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Research Article

Association of Pork to Key Nutrient Intake and Adequacy in US Adolescents Aged 9-18 Years: A Cross-Sectional Analysis of National Health and Nutrition Examination Survey 2011-2018 Data

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Abstract

Adolescents have the greatest disparities between current and recommended nutrient intakes and are at greater risk of nutrient inadequacy. Pork is a rich source of high-quality protein and several important nutrients. We assessed the intakes of pork and their association with nutrient intake and adequacy among adolescents. 24-hour dietary recall data from NHANES 2011-2018 for adolescents aged 9-18 years (n=6,154) were used to estimate intakes. Usual intake of nutrients was determined using the NCI method and % population with intakes below the Estimated Average Requirement (EAR), or above the Adequate Intake (AI) for pork consumers and non-consumers was estimated. Separate analyses were performed for age groups 9-18, 9-13 and 14-18 years. About 53% of adolescents were pork consumers with mean intakes of 54 g/day. Pork consumers had higher intakes ($P<0.05$) of calcium, copper, iron, magnesium, phosphorus, potassium, selenium, sodium, zinc, thiamine, riboflavin, niacin, vitamin B_6, vitamin B_{12} and choline compared to non-consumers. A lower ($P<0.05$) proportion of consumers had intakes below EAR for calcium, copper, iron, magnesium, phosphorus, zinc, thiamine, riboflavin, and vitamin B_{12} than non-consumers. A higher proportion of consumers had intakes above AI for potassium, sodium, and choline than non-consumers. Generally, similar higher intakes and % below EAR or above AI were also noted when the data were analyzed separately for age and gender groups. Pork intake was associated with higher nutrient intakes and nutrient adequacies in US adolescents for certain key nutrients which are inherent to pork or foods consumed with pork.

Keywords: NHANES; vitamins; minerals; usual intakes; nutrient adequacy

Introduction

Adolescents comprise about 13% of the US population equating to almost 43 million individuals. Adolescence is a critical stage of life and an intense period for growth and development as it is the period of transition from childhood to adulthood signified by sexual maturation and major physical and hormonal changes [1-3]. Adolescents generally gain over 40% of their adult weight and over 15% of their adult height during this period and require higher levels of energy, and macro- and micro-nutrients. The 2020–2025 Dietary Guidelines for Americans (DGA) identified that in addition to having lower diet quality than their younger counterparts, adolescents also have the greatest disparities between the recommended and current nutrient intakes and are at greater risk of nutrient inadequacy [4]. Inadequate intakes of micro-nutrients such as calcium, iron, magnesium, phosphorus, potassium, folate, vitamin B_6, vitamin B_{12}, choline, vitamin D among adolescents have been previously identified [5-7]. During adolescence inadequate dietary intakes can have serious health consequences including delayed growth, impaired cognitive function, sexual development disorders, endocrine dysfunction, and inadequate bone mass [8-11]. Yet nutrition in this group has been largely overlooked in global nutrition policy research [10].

Pork is one of the most widely consumed meats in the world, accounting for over a third of total global meat production [12]. In the US, pork ranks third in annual meat consumption after beef and chicken, and is about 25% of overall meat intake [13]. Approximately 52% American children and 59% American adults are pork consumers with a daily intake of 47 and 61 g pork, respectively [14]. Pork is an important source of high-quality protein and several priority micronutrients (Table 1) [14-16]. As reported in cross-sectional studies, intake of pork has been found to contribute significantly (more than 10%) to intakes of several nutrients, including protein, phosphorus, potassium, selenium, thiamine, riboflavin, niacin, vitamin B_6, and vitamin B_{12} [17-19], and was associated with higher intakes and adequacies for several key micronutrients, including many under-consumed nutrients in children (age 2-18 years) and adults (age 19+ years) [14]. In a dietary modeling study using the USDA's Healthy Dietary Patterns, removal of a serving of 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 [20]. While the studies above have looked at the association of pork intake with nutrient intake and nutrient adequacy, none specifically examined adolescents (age 9-18 years).

Table 1: Nutrient composition of Pork* [14-16].

