fortune Journals

Research Article

JOURNAL OF FOOD SCIENCE AND NUTRITION RESEARCH

ISSN: 2642-1100

Intake of pork is associated with higher nutrient intake and adequacy in race/ethnic population subgroups of adults in the United States

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Abstract

Pork is a rich source of high-quality protein and select micronutrients. The US population is ethnically diverse and cultural factors are known to affect dietary intake. Our objective was to evaluate the cross-sectional association of pork consumption on nutrient intake and adequacy among adults of different ethnicities: Hispanic Whites (NHW), non-Hispanic Blacks (NHB), Hispanics (HSP) and non-Hispanic Asians (NHA) using 24-hour dietary recall data from National Health and Nutrition Examination Survey (NHANES) 2011-2018. Usual intake of nutrients from foods were determined using the NCI method and the percentage of population with intakes below the Estimated Average Requirement (EAR) or above the Adequate Intake (AI) for pork consumers and non-consumers were estimated. About 61% NHW, 62% NHB, 57% of HSP, and 50% NHA adults were pork consumers with mean intakes of 62, 57, 58 and 68 g pork/day, respectively. Pork consumers of different ethnicities had higher intakes ($P<0.05$) of phosphorus, selenium, zinc, thiamine, riboflavin, niacin, potassium and choline; and lower proportion of consumers below EAR or higher proportion of consumers above AI for copper, iron, zinc, thiamine, riboflavin, vitamin B_{12} and choline than non-consumers. A comparison between pork consumers of different ethnicities indicated that while HSP consumers had highest intakes for many nutrients, the highest proportions of NHA consumers had lowest proportion below EAR or highest proportion above AI for most nutrients than pork consumers of other ethnicities. These results suggest that pork may play a role in decreasing the incidence of under nutrition.

Keywords: National Health and Nutrition Examination Survey; NHANES; non-Hispanic White; non-Hispanic Black; Hispanics; non-Hispanic Asian; vitamins; minerals; usual intakes; nutrient adequacy.

Introduction

The United States has an increasingly ethnically diverse population. According to a recent analysis of 2010 and 2020 US Census Bureau Report, the diversity index has increased from 54.9% in 2010 to 61.1% in 2020 with 57.8% non-Hispanic Whites (NHW), 18.7% Hispanics (HSP), 12.1% non-Hispanic Blacks (NHB) and 11.4% other ethnic groups [1]. Several studies have reported a large variation in dietary patterns/dietary behaviors, adherence with dietary recommendations and intake of micronutrients across race/ethnic groups [2-7]. A recent analysis of National Health and Nutrition Examination Survey (NHANES) 2011-2018 data reported that non-Hispanic Asians (NHA) consume the most fruits, vegetables and seafood and have the highest diet quality, HSP consume more meat and NHB consume the most

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Citation: Sanjiv Agarwal, Victor L. Fulgoni III. Intake of pork is associated with higher nutrient intake and adequacy in race/ethnic population subgroups of adults in the United States. Journal of Food Science and Nutrition Research. 8 (2025): 14-23.

Received: April 14, 2025
Accepted: April 21, 2025
Published: April 28, 2025

Agarwal and Fulgoni., J Food Sci Nutr Res 2025
DOI:10.26502/jfsnr.2642-110000172

poultry while NHW consume the most dairy [7,8]. As diet is etiologically linked to many health conditions, these diet-related differences in adults of various ethnic backgrounds also contribute to disparities in diet related chronic diseases [9,10]. To that end, the recently released Scientific Report of the 2025 Dietary Guidelines Advisory Committee [11] stressed the importance of health equity, which was defined as the "state in which everyone has a fair and just opportunity to attain their highest level of health". The committee further stated "… centering on health equity is to help HHS and USDA ensure that the resulting guidance in the Dietary Guidelines for Americans (Dietary Guidelines) is relevant to people of diverse racial, ethnic, socioeconomic, and cultural backgrounds, thereby increasing the potential of the guidance to meet nutrient needs, promote health, and reduce risk of chronic disease." [11].

Pork is one of the most widely consumed meats accounting for 36% all meats consumed in the world [12,13]. In the US, pork is the third most consumed meat and is about 25% of all meat intake with an average annual pork consumption of about 50 lbs/person [14,15]. Approximately 60% US adults are pork consumers with an intake of about 60 g/day [16]. Pork meat is a key source of high-quality protein, several micronutrients, is relatively affordable, and is mostly culturally acceptable. A 3 oz eq (85 g) serving of pork (pork, not further specified; FDC ID: 2341267) provides substantial amounts of iron (0.67 mg, 3.7% Daily Value (DV)), zinc (2.07 mg, 18.9% DV), selenium (38.1 µg, 69.2% DV), magnesium (22.1 mg; 5.3% DV), phosphorus (208 mg; 16.6% DV), potassium (342 mg, 7.3% DV), thiamin (0.514 mg, 42.8% DV), riboflavin (0.199 mg; 15.3% DV), niacin (6.42 mg, 40.1% DV), choline (68.9 mg, 12.5% DV), vitamin B_6 (0.523 mg; 30.8% DV), vitamin B_{12} (0.553 µg; 23.0% DV) and protein (23.0 g, 46% DV) for 163 kcal [17,18]. A few cross-sectional studies reported that intake of pork contributes significantly (more than 10%) to intakes of several nutrients, including protein, phosphorus, potassium, selenium, thiamine, riboflavin, niacin, vitamin B_6, and vitamin B_{12} [19-22]. In a dietary modeling study, we recently reported that removal of a serving of red meat including pork was associated with a substantial decrease in several important nutrients including protein, iron, phosphorus, potassium, zinc, selenium, thiamine, riboflavin, niacin, vitamin B_6, vitamin B_{12}, and choline in the USDA's Healthy Dietary Patterns [23]. In a recent analysis of NHANES 2011-2018, pork intake was associated with higher intakes and nutrition adequacies for several key micronutrients, including many under-consumed nutrients and nutrients of concern [16].

