(10):1453–63. https://doi.org/10.1001/jamainternmed.2016.4182.

[12] Kelemen LE, Kushi LH, Jacobs Jr DR, Cerhan JR. Associations of dietary protein with disease and mortality in a prospective study of postmenopausal women. Am J Epidemiol 2005;161(3):239–49. https://doi.org/10.1093/aje/kwi038.

[13] Appel LJ, Sacks FM, Carey VJ, Obarzanek E, Swain JF, Miller ER, et al. Effects of protein, monounsaturated fat, and carbohydrate intake on blood pressure and serum lipids: results of the OmniHeart randomized trial. JAMA. 2005;294(19):2455–64. https://doi.org/10.1001/jama.294.19.2455.

[14] Seidelmann SB, Claggett B, Cheng S, Henglin M, Shah A, Steffen LM, et al. Dietary carbohydrate intake and mortality: a prospective cohort study and meta-analysis. Lancet Public Health 2018;3(9):e419. https://doi.org/10.1016/S2468-2667(18)30135-X.

[15] Streppel MT, Ocké MC, Boshuizen HC, Kok FJ, Kromhout D. Dietary fiber intake in relation to coronary heart disease and all-cause mortality over 40 y: the Zutphen Study. Am J Clin Nutr 2008;88(4):1119–25. https://doi.org/10.1093/ajcn/88.4.1119.

[16] Kim H, Caulfield LE, Garcia-Larsen V, Steffen LM, Coresh J, Rebholz CM. Plant-based diets are associated with a lower risk of incident cardiovascular disease, cardiovascular disease mortality, and all-cause mortality in a general population of middle-aged adults. JAMA. 2019;8(16):e012865. https://doi.org/10.1161/JAHA.119.012865.

[17] Tong TY, Appleby PN, Bradbury KE, Perez-Cornago A, Travis RC, Clarke R, et al. Risks of ischemic heart disease and stroke in meat eaters, fish eaters, and vegetarians over 18 years of follow-up: results from the prospective EPIC-Oxford study. Br Med J 2019;366:l4897. https://doi.org/10.1136/bmj.l4897.

[18] Lippi G, Mattiuzzi C, Cervellin G. Meat consumption and cancer risk: a critical review of published meta-analyses. Crit Rev Oncol Hematol 2016;97:1–14. https://doi.org/10.1016/j.critrevonc.2015.11.008.

[19] Meng Y, Bai H, Wang S, Li Z, Wang Q, Chen L. Efficacy of low carbohydrate diet for type 2 diabetes mellitus management: a systematic review and meta-analysis of randomized controlled trials. Diabetes Res Clin Pract 2017;131:124–31. https://doi.org/10.1016/j.diabres.2017.07.006.

[20] Santos FL, Esteves SS, da Costa Pereira A, Yancy Jr WS, Nunes JP. Systematic review and meta-analysis of clinical trials of the effects of low carbohydrate diets on cardiovascular risk factors. Obes Rev 2012;13(11):1048–66. https://doi.org/10.1111/j.1467-789X.2012.01021.x.

[21] Johnston BC, Zeraatkar D, Han MA, Vernooij RW, Valli C, El Dib R, et al. Unprocessed red meat and processed meat consumption: dietary guideline recommendations from the Nutritional Recommendations (NutriRECS) Consortium. Ann Intern Med 2019;171(10):756–64. https://doi.org/10.7326/M19-1621.

[22] Budhathoki S, Sawada N, Iwasaki M, Yamaji T, Goto A, Kotemori A, et al. Association of animal and plant protein intake with all-cause and cause-specific mortality in a Japanese cohort. JAMA Intern Med 2019;179(11):1509–18. https://doi.org/10.1001/jamainternmed.2806.

[23] Fung TT, van Dam RM, Hankinson SE, Stampfer M, Willett WC, Hu FB. Low-carbohydrate diets and all-cause and cause-specific mortality: two cohort studies. Ann Intern Med 2010;153(5):289–98. https://doi.org/10.1059/0003-4819-153-5-201009070-00003.

[24] Lagiou P, Sandin S, Weiderpass EV, Lagiou A, Mucci LA, Trichopoulos D, et al. Low carbohydrate-high protein diet and mortality in a cohort of Swedish women. J Intern Med 2007;261(4):366–74. https://doi.org/10.1111/j.1365-2796.2007.01774.x.

[25] Sinha R, Cross AJ, Graubard BI, Leitzmann MF, Schatzkin A. (2009). Meat intake and mortality: a prospective study of over half a million people. Arch Intern Med 2009;169(6):562–71. https://doi.org/10.1001/archinternmed.2009.6.

[26] Leventhal AM, Huh J, Dunton GF. (2014). Clustering of modifiable biobehavioral risk factors for chronic disease in US adults: a latent class analysis. Perspect Public Health 2014;134(6):331–8. https://doi.org/10.1177/1757913913495780.

[27] Woolhandler S, Himmelstein DU. The relationship of health insurance and mortality: is lack of insurance deadly? Ann Intern Med 2017;167(6):424–31. https://doi.org/10.7326/M17-1403.

[28] Shea S, Lima J, Diez-Roux A, Jorgensen NW, McClelland RL. Socioeconomic status and poor health outcome at 10 years of follow-up in the multi-ethnic study of atherosclerosis. PloS One 2016;11(11):e0165651. https://doi.org/10.1371/journal.pone.0165651.

[29] Gundersen C, Ziliak JP. Food insecurity and health outcomes. Health Aff 2015;34 (11):1830–9. https://doi.org/10.1377/hlthaff.2015.0645.