	Amount per 100 g	% Daily Value (DV)
Choline	81.1 mg	14.7%
Fat	8.67 g	11.1%
Iron	0.79 mg	4.38%
Magnesium	26 mg	6.19%
Niacin	7.55 mg	47.2%
Phosphorus	245 mg	19.6%
Potassium	402 mg	8.55%
Riboflavin	0.23 mg	18.0%
Protein	27.1 g	54.2%
Selenium	44.8 µg	81.5%
Saturated fatty acids	3.03 g	15.2%
Thiamin	0.61 mg	50.4%
Vitamin B_6	0.62 mg	36.2%
Vitamin B_{12}	0.65 µg	27.1%
Zinc	2.44 mg	22.2%
(*pork, not further specified; FDC ID: 2705862; Food code 22000100)		

We hypothesized that since adolescents have higher nutrient requirements but have suboptimal intakes of several nutrients, intake of pork as nutrient rich source of a number of key nutrients would be associated with improved nutrient intakes and nutrient adequacy among consumers compared to non-consumers. Therefore, the purpose of this study was to evaluate association of pork consumption with nutrient intake and the % below EAR/above AI specifically in adolescents using National Health and Nutrition Examination Survey (NHANES) 2011–2018 data [21], a robust and validated database/program of Centers for Disease Control and Prevention (CDC) that aims to assess the overall nutrition and health status of the American population. We also stratified the data by gender and age (9-13 years for young adolescents and 14-18 years for older adolescents) as these are specific age groups used for DRI and dietary guidelines [4,22].

Methods

Database: NHANES is an ongoing cross-sectional survey that uses a stratified multistage cluster sampling probability design to obtain a nationally representative non-institutionalized sample of the civilian US population. NHANES data are currently continuously collected and released every two years by the National Center for Health Statistics of the CDC. A detailed description of the subject recruitment, survey design, and data collection procedures are available online [21]. NHANES protocols are approved by the Ethics Review Board of National Center for Health Statistics and the present study was a secondary data analysis which lacked personal identifiers, therefore, was exempt from additional approvals by Institutional Review Boards. All participants provided a signed written informed consent. All data obtained from this study are publicly available at: http://www.cdc.gov/nchs/nhanes/.

Study Population: Data from children and adolescents aged 9-18 years (n = 6,154; population weighted N = 41,520,807) participating in NHANES cycles 2011-2012, 2013-2014, 2015-2016 and 2017-2018 were used. Data for those with incomplete or unreliable dietary recall as determined by NHANES staff, with missing day 1 dietary data and those pregnant and/or lactating were excluded from analyses.

Estimates of Dietary Intake: Dietary intake data were obtained from 24-hour dietary recall interviews that were administered using an automated, multiple-pass (AMPM) method [23]. Intakes of calcium, iron, magnesium, phosphorus, potassium, selenium, sodium, zinc, vitamin A, thiamin, riboflavin, niacin, folate, vitamin B_6, vitamin B_{12}, vitamin C, vitamin D, vitamin E and choline from foods were obtained from the total nutrient intake files for each NHANES cycle [24]. Intakes from dietary supplement intakes were not included in the present analysis. Two days of dietary recalls were collected on most subjects; the first day dietary recall was collected in person in the mobile examination center while the second recall (3 to 10 days later) was collected via the telephone. Usual nutrient intakes and the distribution of intakes were estimated using the National Cancer Institute (NCI) method [25] and the percentage of the population below the Estimated Average Requirement (EAR) or above the Adequate Intake (AI) was determined using the cut-point method (except for iron where the probability method was used) for pork consumers and non-consumers separately [26].

Estimates of Pork Intakes: Food and Nutrition Database for Dietary Studies (FNDDS) food codes were used to identify pork containing items [24]. Over three thousand FNDDS food codes included pork such as bologna, sausages, ham, chops, roasts, bacon, salami, hot dogs, scrapple, specific pork cuts, steaks, ground pork, kabob, and in numerous mixed dishes. When pork items were used as "ingredients" of the survey foods, the FNDDS food codes were identified, and recipe calculations were performed using the survey-specific USDA Food Patterns Equivalents database (FPED) which also includes the Food Patterns Equivalents Ingredient Database (FPID) [27]. The FPID descriptions were examined to determine proportion of pork: 100% if entirely pork, 50% or 33% if the description indicated one or two other meat types in addition to pork. For some FNDDS food codes that contained ingredients with missing FPID the food code ingredient profile was modified either by using food code from another NHANES cycle or by using another ingredient code with a similar description. With pork content of pork containing food codes identified, pork intake was summed across all sources of pork consumed during the recall days. Consumers of pork were defined as those individuals consuming any amount of any pork item on either of the two days of dietary recall and those who did not consume any pork on either of the two days of dietary recalls were defined as non-consumers.

Statistics: All analyses were performed using SAS 9.4 (SAS Institute, Cary, NC, USA) software and the data were adjusted for the complex sampling design of NHANES, using appropriate survey weights, strata, and primary sampling units. Data were analyzed separately for those aged 9-18, 9-13 and 14-18 years for sexes combined and for males and females aged 9-18 years aligning with age groups defined by DGA. Data are presented as mean ± standard error of means. Differences in demographics between consumers and non-consumers were determined through regression analyses. Differences in nutrient intakes and the % below EAR/above AI were determined using Z-statistics. For presentation purposes the percentage difference in nutrient intakes between consumers and non-consumers were calculated; additionally, we present the differences in % below the EAR/above AI as percentage unit differences (% units).