Pork intake is also affected by socioeconomic and cultural factors and NHB consumers tend to consume more pork while higher income consumers tend to consume less pork [15]. We hypothesize that intake of pork would be associated with improved nutrient intakes and nutrition adequacy in adults of different ethnicities. Therefore, the purpose of this study was to evaluate association of pork consumption with nutrient intake and the percentage of the population below the Estimated Average Requirement (EAR) or above the Adequate Intake (AL) among different race/ethnicity groups using NHANES 2011–2018 data.

Methods

We used data from NHANES, a large ongoing cross-sectional dietary survey of a nationally representative sample of the noninstitutionalized US population [24]. The NHANES data are collected and currently released by the National Center for Health Statistics (NCHS) of the Center for Disease Control and Prevention (CDC) every 2 years using a multi-stage probability sampling design. Data from four NHANES cycles (2011–2012, 2013-2014, 2015-2016 and 2017–2018) were combined for this analysis. Two 24-hour dietary recalls provided intake data from adults (age 19+ years) who self-identified as NHW (n=7,491), NHB (n=4,528), HSP (n=4,734) and NHA(n=2,282). Pregnant or lactating women, and those with incomplete dietary records or missing data were excluded from the analysis. All participants provided written informed consent, and the Research Ethics Review Board at the National Center for Health Statistics approved the survey protocol. The present study was exempt from additional approvals by Institutional Review Boards as this was a secondary data analysis which lacked personal identifiers. A detailed description of the survey design and the data collection procedures of NHANES are reported elsewhere [24].

Dietary intakes were estimated by using 24-hour recall dietary interviews using USDA's automated multiple-pass method (AMPM) [25]. As part of NHANES examination, detailed information on all foods and beverages consumed by participants in the previous 24-hour period (midnight to midnight) was collected by a trained dietary interviewer. The nutrient intakes from foods were determined using the Food and Nutrient Database for Dietary Studies (FNDDS) for each NHANES cycle [26]. The National Cancer Institute (NCI) method was used to estimate the usual intakes [27] and the distribution of usual intakes utilizing both 24-hour dietary recalls. The cut-point method was used to estimate percentage of the population below the EAR and above the AI for most nutrients except for iron, for which the probability method was used [28].

Pork contents of foods contained in NHANES survey foods were determined by using previously reported methods [16]. Briefly, the Food Patterns Equivalent Database (FPED) and Food Patterns Equivalents Ingredient Database (FPID) were combined with Food and Nutrition Database for Dietary Studies (FNDDS) food codes to quantify pork contents

Agarwal and Fulgoni., J Food Sci Nutr Res 2025
DOI:10.26502/jfsnr.2642-110000172

of all foods [26,29]. The food codes for pork items used as "ingredients" of the survey foods were identified, and proportion of pork was determined by recipe calculations: 100% if entirely pork and 50% or 33% if the description indicated 1 or 2 other types of meat in addition to pork. If a FPID value was missing from any FNDDS food code, the ingredient profile of that food code was replaced by using a food code from another NHANES cycle or another ingredient code with a similar description. Pork consumers were defined as adult NHANES participants who reported consuming any amount of pork products on either of the two days of dietary recall.

Data were analyzed with the use of SAS 9.4 (SAS Institute, Cary, NC, USA) after adjusting for the complex sampling design of NHANES, using appropriate survey weights, strata, and primary sampling units. Two-day dietary weights were used in all intake analyses. Data are presented as mean ± standard error; the z-statistic was used to assess differences in nutrient intakes, % below the EAR and % above the AI and significance was set at P<0.05.

Results

Demographics:

About 60.5% NHW, 61.6% NHB, 56.8% of HSP, and 49.8% NHA adults were pork consumers (Table 1). A greater percentage of pork consumers were male (NHW, HSP); older (NHW, NHB, NHA), obese (NHW), had an education below high school (NHW, NHB), sedentary (NHW); while a smaller percentage of pork consumers were obese (NHA), had an education above high school (NHA, NHB), vigorously active (NHW) and a never smoker (NHA, NHB) compared to their respective non-consumers (Table 1). There were no other differences in other demographic characteristics of consumers and non-consumers of different ethnicities.

Intake of pork:

Mean intake of pork on the first day of 24-hour (in-person) dietary recall among NHW, NHB, HSP and NHA adult consumers were 61.9 ± 1.7, 57.3 ± 2.3, 57.6 ± 1.8 and 68.3 ± 2.9 g (with the 75th percentile intake respectively being 83.9 ± 1.5, 74.9 ± 2.9, 79.6 ± 3.5, 86.1 ± 4.4 g), respectively.

