ACTA SCIENTIFIC NUTRITIONAL HEALTH (ISSN:2582-1423)

Volume 5 Issue 1 January 2021

Research Article

Trends in Orange Juice Consumption and Nutrient Adequacy in Adults 2003-2016

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Received: November 25, 2020

Published: December 22, 2020

Abstract

Introduction: No studies have looked at trends in nutrient intakes, orange juice (OJ) consumption and nutrient adequacy in adults overtime.

Methods: The purpose of this study was to examine secular trends and nutrient intakes, OJ consumption, and nutrient adequacy in adults 19 plus years participating in the 2003-2016 National Health and Nutrition Examination Survey.

Results: Approximately 13% of the total sample consumed OJ with a mean intake of 39.5 g/d (76.2 KJ [0.89% of total energy intake]). Amounts of all 100% fruit juices consumed decreased and whole fruit intake increased from 2003-2016. Intake of total energy, total carbohydrates, added sugars decreased. Intakes of folate, riboflavin, thiamin, and vitamin C decreased and intakes of niacin and vitamin B6 increased. Intakes of iron, sodium, and zinc decreased and intake of calcium, magnesium and phosphorus increased. Percentage of adults below the EAR decreased for ten nutrients (i.e. folate, riboflavin, thiamin, vitamins B6, and D, calcium, iron, magnesium, phosphorous and zinc) and the percent above the AI increased for two nutrients (i.e. dietary fiber and sodium) across the deciles of OJ consumption. OJ, other 100% fruit juices, fruits, breads/rolls/tortillas, and ready-to-eat cereals were major food sources of many nutrients that were consumed at levels below recommendations.

Conclusion: There were changes in intake and nutrient adequacy among adults overtime which varied by OJ consumption. Food patterns varied among consumers and non-consumers suggesting that studies looking at the consumption versus non-consumption of foods need to look at food patterns within the context of the total diet.

Keywords: Orange Juice Consumption; 100% Fruit Juice Consumption; Secular Trends; Nutrient Intake; Nutrient Adequacy; NHANES

Introduction

In 1924 a team of researchers were contracted by the Florida Citrus Commission to provide better juices for the armed forces and to make more efficient use of the Florida's orange crop. This was prompted by an overproduction of citrus fruits resulting in destruction of 30% of trees. In the 1930s the production of orange juice (OJ) exploded, this was due to the industrialization of the US and the use of pasteurization and improved canning processes. By 1986 the growth rate was 32.5% which has dramatically decreased to -5.3% growth rate in 2015 [1]. A possible cause for the dramatic decline in OJ consumption was a result of consumers's concerns over the sugar content in OJ and not being fully aware of the numerous health benefits of OJ.

There has been an emerging debate among scientists that 100% fruit juice (FJ) is worse for health than soda due to the sugar content and the type of sugar, namely fructose. Both soda and 100% FJ

contain approximately 110 calories and 20-26 grams (g) of sugar per cup [2]. Due to their similar sugar contents, some researchers have started grouping juices and soda together, suggesting that they should be avoided to an equal extent. However, soda and juice are unlikely to affect one's health in the same ways [3]. On average FJ has a fructose concentration of about 45.5 g per liter, only a bit less than the average of 50 g per liter for sodas [4]. Majority of studies have shown that high sugar consumption has been related to adverse outcomes [5] and that fructose, which is processed entirely in the liver where it is converted to fat, increases the risk for obesity, diabetes, cardiovascular disease and liver disease [4,6]. This has led to dietary recommendations to limit the intake of added sugars [7]. However, the assertion that fructose intake is related to adverse health outcomes is not universally accepted. The 2020 Dietary Guidelines Advisory Committee reports [7] that 100% FJ "can be part of healthy eating patterns;" however, it recommends that at least half the fruit recommendation consumed as whole fruit since that is a better source of fiber than FJ.

One hundred percent fruit juices (FJ) contribute a variety of key vitamins, minerals, and other bioactive compounds to the diet. FJ provides vitamin C, potassium, thiamin, folate, vitamin B6, and magnesium as well as numerous phytochemicals in varying amounts depending on the type of juice [8,9]. Several studies have investigated the effects of 100 % FJ on nutrient intakes [9-14], diet quality [9,15,16], and health status of consumers [9-11,16-19].

Although considerable work has been published regarding 100% FJ consumption, few studies are available on specific types of 100% FJ. One study did find that among types of 100% FJ examined, citrus juices were the most nutrient dense regardless of type of density measures used in the evaluation [8]. OJ is one of the most popular 100% FJ in the United States. OJ is high in many nutrients, including vitamin C, folate, and potassium. The USDA provides the following information for 250 mL1 cup (8 oz) of OJ: 460 kilojoules (KJ) (110 calories), 2 g of protein, 26 g of carbohydrates, and 67% of the Reference Daily Intake (RDI) for Vitamin C, 15% for folate, 10% for potassium, and 6% for magnesium. Most of the carbohydrates are provided in the form of the naturally occurring sugar fructose [20].

Few studies have looked at the association of OJ consumption on macronutrient intake [21,22], nutrient adequacy [21,23], diet quality and body composition [21,22]. In a critical review [24], the studies confirmed that moderate consumption of 100% citrus juices, specifically OJ, may provide meaningful nutritional benefits without negatively impacting body weight [24]. With regard to health outcomes, OJ consumption did not adversely affect insulin sensitivity, circulating lipids or body weight in adults [25]. Consumption of OJ was not associated with Type 2 diabetes [26-28], cardiovascular disease [29-31], or risk of gout [32]. Few studies have shown the beneficial effects of OJ on blood pressure [33,34], bone health [35], cognitive function [36] and with improved biomarkers of health [17,18].