Results

About 53% of adolescents aged 9-18 years were consumers of pork. There were no overall differences ($P>0.05$) in demographic characteristics of consumers and non-consumers except that a greater percentage ($P<0.05$) of pork consumers were male (5.2% units more) and current smokers (1.3% units more) compared to non-consumers (Table 2).

Table 2: Demographics associated with pork consumption in adolescents aged 9–18 years.

	Non-Consumers	Consumers	P values for difference
Sample n	2,861	3,293	
Population N	19,663,293	21,857,514	
Mean Age (Years	13.5 ± 0.1	13.5 ± 0.1	0.7548
Gender (% Male)	47.4 ± 1.6	52.6 ± 1.4	0.0166
Underweight (%)	4.22 ± 0.62	3.18 ± 0.48	0.1624
Normal weight (%)	59.5 ± 1.4	58.3 ± 1.3	0.5489
Overweight (%)	15.7 ± 0.9	17.2 ± 0.8	0.2332
Obese (%)	20.6 ± 1.3	21.3 ± 1.1	0.6480
Ethnicity			
Hispanic (%)	23.3 ± 2.1	24.1 ± 2.1	0.5338
non-Hispanic White (%)	52.8 ± 2.5	51.4 ± 2.7	0.4650
non-Hispanic Black (%)	13.2 ± 1.3	14.3 ± 1.6	0.3580
non-Hispanic Asian (%)	5.30 ± 0.68	4.34 ± 0.52	0.1468
Poverty Income Ratio (PIR)			
< 1.35 (%)	32.1 ± 1.9	34.6 ± 2.1	0.1422
1.35 to ≤ 1.85 (%)	11.6 ± 0.9	12.1 ± 1.0	0.7071

> 1.85 (%)	56.3 ± 2.2	53.3 ± 2.1	0.1121
Education			
< High School (%)	98.8 ± 0.3	98.8 ± 0.3	0.9172
High School (%)	1.23 ± 0.27	1.19 ± 0.30	0.9172
> High School (%)	0.00	0.00	
Physical Activity			
Sedentary (%)	18.6 ± 1.2	17.1 ± 1.0	0.3299
Moderate (%)	28.7 ± 1.2	30.3 ± 1.2	0.2835
Vigorous (%)	52.8 ± 1.5	52.6 ± 1.4	0.9442
Smoking never (%)	87.3 ± 1.1	85.4 ± 1.1	0.1473
Pork consumers were those adolescents who consumed any amount of pork on either of the two days of dietary recalls, and non-consumers were those who did not. Two days 24-hour dietary recall data from NHANES 2011–2018. Data is presented as Mean ± Standard Error.			

The mean intake of pork was 53.6 ± 2.9 g/day (32.9 ± 1.4 and 131 ± 8 g/day for the 50th and 90th percentile of intakes, respectively) among consumers. Mean per capita intake of total pork intake was 19.6 ± 1.2 g/d while fresh pork intake was 6.39± 0.57 g/d and processed pork intake was 13.2 ± 0.9 g/d. Pork intake has not changed over the last 18 years (β = -0.44 ± 0.23 g/cycle; $P_{linear\ cycle\ trend}$ = 0.0536). Pork consumers compared to non-consumers had 10% higher intakes of energy, 17% higher intakes of protein, 6% higher intake of carbohydrate, 14% higher intakes of fat, 14% higher intakes of saturated fat and 4% higher intake of percent calories from saturated fat (Table 3).

Table 3: Intake of energy, macronutrients and diet quality among adolescents aged 9–18 years non-consumers and consumers of pork.

	Non-Consumers	Consumers	P values for difference
Energy (kcal)	1930 ± 23	2131 ± 24	<0.0001
Protein (g)	67.7 ± 1.1	79.4 ± 1.3	<0.0001
Carbohydrate (g)	256 ± 3	271 ± 3	0.0004
Total fat (g)	73.1 ± 1.0	83.2 ± 1.1	<0.0001
Total saturated fatty acids (g)	25.1 ± 0.4	28.6 ± 0.4	<0.0001
Energy from saturated fat (%)	11.3 ± 0.1	11.7 ± 0.1	0.0047
Pork consumers were those adolescents who consumed any amount of pork on either of the two days of dietary recalls, and non-consumers were those who did not. Two days 24-hour dietary recall data from NHANES 2011–2018. Data is presented as Mean ± Standard Error.			