Table 1: Demographics of adults aged 19+ years pork consumers and non-consumers by ethnicities.

	non-Hispanic Whites (NHW)		non-Hispanic Blacks (NHB)		Hispanics (HSP)		non-Hispanic Asians (NHA)	
	Non-consumers	Consumers	Non-consumers	Consumers	Non-consumers	Consumers	Non-consumers	Consumers
Sample n	2,957	4,534	1,738	2,790	2,044	2,690	1,145	1,137
Population N	6,07,69,071	8,86,96,752	1,01,39,123	1,62,89,458	1,47,73,995	2,00,97,699	64,72,031	63,36,999
Mean Age (years)	48.6 ± 0.5	51.0 ± 0.5**	43.9 ± 0.5	45.3 ± 0.5**	42.1 ± 0.6	41.0 ± 0.4	43.4 ± 0.7	45.9 ± 0.7**
Gender (% Male)	44.0 ± 1.3	53.3 ± 0.8**	45.5 ± 1.3	47.2 ± 1.0	45.8 ± 1.1	53.7 ± 1.0**	48.5 ± 1.7	47.6 ± 1.8
Obese (%)	33.2 ± 1.3	40.6 ± 1.0**	48.1 ± 1.7	48.0 ± 1.1	42.3 ± 1.5	45.6 ± 1.3	16.0 ± 1.3	11.7 ± 1.5*
Poverty Income Ratio								
< 1.35 (%)	18.2 ± 1.3	17.5 ± 1.1	37.4 ± 2.1	40.2 ± 2.1	40.8 ± 1.9	42.7 ± 1.8	21.9 ± 2.6	20.7 ± 2.5
1.35 ≤ 1.85 (%)	8.65 ± 0.82	8.57 ± 0.63	13.5 ± 1.3	12.0 ± 0.8	14.9 ± 1.5	13.9 ± 1.4	9.34 ± 1.74	8.21 ± 0.97
> 1.85 (%)	73.1 ± 1.7	73.9 ± 1.4	49.1 ± 2.3	47.8 ± 2.1	44.3 ± 2.3	43.5 ± 1.9	68.7 ± 2.9	71.1 ± 2.8
Education								
< High School (%)	28.8 ± 1.7	34.1 ± 1.6**	41.5 ± 1.8	46.7 ± 1.6*	60.3 ± 1.8	58.9 ± 1.8	25.0 ± 2.5	26.4 ± 2.5
High School (%)	33.1 ± 1.3	34.0 ± 1.0	37.3 ± 1.2	36.3 ± 1.2	26.2 ± 1.5	29.1 ± 1.5	18.7 ± 1.7	23.0 ± 1.9
> High School (%)	38.1 ± 1.6	31.9 ± 1.7**	21.2 ± 1.6	17.1 ± 1.2**	13.5 ± 1.1	12.0 ± 1.0	56.3 ± 3.1	50.6 ± 2.5
Physical Activity								
Sedentary (%)	18.1 ± 0.8	22.0 ± 1.0**	22.3 ± 1.2	25.0 ± 1.4	23.3 ± 1.3	23.9 ± 1.1	23.5 ± 1.5	21.2 ± 2.2
Moderate (%)	35.7 ± 1.3	37.2 ± 1.2	36.8 ± 1.6	34.8 ± 1.1	34.4 ± 1.5	31.1 ± 1.6	39.9 ± 1.8	37.1 ± 1.9
Vigorous (%)	46.2 ± 1.3	40.8 ± 1.3**	40.9 ± 1.6	40.2 ± 1.3	42.3 ± 1.6	45.0 ± 1.9	36.6 ± 2.2	41.7 ± 1.7
Never Smoker (%)	53.1 ± 1.1	49.2 ± 1.1**	60.3 ± 1.8	54.2 ± 1.3**	65.2 ± 1.8	61.9 ± 1.4	76.2 ± 1.7	75.2 ± 1.9

Two days 24-hour dietary recall data from NHANES 2011–2018. Pork consumers were those adults who consumed any amount of pork on either of the two days of dietary recalls, and non-consumers were those who did not. Data is presented as mean ± standard error. * and ** significantly different from non-consumers at P<0.05 and P<0.01, respectively.

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DOI:10.26502/jfsnr.2642-110000172

Mean per capita intakes on the first day of 24-hour (in-person) dietary recall were 25.6 ± 0.9, 25.1 ± 1.3, 24.3 ± 0.9, 25.8 ± 1.7 g pork for NHW, NHB, HSP and NHA adult population respectively.

Comparison of nutrient intakes among pork consumers and non-consumers:

There were significant differences in nutrient intake between adult pork consumers and non-consumers of different ethnicities (Table 2). Pork consumers of all ethnicities had higher intakes of phosphorus (6-16%), selenium (20-23%), zinc (9-17%), thiamine (17-22%), riboflavin (6-13%), niacin (11-15%), potassium (6-11%), sodium (19-24%) and choline (20-28%), than their respective non-consumers. Pork consumers also had higher intakes of iron (4-10%, except for NHA), vitamin B_6 (7-10%, except for NHW), and vitamin B_{12} (8-13%, except for NHW and NHB) than their respective non-consumers. Additionally, there were higher intakes of calcium (10%), copper (6-10%), magnesium (5-7%) and vitamin E (7-8%) among NHB and HSP pork consumers as compared to non-consumer counterparts, and of folate (8%) and vitamin D (9%) among HSP pork consumers as compared to their non-consumer counterparts. However, NHW pork consumers had lower intakes of vitamin C (-8%) as compared to non-consumers.