[30] Hung HC, Joshipura KJ, Colditz G, Manson JE, Rimm EB, Speizer FE, et al. The association between tooth loss and coronary heart disease in men and women. J Public Health Dent 2004;64(4):209–15. https://doi.org/10.1111/j.1752-7325.2004.tb02755.x.

[31] Selivanova A, Cramm JM. The relationship between healthy behaviors and health outcomes among older adults in Russia. BMC Public Health 2014;14(1):1183. https://doi.org/10.1186/1471-2458-14-1183.

[33] Centers for Disease Control and Prevention. National Health and Nutrition Examination Survey: 2015–2016 data documentation, codebook, and frequencies. https://wwwn.cdc.gov/Nchs/Nhanes/2015-2016/DR1IFF_I.htm (accessed 01 March 2020).

[34] Ahuja, J. K. A., Montville, J. B., Omolewa-Tomobi, G., Heendeniya, K. Y., Martin, C. L., Steinfeldt, L. C. et al. USDA Food and Nutrient Database for Dietary Studies, 5.0–Documentation and user guide. 2012. US Department of Agriculture, Agricultural Research Service, Food Surveys Research Group: Beltsville, MD, USA. (accessed 01 March 2020).

[35] Vega-López S, Lichtenstein AH. Dietary protein type and cardiovascular disease risk factors. Prev Cardiol 2005;8(1):31–40. https://doi.org/10.1111/j.1520-037X.2005.3923.x.

[36] Nilsson LM, Winkvist A, Eliasson M, Jansson JH, Hallmans G, Johansson I, et al. Low-carbohydrate, high-protein score and mortality in a northern Swedish population-based cohort. Eur J Clin Nutr 2012;66(6):694. https://doi.org/10.1038/ejcn.2012.9.

[37] Thorning TK, Raziani F, Bendsen NT, Astrup A, Tholstrup T, Raben A. Diets with high-fat cheese, high-fat meat, or carbohydrate on cardiovascular risk markers in overweight postmenopausal women: a randomized crossover trial. Am J Clin Nutr 2015;102(3):573–81. https://doi.org/10.3945/ajcn.115.109116.

[38] Tsugane S. Why has Japan become the world's most long-lived country: insights from a food and nutrition perspective. Eur J Clin Nutr 2021;75(6):921–8. https://doi.org/10.1038/s41430-020-0677-5.

[40] Schultz WM, Kelli HM, Lisko JC, Varghese T, Shen J, Sandesara P, et al. Socioeconomic status and cardiovascular outcomes: challenges and interventions. Circulation. 2018;137(20):2166–78. https://doi.org/10.1161/CIRCULATIONAHA.117.029652.

[41] Gao Z, Chen Z, Sun A, Deng X. Gender differences in cardiovascular disease. Med Novel Technol Dev 2019;4:100025. https://doi.org/10.1016/j.medntd.2019.100025.

[42] Trohel G, Bertaud-Gounot V, Soler M, Chauvin P, Grimaud O. Socio-economic determinants of the need for dental care in adults. PloS One 2016;11(7):e0158842. https://doi.org/10.1371/journal.pone.0158842.

[43] Yokoyama Y, Barnard ND, Levin SM, Watanabe M. Vegetarian diets and glycemic control in diabetes: a systematic review and meta-analysis. Cardiovasc Diagnosis Therapy 2014;4(5):373–82. https://doi.org/10.3978/j.issn.2223-3652.2014.10.04.

[44] North BJ, Sinclair DA. The intersection between aging and cardiovascular disease. Circ Res 2012;110(8):1097–108. https://doi.org/10.1161/CIRCRESAHA.111.246876.

[45] Chen TC, Clark J, Riddles MK, Mohadjer LK, Fakhouri TH. National Health and Nutrition Examination Survey, 2015–2018: sample design and estimation procedures. https://stacks.cdc.gov/view/cdc/88305.

[46] Silbernagel G, Scharnagl H, Saely CH, Reinthaler M, Rief M, Kleber ME, et al. The LDL apolipoprotein B-to-LDL cholesterol ratio: association with cardiovascular mortality and a biomarker of small, dense LDLs. Biomedicines. 2022 Jun 2;10(6):1302.

[47] Kannel WB, Dawber TR, Kagan A, Revotskie N, Stokes III JO. Factors of risk in the development of coronary heart disease—six-year follow-up experience: the Framingham Study. Ann Intern Med 1961 Jul 1;55(1):33–50.

[48] Mudrakova E, Poledne R, Kovář J. Postprandial triglyceridemia after single dose of alcohol in healthy young men. Nutr Metab Cardiovasc Dis 2013 Mar 1;23(3):183–8.

[49] Willer CJ, Schmidt EM, Sengupta S, Peloso GM, Gustafsson S, Kanoni S, et al. Discovery and refinement of loci associated with lipid levels. Nat Genet 2013 Nov;45(11):1274.

[50] Sallis R, Franklin B, Joy L, Ross R, Sabgir D, Stone J. Strategies for promoting physical activity in clinical practice. Prog Cardiovasc Dis 2015 Jan 1;57(4):375–86.

[51] Lobelo F, de Quevedo IG. The evidence in support of physicians and health care providers as physical activity role models. Am J Lifestyle Med 2016 Jan;10(1):36–52.

[52] Trost SG, Owen N, Bauman AE, Sallis JF, Brown W. Correlates of adults' participation in physical activity: review and update. Med Sci Sports Exerc 2002 Dec 1;34(12):1996–2001.