Adolescent (age 9-18 years) consumers of pork had ≥10% higher (P<0.05) usual intakes of copper, phosphorus, selenium, zinc, thiamine, niacin, vitamin B_6, vitamin B_{12}, vitamin D, potassium and choline; in addition, pork consumers had a 5% (but <10%) higher intake of calcium, iron, magnesium and riboflavin (Table 4). A lower proportion (P<0.05) of pork consumers had intakes below EAR for calcium (-9% units), copper (-7% units), iron (-3% units), magnesium (-6% units), phosphorus (-16% units), zinc (-13% units), thiamine (-5% units), riboflavin (-3% units) and vitamin B_{12} (-3% units), and higher proportion (P<0.05) were above AI for potassium (10% units) and choline (5% units) than non-consumers (Table 4). However, pork consumers also had 17% higher (P<0.05) intakes of sodium than non-consumers while virtually all of adolescent population, irrespective of their pork consumption, had sodium intakes above the AI (Table 4).

Table 4: Usual nutrient intakes and percentage of population below EAR or above AI among adolescents aged 9-18 years non-consumers and consumers of pork.

	Usual Intakes			% Below EAR or Above AI		
	Non-Consumers (n=2,861)	Consumers (n=3,293)	P value	Non-Consumers (n=2,861)	Consumers (n=3,293)	P value
	EAR Nutrients			% below EAR		
Calcium (mg)	981 ± 19	1072 ± 18	0.0005	66.8 ± 2.2	57.6 ± 2.0	0.0016
Copper (mg)	0.94 ± 0.01	1.05 ± 0.02	<0.0001	12.3 ± 1.7	5.01 ± 1.13	0.0004
Iron (mg)	14.4 ± 0.3	15.3 ± 0.2	0.0126	6.69 ± 1.03	3.29 ± 0.60	0.0044
Magnesium (mg)	239 ± 3	256 ± 4	0.0007	59.7 ± 1.4	53.6 ± 1.6	0.0038
Phosphorus (mg)	1244 ± 17	1400 ± 19	<0.0001	34.0 ± 1.9	18.3 ± 2.2	<0.0001
Selenium (µg)	93.3 ± 1.6	113 ± 2	<0.0001	<1.00	<1.00	
Zinc (mg)	9.94 ± 0.19	11.2 ± 0.2	<0.0001	25.9 ± 2.3	12.7 ± 2.3	<0.0001
Vitamin A, RE (µg)	581 ± 13	618 ± 14	0.0528	41.0 ± 2.1	36.6 ± 2.3	0.1573
Thiamin (mg)	1.51 ± 0.03	1.76 ± 0.03	<0.0001	6.21 ± 1.14	1.58 ± 0.70	0.0005
Riboflavin (mg)	1.91 ± 0.04	2.07 ± 0.03	0.0014	4.69 ± 0.99	1.51 ± 0.66	0.0077
Niacin (mg)	22.5 ± 0.4	25.1 ± 0.5	0.0000	1.37 ± 0.55	<1.00	
Folate, DFE (µg)	528 ± 11	552 ± 11	0.1229	9.58 ± 1.68	6.11 ± 1.65	0.1397
Vitamin B_6 (mg)	1.78 ± 0.04	1.97 ± 0.04	0.0008	7.07 ± 1.56	3.77 ± 1.23	0.0959
Vitamin B_{12} (µg)	4.66 ± 0.1	5.24 ± 0.12	0.0002	5.61 ± 0.95	2.11 ± 0.69	0.0029
Vitamin C (mg)	69.0 ± 2.0	74.5 ± 2.8	0.1100	34.8 ± 2.5	31.8 ± 3.1	0.4563
Vitamin D (µg)	4.85 ± 0.16	5.37 ± 0.12	0.0093	93.5 ± 1.1	93.7 ± 0.9	0.8618
Vitamin E, ATE (mg)	7.7 ± 0.18	7.96 ± 0.16	0.2803	80.8 ± 2.4	81.7 ± 2.3	0.7807
	AI Nutrients			% above AI		
Potassium (mg)	2109 ± 31	2334 ± 34	<0.0001	24.5 ± 1.9	34.1 ± 2.1	0.0009
Sodium (mg)	3012 ± 41	3539 ± 48	<0.0001	99.3 ± 0.3	100.0 ± 0.0	0.0436
Choline (mg)	238 ± 4	292 ± 5	<0.0001	3.44 ± 0.90	8.7 ± 1.3	0.0010

Pork consumers were those adolescents who consumed any amount of pork on either of the two days of dietary recalls, and non-consumers were those who did not. Two days 24-hour dietary recall data from NHANES 2011–2018. Gender combined data presented as mean ± Standard Error; AI, Adequate Intake; ATE: alpha tocopherol equivalents; EAR, Estimated Average Requirement; DFE: dietary folate equivalents; RE: retinol activity equivalents.