Comparison of % below the EAR or above the AI among pork consumers and non-consumers:

There were significant differences across race/ethnicity groups in the proportion of adult pork consumers and non-consumers meeting nutrient recommendations (Table 3). A

Table 2: Usual intakes of nutrients among adults aged 19+ years by pork consumption status and ethnicity.

	non-Hispanic Whites (NHW)		non-Hispanic Blacks (NHB)		Hispanics (HSP)		non-Hispanic Asians (NHA)	
	Non-consumers	Consumers	Non-consumers	Consumers	Non-consumers	Consumers	Non-consumers	Consumers
EAR Nutrients								
Calcium (mg)	986 ± 14	1017 ± 10	777 ± 18	855 ± 14**	949 ± 19	1040 ± 17**	817 ± 23	760 ± 21
Copper (mg)	1.26 ± 0.02	1.27 ± 0.01	1.08 ± 0.02	1.14 ± 0.02*	1.18 ± 0.02	1.30 ± 0.02**	1.4 ± 0.04	1.41 ± 0.02
Iron (mg)	14.4 ± 0.2	15.0 ± 0.1**	12.8 ± 0.3	13.9 ± 0.2**	14.4 ± 0.3	15.8 ± 0.3**	13.9 ± 0.4	14.0 ± 0.2
Magnesium (mg)	311 ± 4	310 ± 3	263 ± 4	275 ± 4*	304 ± 5	326 ± 4**	321 ± 7	317 ± 5
Phosphorus (mg)	1346 ± 17	1472 ± 11**	1153 ± 17	1333 ± 18**	1350 ± 22	1542 ± 20**	1236 ± 27	1304 ± 19*
Selenium (mcg)	102 ± 2	122 ± 1**	99.4 ± 1.5	122 ± 2**	109 ± 2	131 ± 2**	108 ± 2	130 ± 2**
Zinc (mg)	10.9 ± 0.1	11.9 ± 0.1**	9.4 ± 0.2	10.7 ± 0.2**	10.6 ± 0.2	12.4 ± 0.2**	9.66 ± 0.22	10.9 ± 0.1**
Vitamin A, RE (µg)	692 ± 17	668 ± 13	544 ± 19	543 ± 14	579 ± 19	581 ± 15	629 ± 22	615 ± 18
Thiamin (mg)	1.48 ± 0.02	1.74 ± 0.01**	1.31 ± 0.03	1.58 ± 0.02**	1.46 ± 0.03	1.78 ± 0.02**	1.49 ± 0.03	1.74 ± 0.03**
Riboflavin (mg)	2.19 ± 0.03	2.33 ± 0.02**	1.61 ± 0.03	1.82 ± 0.03**	1.94 ± 0.04	2.18 ± 0.04**	1.73 ± 0.04	1.86 ± 0.05*
Niacin (mg)	24.8 ± 0.4	27.3 ± 0.2**	23.2 ± 0.4	26.3 ± 0.3**	25.1 ± 0.5	28.6 ± 0.4**	22.7 ± 0.5	26.1 ± 0.5**
Folate, DFE (µg)	530 ± 10	533 ± 6	457 ± 13	478 ± 7	520 ± 12	562 ± 10**	556 ± 14	536 ± 12
Vitamin B_6 (mg)	2.12 ± 0.04	2.21 ± 0.03	1.88 ± 0.04	2.01 ± 0.03**	2.15 ± 0.06	2.36 ± 0.04**	1.96 ± 0.05	2.14 ± 0.05*
Vitamin B_{12} (µg)	5.06 ± 0.1	5.29 ± 0.09	4.30 ± 0.13	4.60 ± 0.10	4.72 ± 0.14	5.08 ± 0.11*	3.94 ± 0.14	4.46 ± 0.16*
Vitamin C (mg)	79.6 ± 2.4	72.9 ± 1.5*	82.7 ± 2.2	84.4 ± 2.5	86.0 ± 3.7	92.1 ± 2.8	91.6 ± 3.2	99.9 ± 2.9
Vitamin D (µg)	4.63 ± 0.13	4.74 ± 0.09	3.94 ± 0.15	3.91 ± 0.09	4.35 ± 0.15	4.74 ± 0.12*	4.81 ± 0.2	4.90 ± 0.24
Vitamin E, ATE (mg)	9.72 ± 0.21	9.37 ± 0.13	8.28 ± 0.19	8.93 ± 0.18*	8.35 ± 0.21	8.92 ± 0.2*	8.52 ± 0.3	8.49 ± 0.2
AI Nutrients								
Potassium (mg)	2624 ± 34	2792 ± 25**	2209 ± 29	2451 ± 31**	2536 ± 45	2818 ± 32**	2572 ± 55	2751 ± 39**
Sodium (mg)	3168 ± 34	3783 ± 31**	3002 ± 46	3711 ± 45**	3205 ± 46	3900 ± 51**	3298 ± 64	4105 ± 94**
Choline (mg)	300 ± 4	359 ± 4**	273 ± 5	349 ± 5**	318 ± 6	383 ± 5**	291 ± 7	362 ± 7**

Two days 24-hour dietary recall data from NHANES 2011–2018. Pork consumers were those adults who consumed any amount of pork on either of the two days of dietary recalls, and non-consumers were those who did not. Gender combined data presented as mean ± standard error; * and ** significantly different from non-consumers at P<0.05 and P<0.01, respectively; AI, Adequate Intake; ATE, alpha tocopherol equivalents; EAR, Estimated Average Requirement; DFE, dietary folate equivalents; RE, retinol activity equivalents.