When we stratified data for adolescents age 9-18 years by gender, both adolescent male (M) and female (F) pork consumers had ≥10% higher (P<0.05) intakes of phosphorus, selenium, zinc, thiamine, sodium and choline (Table 5). In addition, adolescent male and female pork consumers had ≥5% higher intakes of calcium, copper, magnesium, riboflavin, niacin, vitamin B_6, and potassium. A lower (P<0.05) proportion of both adolescent male (M) and female (F) pork consumers had intakes below EAR for copper (-5% units M, -8% units F), phosphorus (-10% units M, -18% units F), zinc (-9% units M, -17% units F) and riboflavin (-2% units M, -4% units F); and a higher proportion (P<0.05) were above AI for potassium (8% units M, 11% units F) and choline (6% units M, 4% units F) compared to respective non-consumers (Table 5). Female adolescent consumers additionally had higher (P<0.05) intakes of iron (7%), vitamin A (11%), vitamin B_{12} (15%) and vitamin D (17%); and a lower (P<0.05) proportion had intakes below EAR for iron (-5% units), magnesium (-7% units), vitamin A (-9% units), thiamine (-6% units) and vitamin B_{12} (-4% units); and a higher proportion (P<0.05) were above AI for sodium (1% units). A lower (P<0.05) proportion (-9% units) of male consumers were also below EAR for calcium (Table 5).

Table 5: Usual nutrient intakes and percentage of population below EAR or above AI among adolescents aged 9-18 years non-consumers and consumers of pork by gender.

	Usual Intakes				% Below EAR or Above AI			
	Male (M)		Female (F)		Male (M)		Female (F)	
	Non-Consumers (n=1,374)	Consumers (n=1,701)	Non-Consumers (n=1,487)	Consumers (n=1,592)	Non-Consumers (n=1,374)	Consumers (n=1,701)	Non-Consumers (n=1,487)	Consumers (n=1,592)
	EAR Nutrients				% below EAR			
Calcium (mg)	1087 ± 26	1164 ± 21*	887 ± 19	965 ± 23**	55.5 ± 2.8	46.7 ± 2.3*	76.5 ± 2.2	69.9 ± 2.7
Copper (mg)	1.01 ± 0.02	1.12 ± 0.02**	0.89 ± 0.01	0.97 ± 0.02**	8.10 ± 1.59	2.69 ± 0.82**	15.8 ± 2.2	7.52 ± 1.66**
Iron (mg)	16.2 ± 0.4	16.8 ± 0.3	12.8 ± 0.3	13.7 ± 0.3*	2.19 ± 0.77	<1.00	10.8 ± 1.4	5.94 ± 0.97**
Magnesium (mg)	260 ± 5	274 ± 4*	222 ± 3	236 ± 4**	53.2 ± 1.9	50.2 ± 1.9	65.1 ± 1.6	57.6 ± 2.3**
Phosphorus (mg)	1392 ± 25	1527 ± 21**	1113 ± 17	1260 ± 24**	19.6 ± 2.5	9.17 ± 1.76**	46.7 ± 2.0	28.6 ± 3.1**
Selenium (μg)	104 ± 2	126 ± 2**	84 ± 1	100 ± 2**	<1.00	<1.00	<1.00	<1.00
Zinc (mg)	11.3 ± 0.3	12.4 ± 0.2**	8.67 ± 0.15	9.82 ± 0.2**	16.9 ± 2.7	7.82 ± 1.70**	34.2 ± 2.3	17.6 ± 3.1**
Vitamin A, RE (μg)	647 ± 20	654 ± 18	521 ± 13	576 ± 15**	38.1 ± 2.8	38.9 ± 2.6	43.5 ± 2.4	34.6 ± 2.8*
Thiamin (mg)	1.69 ± 0.04	1.94 ± 0.04**	1.35 ± 0.03	1.56 ± 0.03**	3.49 ± 0.88	<1.00**	8.98 ± 1.52	2.56 ± 1.08**
Riboflavin (mg)	2.15 ± 0.05	2.28 ± 0.04*	1.69 ± 0.03	1.84 ± 0.04**	3.00 ± 0.77	1.18 ± 0.47*	6.15 ± 1.27	2.01 ± 0.88**
Niacin (mg)	25.5 ± 0.5	27.8 ± 0.6**	19.7 ± 0.4	22.1 ± 0.5**	<1.00	<1.00	2.48 ± 0.88	<1.00
Folate, DFE (μg)	588 ± 15	598 ± 14	475 ± 11	500 ± 12	4.70 ± 1.37	3.42 ± 1.21	13.8 ± 2.2	9.50 ± 2.31
Vitamin B_6 (mg)	2.02 ± 0.05	2.17 ± 0.05*	1.57 ± 0.03	1.76 ± 0.04**	3.55 ± 1.09	2.26 ± 0.82	10.2 ± 2.1	5.37 ± 1.69