Agarwal and Fulgoni., J Food Sci Nutr Res 2025
DOI:10.26502/jfsnr.2642-110000172

smaller proportion of adult pork consumers of all ethnicities had intakes below the EAR for copper (3-6% units), iron (3-5% units), zinc (9-23% units), riboflavin (2-9% units) and vitamin B_{12} (4-12% units), and a higher proportion had intakes above the AI for choline (5-8% units), than their respective non-consumers. A smaller proportion of pork consumers of different ethnicities also had intakes below the EAR for calcium (5-11% units, except for NHA), thiamine (9-18% units except for NHA), folate (4-7% units except for NHW and NHB) and vitamin B_6 (6-9% units, except for NHB), and a higher proportion had intakes above the AI for potassium (7-9% units, except for NHW), compared to their respective non-consumers. However, 2-4% units more NHW, NHB and NHA consumers of pork had intakes below the EAR for vitamin D and 1-2% units more NHW, NHB and HSP consumers exceeded the AI for sodium compared to their respective non-consumers. Additionally, a larger proportion of NHW consumers of pork had intakes below the EAR for vitamin C (4% units) and E (6% units) than their non-consumers.

Comparison of nutrient intakes among pork consumers of different ethnicities:

There were significant differences in nutrient intakes among pork consumers of different ethnicities (Table 4). Compared to consumers of other ethnicities, HSP

Table 3: Percentage of adults aged 19+ years meeting nutrient recommendations by pork consumption status and ethnicity.

	non-Hispanic Whites (NHW)		non-Hispanic Blacks (NHB)		Hispanics (HSP)		non-Hispanic Asians (NHA)	
	Non-consumers	Consumers	Non-consumers	Consumers	Non-consumers	Consumers	Non-consumers	Consumers
	% population below Estimated Average Requirement (EAR)							
Calcium	43.9 ± 1.5	38.9 ± 1.1**	65.1 ± 2.5	53.7 ± 1.7**	42.1 ± 2.2	33.3 ± 1.5**	59.4 ± 2.9	65.3 ± 3.0
Copper	10.3 ± 0.9	4.70 ± 0.59**	17.0 ± 2.0	11.4 ± 1.0*	10.1 ± 1.3	5.43 ± 0.89**	4.20 ± 1.11	1.24 ± 0.65*
Iron	7.01 ± 0.62	3.55 ± 0.27**	10.2 ± 1.0	5.25 ± 0.51**	7.60 ± 0.78	4.82 ± 0.52**	7.82 ± 0.93	4.41 ± 0.48**
Magnesium	50.2 ± 1.6	53.0 ± 1.3	68.3 ± 1.6	66.2 ± 1.6	52.3 ± 2.3	47.1 ± 1.7	47.2 ± 2.6	46.4 ± 2.3
Phosphorus	1.48 ± 0.36	<1.00	3.05 ± 1.16	<1.00	1.47 ± 0.44	<1.00	1.44 ± 0.56	<1.00
Selenium	1.77 ± 0.48	<1.00	1.91 ± 0.64	<1.00	1.24 ± 0.46	<1.00	0.24 ± 0.26	<1.00
Zinc	22.6 ± 1.7	11.8 ± 1.5**	36.6 ± 2.8	20.2 ± 1.9**	20.9 ± 2.5	11.5 ± 1.3**	30.9 ± 3.2	8.30 ± 2.19**
Vitamin A, RE	39.6 ± 1.8	39.6 ± 2.1	59.2 ± 2.6	58.1 ± 2.5	53.5 ± 2.5	54.3 ± 2.1	48.9 ± 2.9	46.4 ± 3.6
Thiamin	14.1 ± 1.4	2.60 ± 0.46**	22.1 ± 2.1	4.48 ± 1.12**	12.9 ± 1.9	3.96 ± 0.77**	9.83 ± 1.51	<1.00
Riboflavin	3.58 ± 0.6	1.18 ± 0.22**	13.5 ± 1.8	4.95 ± 0.94**	5.68 ± 1.09	3.19 ± 0.54*	9.93 ± 1.63	3.91 ± 1.07**
Niacin	3.33 ± 0.71	<1.00	2.53 ± 1.07	<1.00	3.03 ± 0.76	<1.00	2.97 ± 1.05	<1.00
Folate, DFE	14.6 ± 1.6	12.9 ± 1.2	23.0 ± 2.3	18.8 ± 1.9	16.0 ± 1.9	9.39 ± 1.51**	11.3 ± 1.8	6.88 ± 1.31*
Vitamin B_6	15.8 ± 1.5	10.1 ± 1.0**	16.9 ± 2.0	12.4 ± 1.4	12.7 ± 1.6	6.90 ± 1.17**	13.7 ± 1.9	4.77 ± 1.33**
Vitamin B_{12}	7.23 ± 1.23	2.86 ± 0.68**	9.45 ± 2.19	4.21 ± 1.22*	9.59 ± 1.83	4.03 ± 1.13**	17.2 ± 2.8	4.98 ± 1.38**
Vitamin C	50 ± 1.6	54.2 ± 1.3*	44.8 ± 2.1	40.8 ± 2.6	41.4 ± 3.7	37.4 ± 2.5	32.2 ± 3.2	27.1 ± 2.5
Vitamin D	93.2 ± 0.8	95.6 ± 0.6*	96.1 ± 0.8	99.4 ± 0.3**	94.7 ± 1.0	97.2 ± 0.8	91.7 ± 1.3	96.1 ± 1.7*
Vitamin E, ATE	73.9 ± 1.7	80 ± 1.1**	85.7 ± 1.6	83.4 ± 1.8	85.3 ± 1.6	82.7 ± 1.9	84.0 ± 2.4	87.9 ± 2.0
	% population above Adequate Intake (AI)							
Potassium	32.2 ± 1.6	34.9 ± 1.4	13.9 ± 1.6	20.6 ± 1.7**	26.5 ± 2.1	35.1 ± 1.5**	26.8 ± 2.7	34.9 ± 2.3*
Sodium	98.0 ± 0.5	99.8 ± 0.1**	97.3 ± 1.0	99.5 ± 0.2*	98.5 ± 0.5	99.6 ± 0.1*	99.4 ± 0.5	99.97 ± 0.04
Choline	4.33 ± 0.8	9.64 ± 1.17**	2.27 ± 0.69	10.4 ± 1.3**	7.17 ± 1.25	15.1 ± 1.4**	3.69 ± 1.2	8.23 ± 1.76*

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DOI:10.26502/jfsnr.2642-110000172

pork consumers had the highest intakes of most nutrients including calcium, iron, magnesium, phosphorus, selenium, zinc, thiamine, niacin, folate, vitamin B_6, vitamin B_{12}, potassium and choline, and lowest intake of vitamin E. NHB pork consumers had the lowest intakes of copper, iron, magnesium, selenium, zinc, vitamin A, thiamine, riboflavin, folate, vitamin B_6, vitamin D, potassium, sodium and choline than consumers of other ethnicities. NHW pork consumers had the highest intake of vitamin A, riboflavin and vitamin E, and lowest intake of selenium; while NHA consumers had the highest intakes of copper, vitamin C, vitamin D and sodium, and the lowest intakes of calcium, phosphorus, niacin and vitamin B_{12} compared to consumers of other ethnicities.

Comparison of % below the EAR or above the AI among pork consumers of different ethnicities:

The proportion of pork consumers with intakes below the EAR or above the AI also varied by ethnicity (Table 5). The lowest proportion of pork consumers with intakes below the EAR for iron, vitamin A, riboflavin and vitamin D were among NHA, while HSP had the lowest proportion below the EAR for calcium, and highest proportion above AI for potassium and choline. For copper, magnesium, zinc, folate, vitamin B_6, and vitamin C, NHA had the lowest proportion below the EAR as compared to other ethnicities. The highest proportion of pork consumers below the EAR for copper, iron, magnesium, zinc, vitamin A, riboflavin, folate, vitamin B_6, and vitamin D were among NHB (this group also had the lowest proportion with intakes above the AI for potassium), while NHA had the highest proportion below the EAR for calcium and the lowest proportion with intakes above the AI for choline. There were no significant ethnic differences in nutrient adequacies for thiamine, vitamin B12 and vitamin E. Irrespective of ethnic background, less than 1% pork consumers were below EAR for phosphorus, selenium and niacin and almost all pork consumers were above AI for sodium.

Discussion

The results of the present analysis of NHANES cross-sectional data indicate that adult consumers of pork from different ethnicities have higher intakes and lower prevalence

Table 4: Ethnic differences in usual intakes of nutrients among adult (aged 19+ years) pork consumers.

	non-Hispanic Whites (NHW)	non-Hispanic Blacks (NHB)	Hispanics (HSP)	non-Hispanic Asians (NHA)
EAR Nutrients				
Calcium (mg)	1017 ± 10[a]	855 ± 14[b]	1040 ± 17[a]	760 ± 21[c]
Copper (mg)	1.27 ± 0.01[a]	1.14 ± 0.02[b]	1.30 ± 0.02[a]	1.41 ± 0.02[c]
Iron (mg)	15.0 ± 0.1[a]	13.9 ± 0.2[b]	15.8 ± 0.3[c]	14.0 ± 0.2[b]
Magnesium (mg)	310 ± 3[a]	275 ± 4[b]	326 ± 4[c]	317 ± 5[ac]
Phosphorus (mg)	1472 ± 11[a]	1333 ± 18[b]	1542 ± 20[c]	1304 ± 19[b]
Selenium (µg)	122 ± 1[a]	122 ± 2[a]	131 ± 2[b]	130 ± 2[b]
Zinc (mg)	11.9 ± 0.1[a]	10.7 ± 0.2[b]	12.4 ± 0.2[c]	10.9 ± 0.1[b]
Vitamin A, RE (µg)	668 ± 13[a]	543 ± 14[b]	581 ± 15[bc]	615 ± 18[c]
Thiamin (mg)	1.74 ± 0.01[a]	1.58 ± 0.02[b]	1.78 ± 0.02[a]	1.74 ± 0.03[a]
Riboflavin (mg)	2.33 ± 0.02[a]	1.82 ± 0.03[b]	2.18 ± 0.04[c]	1.86 ± 0.05[b]
Niacin (mg)	27.3 ± 0.2[a]	26.3 ± 0.3[b]	28.6 ± 0.4[c]	26.1 ± 0.5[b]
Folate, DFE (µg)	533 ± 6[a]	478 ± 7[b]	562 ± 10[c]	536 ± 12[ac]
Vitamin B_6 (mg)	2.21 ± 0.03[a]	2.01 ± 0.03[b]	2.36 ± 0.04[c]	2.14 ± 0.05[a]
Vitamin B_{12} (µg)	5.29 ± 0.09[a]	4.60 ± 0.10[b]	5.08 ± 0.11[a]	4.46 ± 0.16[b]
Vitamin C (mg)	72.9 ± 1.5[a]	84.4 ± 2.5[b]	92.1 ± 2.8[c]	99.9 ± 2.9[c]
Vitamin D (µg)	4.74 ± 0.09[a]	3.91 ± 0.09[b]	4.74 ± 0.12[a]	4.90 ± 0.24[a]
Vitamin E, ATE (mg)	9.37 ± 0.13[a]	8.93 ± 0.18[b]	8.92 ± 0.2[ab]	8.49 ± 0.2[b]
AI Nutrients				
Potassium (mg)	2792 ± 25[a]	2451 ± 31[b]	2818 ± 32[a]	2751 ± 39[a]
Sodium (mg)	3783 ± 31[a]	3711 ± 45[a]	3900 ± 51[b]	4105 ± 94[b]
Choline (mg)	359 ± 4[a]	349 ± 5[a]	383 ± 5[b]	362 ± 7[a]

Two days 24-hour dietary recall data from NHANES 2011–2018. Gender combined data presented as mean ± standard error. Values with different superscripts in a row are significantly different at P<0.05. AI, Adequate Intake; ATE, alpha tocopherol equivalents; EAR, Estimated Average Requirement; DFE, dietary folate equivalents; RE, retinol activity equivalents.