Vitamin B_{12} (µg)	5.51 ± 0.16	5.92 ± 0.17	3.89 ± 0.08	4.49 ± 0.12**	1.64 ± 0.58	<1.00	9.18 ± 1.36	3.72 ± 1.15**
Vitamin C (mg)	71.9 ± 2.6	77.7 ± 3.3	66.8 ± 2.2	71.2 ± 3.2	34.2 ± 2.7	31.4 ± 3.2	35.2 ± 2.9	31.9 ± 3.5
Vitamin D (µg)	5.68 ± 0.22	5.88 ± 0.17	4.09 ± 0.16	4.80 ± 0.14**	89.9 ± 1.5	91.4 ± 1.2	96.6 ± 0.8	96.3 ± 0.7
Vitamin E, ATE (mg)	8.36 ± 0.29	8.38 ± 0.2	7.09 ± 0.17	7.49 ± 0.18	74.8 ± 3.4	77.9 ± 2.8	86.3 ± 2.1	85.7 ± 2.1
	AI Nutrients				% above AI			
Potassium (mg)	2316 ± 45	2517 ± 40**	1928 ± 30	2136 ± 39**	25.2 ± 2.4	33.3 ± 2.4*	23.9 ± 1.9	35.3 ± 2.8**
Sodium (mg)	3348 ± 61	3851 ± 62**	2707 ± 41	3193 ± 54**	99.9 ± 0.1	100.0 ± 0.01	98.7 ± 0.5	99.9 ± 0.1*
Choline (mg)	269 ± 6	319 ± 7**	211 ± 5	260 ± 5**	5.27 ± 1.20	11.5 ± 1.7**	1.64 ± 0.76	5.65 ± 1.27**

Pork consumers were those adolescents who consumed any amount of pork on either of the two days of dietary recalls, and non-consumers were those who did not. Two days 24-hour dietary recall data from NHANES 2011–2018. 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.

When we stratified results for adolescents by age groups, pork consumers of both adolescents aged 9-13 years (YA) and 14-18 years (OA) had ≥ 10% higher (P<0.05) intakes of copper, phosphorus, selenium, zinc, thiamine, niacin, vitamin B_6, potassium, sodium and choline. (Table 6). In addition, pork consumers of both adolescents aged 9-13 years and 14-18 years had ≥ 5% higher (P<0.05) intakes of calcium, magnesium, riboflavin, and vitamin B_{12}. A lower (P<0.05) proportion of adolescent pork consumers (both YA and OA) were below EAR for calcium (-10% units YA, -9% units OA), copper (-4% units YA, -11% units OA), iron (-6% units OA), magnesium (-10% units YA), phosphorus (-15% units YA, -16% units OA), zinc (-12% units YA, -15% units OA), vitamin A (-8% units YA), thiamine (-8% units OA), riboflavin (-5% units OA) and vitamin B_{12} (-4% units OA); and a higher proportion (P<0.05) were above AI for potassium (12% units YA, 8% units OA), choline (9% units YA) and sodium (1% units OA), compared to respective non-consumers (Table 6).

Table 6: Usual nutrient intakes and percentage of population below EAR or above AI among adolescent non-consumers and consumers of pork by age groups.

	Usual Intakes				% Below EAR or Above AI			
	Age 9-13 years (YA)		Age 14-18 years (OA)		Age 9-13 years (YA)		Age 14-18 years (OA)	
	Non-Consumers (n=1,462)	Consumers (n=1,720)	Non-Consumers (n=1,399)	Consumers (n=1,573)	Non-Consumers (n=1,462)	Consumers (n=1,720)	Non-Consumers (n=1,399)	Consumers (n=1,573)
	EAR Nutrients				% below EAR			
Calcium (mg)	1008 ± 20	1101 ± 17**	954 ± 24	1041 ± 24*	64.2 ± 2.3	54.1 ± 2.0**	69.7 ± 2.6	61.1 ± 2.8*
Copper (mg)	0.94 ± 0.01	1.03 ± 0.02**	0.95 ± 0.02	1.06 ± 0.02**	5.83 ± 1.37	1.79 ± 0.61**	19.1 ± 2.4	8.02 ± 1.78**
Iron (mg)	14.8 ± 0.3	15.5 ± 0.3	13.9 ± 0.4	15.1 ± 0.3*	1.44 ± 0.49	<1.00	11.9 ± 1.6	5.99 ± 1.03**