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Table 5: Ethnic differences in percent population of adult (aged 19+ years) pork consumers meeting nutrient recommendations.

	non-Hispanic Whites (NHW)	non-Hispanic Blacks (NHB)	Hispanics (HSP)	non-Hispanic Asians (NHA)
% consumers below Estimated Average Requirement (EAR)				
Calcium	38.9 ± 1.1[a]	53.7 ± 1.7[b]	33.3 ± 1.5[c]	65.3 ± 3.0[d]
Copper	4.70 ± 0.59[a]	11.4 ± 1.0[b]	5.43 ± 0.89[a]	1.24 ± 0.65[c]
Iron	3.55 ± 0.27[a]	5.25 ± 0.51[b]	4.82 ± 0.52[b]	4.41 ± 0.48[ab]
Magnesium	53.0 ± 1.3[a]	66.2 ± 1.6[b]	47.1 ± 1.7[c]	46.4 ± 2.3[c]
Phosphorus	<1.00	<1.00	<1.00	<1.00
Selenium	<1.00	<1.00	<1.00	<1.00
Zinc	11.8 ± 1.5[a]	20.2 ± 1.9[b]	11.5 ± 1.3[a]	8.30 ± 2.19[a]
Vitamin A, RE	39.6 ± 2.1[a]	58.1 ± 2.5[b]	54.3 ± 2.1[bc]	46.4 ± 3.6[ac]
Thiamin	2.60 ± 0.46[a]	4.48 ± 1.12[a]	3.96 ± 0.77[a]	<1.00
Riboflavin	1.18 ± 0.22[a]	4.95 ± 0.94[b]	3.19 ± 0.54[b]	3.91 ± 1.07[b]
Niacin	<1.00	<1.00	<1.00	<1.00
Folate, DFE	12.9 ± 1.2[a]	18.8 ± 1.9[b]	9.39 ± 1.51[ac]	6.88 ± 1.31[c]
Vitamin B_6	10.1 ± 1.0[a]	12.4 ± 1.4[a]	6.90 ± 1.17[b]	4.77 ± 1.33[b]
Vitamin B_{12}	2.86 ± 0.68[a]	4.21 ± 1.22[a]	4.03 ± 1.13[a]	4.98 ± 1.38[a]
Vitamin C	54.2 ± 1.3[a]	40.8 ± 2.6[b]	37.4 ± 2.5[b]	27.1 ± 2.5[c]
Vitamin D	95.6 ± 0.6[a]	99.4 ± 0.3[b]	97.2 ± 0.8[a]	96.1 ± 1.7[ab]
Vitamin E, ATE	80 ± 1.1[a]	83.4 ± 1.8[a]	82.7 ± 1.9[a]	87.9 ± 2.0[a]
% consumers above Adequate Intakes (AI)				
Potassium	34.9 ± 1.4[a]	20.6 ± 1.7[b]	35.1 ± 1.5[a]	34.9 ± 2.3[a]
Sodium	99.8 ± 0.1[ab]	99.5 ± 0.2[a]	99.6 ± 0.1[a]	99.97 ± 0.04[b]
Choline	9.64 ± 1.17[a]	10.4 ± 1.3[a]	15.1 ± 1.4[b]	8.23 ± 1.76[a]

Two days 24-hour dietary recall data from NHANES 2011–2018. Gender combined data presented as mean ± standard error. Values with different superscripts in a row are significantly different at P<0.05. ATE, alpha tocopherol equivalents; DFE, dietary folate equivalents; RE, retinol activity equivalents.

of inadequacies of key micronutrients, including many "under-consumed nutrients" and "nutrients of public health concern" compared to non-consumers. A comparison between pork consumers of different ethnicities revealed that while HSP consumers had higher intakes for many nutrients, higher proportions of NHA consumers met recommendations for most nutrients compared to pork consumers of other ethnicities. To the best of our knowledge, this is the first report to investigate the ethnic differences in the association of intake of pork with nutrient adequacy among adults using a nationally representative US population.

Pork consumption was associated with significantly increased nutrient intakes and decreased the percent of the population below the EAR or increased percent or the population above the AI for most nutrients in all race/ethnic population subgroups. Many Americans are not consuming the recommended amounts of several nutrients such as calcium, potassium, iron (adolescent and adult females), magnesium, choline, and vitamins A, D, E, and C [30]. Nutrient inadequacies can lead to deficiencies which are associated with increased risks of several adverse health effects including cardiovascular disease, stroke, impaired cognitive function, cancer, eye diseases, poor bone health and other conditions [30-33]. Low intakes of calcium, potassium, dietary fiber, and vitamin D are associated with health concerns and therefore are considered as components of public health concern for the general U.S. population [34].

In the present analysis, depending upon the ethnicity, the observed differences in the prevalence of population below the EAR between adult pork consumers and non-consumers ranged from 3-5% units for iron to 9-23% units for zinc. To put these results into perspective, we estimated the potential impact of pork consumption on a population basis. Since we used population weighted nationally representative data in the present analysis, the sample size of 4,534 NHW, 2,790 NHB, 2,690 HSP and 1,137 NHA adult consumers of pork represented 88.7 million NHW, 16.3 million NHB, 20.1 million HSP, and 6.3 million NHA adults, respectively, and a 1% unit change in percentage of the population below the EAR or above the AI among consumers would translate into additional 890,000 NHW, 160,000 NHB, 200,000 HSP and 60,000 NHA adult population meeting EAR/AI recommendations.

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DOI:10.26502/jfsnr.2642-110000172

To date, there is only limited research available on ethnic differences in nutrient intakes. We found that the HSP pork consumers had the highest intakes for most nutrients and NHB pork consumers had the lowest intakes of most nutrients compared to pork consumers of other ethnicities. Higher intakes of vitamin D and potassium among NHW adults and lower intakes of calcium among NHB adults compared to adults from other ethnicities was reported earlier from NHANES 2003-2006 analysis [6]. Similarly, in NHANES III and NHANES 1999-2002 analysis, NHB men and women had lower intakes of vitamin E, iron and folate compared to NHW, and Mexican Americans had higher intakes of vitamin C than NHW and lower intake vitamin D compared to all ethnicities [35]. An earlier report from CDC also indicated that about 10% of the U.S. population had nutrient-related biomarkers-based deficiencies which varied by age, gender, or race/ethnicity and could be as high as nearly one third of certain population groups [33].

A major strength of our study was the use of a several cycles of NHANES, a large nationally representative population-based dataset, which includes a sufficiently large sample size of ethnic groups. Another strength is determining usual intake to assess the percentage of the population below the EAR/above the AI. One of the limitations to our study was that the nutrient intake estimates relied on self-reported dietary recall which are based on memory and as such were subject to misreporting. Another limitation is that NHANES has a cross-sectional design, and therefore, causal relationships cannot be determined. While this study utilized two 24-hour dietary recalls, it is possible participants consumed pork on days other than those reported, which would result in underestimation of pork consumers. Additionally, the association of pork intake with higher nutrient intake and lower nutrient inadequacies may also be due, at least in some part, to other foods that are consumed with pork. Finally, the NHA group is a heterogeneous population with diverse ethnic origins, dietary behaviors and other lifestyle factors, cultural beliefs and behaviors, however, data on NHA was aggregated as a single racial/ethnic group in the NHANES without consideration of ethnic origins.

Conclusions

The result of this study shows that pork consumers compared to non-consumers had higher intake and nutrition adequacy of several nutrients including several nutrients of public health concern and therefore it is likely that pork may play a role in decreasing the incidence of under nutrition. Efforts to better communicate dietary recommendations, possibly using customized cultural relevant messages, should be considered to help certain race/ethnic groups meet nutrient needs. These results also suggest that any recommendations to reduce/remove pork from diets must ensure that the nutrients provided by pork are replaced through other dietary changes. Future studies are needed to examine the long-term impact of pork consumption on diet quality, nutrient intake, and health promotion in ethnic populations.

List of Abbreviations

AI: Adequate intake; ATE: Alpha tocopherol equivalents; CDC: Center for Disease Control and Prevention; DFE: Dietary folate equivalents; DGA: Dietary Guidelines for Americans; EAR: Estimated Average Requirement; FNDDS: Food and Nutrition Database for Dietary Studies; FPED: Food Patterns Equivalents Database; FPID: Food Patterns Equivalents Ingredient Database; HSP: Hispanics; NCI: National Cancer Institute; NCHS: National Center for Health Statistics; NHANES: National Health and Nutrition Examination Survey; NHA: non-Hispanic Asians; NHB: non-Hispanic Blacks; NHW: non-Hispanic Whites; RE: Retinol equivalents.

Ethics approval and consent to participate

The data used for this manuscript were from the National Health and Nutrition Examination Survey (NHANES) and all participants or proxies provided written informed consent; data collection for NHANES was approved by the Research Ethics Review Board of the National Center for Health Statistics. NHANES has stringent consent protocols and procedures to ensure confidentiality and protection from identification. This study was a secondary data analysis, which lacked personal identifiers, and therefore did not require Institutional Review Board review.

Availability of data and materials

The datasets analyzed in this study are available in the Center for Disease Control and Prevention repository; available online: http://www.cdc.gov/nchs/nhanes/ (accessed on 07 November 2024).

Conflict of interests

SA, as Principal of NutriScience LLC performs, consulting for various food and beverage companies and related entities. VLF, as Senior Vice President of Nutrition Impact, LLC, performs consulting and database analyses for various food and beverage companies and related entities.

Funding

This research was funded by the Pork Checkoff. Pork Checkoff had no role in the analyses/interpretation of results and did not review the manuscript prior to submission.

Authors' contributions

SA participated in the project conception, research design, development of overall research plan, interpretation of the data, drafting of the manuscript, revision of the manuscript,

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DOI:10.26502/jfsnr.2642-110000172

and the approval of the final version. VLF participated in the project conception, research design, development of overall research plan, NHANES dietary data analysis, statistical analysis, interpretation of the data, revision of the manuscript, and the approval of the final version. Both authors have read and agreed to the published version of the manuscript.

Acknowledgments

This research was funded by the Pork Checkoff.

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