Magnesium (mg)	240 ± 4	253 ± 4*	239 ± 4	260 ± 5**	31.7 ± 2.6	21.7 ± 2.4**	86.8 ± 2.2	83.6 ± 2.2
Phosphorus (mg)	1250 ± 19	1398 ± 19**	1244 ± 25	1399 ± 27**	33.4 ± 2.0	18.6 ± 2.0**	34.0 ± 2.6	18.4 ± 2.8**
Selenium (µg)	90.2 ± 1.7	110 ± 2**	96.4 ± 2.1	117 ± 2**	<1.00	<1.00	<1.00	<1.00
Zinc (mg)	9.97 ± 0.21	11.2 ± 0.2**	9.87 ± 0.26	11.1 ± 0.3**	21.3 ± 2.4	9.11 ± 1.92**	30.4 ± 3.0	15.9 ± 3.0**
Vitamin A, RE (µg)	610 ± 17	670 ± 16*	551 ± 15	571 ± 16	26.3 ± 2.5	18.1 ± 2.4*	55.5 ± 2.5	54.2 ± 2.7
Thiamin (mg)	1.54 ± 0.03	1.76 ± 0.03**	1.48 ± 0.03	1.76 ± 0.04**	1.70 ± 0.53	<1.00	10.9 ± 1.8	2.66 ± 1.15**
Riboflavin (mg)	1.93 ± 0.04	2.12 ± 0.04**	1.87 ± 0.05	2.02 ± 0.05*	2.60 ± 0.67	<1.00	7.01 ± 1.42	2.43 ± 1.03**
Niacin (mg)	21.8 ± 0.4	24 ± 0.4**	23.1 ± 0.5	26.0 ± 0.6**	<1.00	<1.00	1.95 ± 0.75	<1.00
Folate, DFE (µg)	548 ± 13	565 ± 12	508 ± 13	541 ± 14	2.98 ± 0.98	1.57 ± 0.74	16.1 ± 2.5	10.3 ± 2.5
Vitamin B_6 (mg)	1.76 ± 0.04	1.93 ± 0.04**	1.80 ± 0.05	2.00 ± 0.06*	3.65 ± 1.14	1.73 ± 0.75	10.4 ± 2.1	5.62 ± 1.68
Vitamin B_{12} (µg)	4.65 ± 0.13	5.37 ± 0.14**	4.68 ± 0.12	5.12 ± 0.17*	3.14 ± 0.70	<1.00	7.87 ± 1.28	3.49 ± 1.07**
Vitamin C (mg)	76.8 ± 2.6	79.5 ± 3.1	61.3 ± 2.4	70.0 ± 3.4*	13.9 ± 3.0	15.1 ± 2.8	55.3 ± 3.0	47.3 ± 4.0
Vitamin D (µg)	5.25 ± 0.19	5.93 ± 0.15**	4.45 ± 0.19	4.83 ± 0.16	91.6 ± 1.5	91.1 ± 1.1	95.1 ± 0.9	96.2 ± 0.8
Vitamin E, ATE (mg)	7.9 ± 0.23	7.89 ± 0.19	7.5 ± 0.21	8.03 ± 0.19	69.5 ± 3.0	70.6 ± 3.0	92.3 ± 2.2	92.0 ± 2.0
	AI Nutrients				% above AI			
Potassium (mg)	2125 ± 37	2333 ± 35**	2088 ± 42	2335 ± 48**	30.1 ± 2.2	42.2 ± 2.5**	18.7 ± 2.2	26.5 ± 2.7*
Sodium (mg)	2966 ± 50	3439 ± 51**	3055 ± 54	3635 ± 68**	99.8 ± 0.1	100.0 ± 0.0	98.8 ± 0.5	99.9 ± 0.1*
Choline (mg)	235 ± 5	289 ± 5**	241 ± 6	294 ± 7**	5.91 ± 1.41	15.1 ± 2.1**	<1.00	2.71 ± 0.77

Pork consumers were those adolescents who consumed any amount of pork on either of the two days of dietary recalls, and non-consumers were those who did not. Two days 24-hour dietary recall data from NHANES 2011–2018. 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.

Discussion

The results of the present analysis of NHANES cross-sectional data indicate that adolescent consumers of pork have higher intakes and lower prevalence of inadequacies of key micronutrients, including many "under-consumed nutrients" and "nutrients of public health concern" [4,5] compared to non-consumers. To the best of our knowledge, this is probably the first report to investigate the association of intake of pork with nutrient adequacy in a nationally representative sample of US adolescents.

Adolescence is a critical stage in the life cycle characterized by a period of rapid growth, onset of puberty and maturity, and a transition period from childhood to adulthood and adequate nutrition is therefore extremely important during this period. However, poor diet quality of adolescents lacking in several key nutrients pose a significant public health challenge [4]. A recently published study on the association of beef with nutrient adequacy

[6], reported high (over 50%) prevalence of inadequate intakes of nutrients (Ca, Mg, K, vitamin A, vitamin D and vitamin E) among 14-18 years old male and female adolescents, and consumption of beef was associated with higher intakes and lower prevalence of inadequacy for several of these and other micronutrients. Similar high prevalence (over 60%) of nutritional inadequacy for calcium, choline, magnesium, vitamin D, and vitamin E and their improvement with addition of eggs were also reported in a dietary modeling study [7]. In the present analysis, we find that adolescent pork consumers (age 9-18 years) have higher intakes and lower % below EAR or higher % above AI of calcium, copper, iron, magnesium, phosphorus, zinc, thiamine, riboflavin, niacin, vitamin B_{12}, vitamin D, potassium and choline. Many American adolescents are not consuming the recommended amounts of several nutrients such as calcium, potassium, iron, magnesium, choline, and vitamins A, D, E, and C [5]. Calcium, potassium, dietary fiber, and vitamin D are also considered nutrients of public health concern for the general U.S. population as their low intakes are associated with health concerns [4]. We could not find any other studies examining nutrient intake or the percentage below the EAR/above the AI among adolescent population by pork consumption status. Although, in a limited number of studies, pork has been shown to contribute a significant amount of nutrients in the diets of American adults [17] and its consumption was associated with similar higher nutrient intakes and a lower % below EAR/higher % above AI in some other population groups by us [14] and by others [18,19], none of these studies specifically analyzed pork intake and the % below EAR/above AI among adolescents. In the present study we also separately analyzed the data for young (age 9-13 years) and older (age 14-18 years) adolescents as well as for males and female adolescents aged 9-18 years and pork intake was associated with higher nutrient intakes and lower % below EAR/higher % above AI in both age/gender groups.

Pork consumers also had higher intakes of saturated fat. DGA 2020-2025 has identified saturated fat as a nutrient of concern and recommended limiting intake to less than 10% calories due to its potential role in CVD [4,5]. Lower fat/saturated versions of fresh and processed pork exist and should be the preferred options.

We also estimated the potential impact of pork consumption on population basis. NHANES is a nationally probability sample, and 6,154 adolescents in our study represented 41.5 million adolescents with the 2,861 non-consumers representing 19.7 million adolescents with the 3,293 consumers representing 21.9 million adolescents. Therefore, 1 percentage unit (% unit) change in % below EAR/above AI in non-consumers would translate to additional 200,000 adolescents (1% of 19.7 million represented by 2,861 non-consumers). A decrease in proportion of adolescent population below the EAR for example, for zinc from 25.9% among non-consumers to 12.7% among pork consumers suggest that about 2.6 million adolescent non-consumers would no longer be below the EAR for zinc if they incorporated pork into their diet. However, we need to be clear that this estimate assumes that not only non-consumers consume pork but also consume a diet similar to current pork consumers in all other aspects.

Interestingly, while adolescent pork consumers, as compared to non-consumers, had higher intake for pork specific nutrients such as iron, B-vitamins, zinc, potassium and choline, consumers of pork also had higher intakes of calcium and vitamin D which are not necessarily in pork. This could be due to the overall dietary pattern and the differences in food group intakes such as milk and cheese among pork consumers.

The major strength of our study includes the use of NHANES, a large nationally representative dataset and the use of NCI method to assess usual intake and % below EAR/above AI. Additionally, we used Dietary Reference Intakes and Dietary Guidelines recommended age ranges to define our adolescent population [4,21]. On the other hand, this study has several limitations including the use of cross-sectional analyses of NHANES which cannot be used to assess causal relationships and the use of memory based self-reported dietary recalls which are known to be subject to reporting bias [28]. Although 24-hour dietary recalls collected on two different days were used to define pork consumption status and assess dietary intakes, it is possible participants consumed pork on days other than those reported, which would result in underestimation of pork intake. It is likely that the associations of pork intake with nutrient intakes and adequacy as noted in the present analysis may (at least in some part) also be due to the other dietary differences of pork consumers and non-consumers. Additionally, nutrient intakes were estimated only from foods, and dietary supplements were not included.

Conclusions

The result of this study shows that pork consumption among adolescent population was associated with improved intake and lower % below EAR/higher % above the AI of several nutrients including several nutrients of public health concern and therefore it is likely that pork may play a critical role in decreasing the incidence of under nutrition. These results also suggest that due to the rapid growth and increased nutrient requirement during adolescence, any recommendations to reduce/remove pork from diets must ensure that the nutrients provided by pork are replaced with other dietary changes. Future studies are needed to examine the long-term impact of pork consumption on diet quality, nutrient intake, and health promotion.

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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. 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).

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Conflict of Interests: Sanjiv Agarwal at NutriScience LLC performs consulting for various food and beverage companies and related entities. Victor L. Fulgoni, III at Nutrition Impact LLC performs consulting and database analyses for various food and beverage companies and related entities. Support for this research project was provided by the Pork Checkoff. Pork Checkoff had no role in the analyses/interpretation of results.

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