To determine nutrient adequacy, the 2015 DGAC [5] examined the intake distribution for eleven vitamins and nine minerals using nutrient intake data from a representative sample of the U.S population. Data showed that vitamins A, D, E and C, folate, calcium and magnesium were under-consumed relative to the EAR. Potassium and fiber were under-consumed relative to the Adequate Intake (AI). Calcium, potassium, dietary fiber and vitamin D were considered nutrients of public health concern because low intakes were associated with health concerns. Given that OJ, the predominant 100% FJ consumed, contributed to higher intakes of some of these key nutrients in the diets of adults [9,21,23,24] and per capita consumption has decreased over the past ten years [37], no studies have looked at secular trends in OJ consumption and nutrient adequacy in adults over time. The objective of this study was to examine secular trends in OJ consumption along with trends in nutrient adequacy from 2003-2016 in adults 19+ years (y).

Methods

Study design, subjects, and demographics

Data from the National Health and Nutrition Examination Survey (NHANES) were used to assess dietary intakes of adults aged 19+ y. The NHANES is a cross-sectional survey that uses a complex, multistage, probability sampling procedure to provide nationally representative estimates on the nutritional status of the non-institutionalized US civilian population. Full details of the sampling framework and analytical considerations can be found elsewhere [38,39]. Written informed consent was obtained for all participants as described in the NHANES interviewer procedures manual [40]. The NHANES protocols were approved by the National Center for Health Statistics ethics review board [41]. Because this was a secondary data analysis with a lack of personal identifiers, this study was exempted by the Institutional Review Boards associated with the co-authors.

NHANES 2003-2016 data age 19+ y (n = 40,544) was used after exclusions of unreliable data (n = 4,310) and pregnant or lactating females (n = 1,164); resulting in a total sample of (n = 35,148) Sample-weighted data were used in all statistical analyses [39], and all analyses were performed using SAS 9.4 (SAS Institute, Cary, NC) to adjust the variance for the clustered sample design. Means ± SEs were determined for nutrient intake and food group consumption for each two year cycle of NHANES from 2003-2016.

To obtain an adequate sample size to produce reliable estimates within this age group, data from seven cycles of NHANES (2003-2016) were combined [42,43]. Most demographic information was collected via interviews using cycle appropriate questionnaires [44,45]. Household poverty income ratio (PIR) was classified into three categories: <1.35, 1.35≤1.85 and >1.85. Weight, and height were obtained using the NHANES Anthropometry Procedures Manual [46]. Body mass index (BMI) was calculated as body weight (kg) divided by height (m^2). Adults with a BMI of 25 to 29.9 and ≥ 30 were considered overweight or obese, respectively National Heart, Lung, and Blood Institute [47]. Each participant self-reported their race or ethnic group according to pre-defined categories used in the NHANES.

Dietary intake

An in-person 24-h dietary recall was administered by trained interviewers using an Automated Multiple-Pass Method [40] and a second recall was collected via a telephone interview 3-10 days after the in-person interview. Energy and nutrient intake from foods were determined using respective Food and Nutrient Database for Dietary Studies for each NHANES cycle [48] available from total nutrient intake files. Use of supplements was not included in the analyses. Only recall data judged to be complete and reliable by the National Center for Health Statistics staff were included in these analyses. Detailed descriptions of the dietary recalls and data collection are available in the NHANES Dietary Interviewer's Training Manual [49].

OJ consumption was determined using the OJ food codes in the What We Eat In America (WWEIA): 61210000 (OJ, not further specified; 61210010 OJ freshly squeezed, 61210220 OJ, canned, bottled or in a carton, 61210250 OJ with calcium added, canned, bottled or in a carton, 61210620 OJ, frozen (reconstituted with water), 61210720 OJ, frozen, not reconstituted, 61210820 OJ, frozen, with calcium added (reconstituted with water), 67205000 OJ, baby food. Other 100% juices were defined as other citrus juices other than OJ (food category: 7002), apple juices (food category: 7004), and other juices (food category: 7006).

WWEIA food category classification system was used to classify all foods consumed [50]. Categorization at the subgroup level (n = 48) was used to determine the significant contributors to total nutrient intake. Energy and nutrients from each subgroup of foods were summed across the single 24-h dietary recall for all subjects. Total dietary intakes were obtained by summing intakes across all foods. Sources of energy and nutrients were compared for 2003-2004 and 2015-2016 among and between OJ consumers and non-consumers.

Statistical analyses

Usual Intake (UI) of OJ and nutrients was determined using the National Cancer Institute (NCI) method [51]. The NCI macros (Mixtran and Distrib) were used to generate parameter effects after covariate adjustments and to estimate the distribution of UI. The one part NCI model was used for nutrients since these substances are consumed on most days by most subjects. The two part model (frequency and amount) was used for OJ usual intakes. Covariates for these analyses were the day of the week of the 24-h recall [coded as weekend (Friday-Sunday) or weekday (Monday-Thursday)] and sequence of dietary recall (first or second); variance estimates were obtained using the two days of intake with one-day sampling weights. Deciles of OJ consumption were determined based on individual usual intakes with non-consumers in the first decile and consumers of OJ separated in nine relatively equal intake groups

Mean intakes and standard errors were generated separately for each survey cycle for OJ, FJ, other juices, total fruit, whole fruit, macronutrients, and 15 vitamins and minerals associated with OJ intake. Linear regression coefficients for changes over time from 2003-2016 were generated. Usual nutrient intake distribution were generated for each decile of OJ consumption and nutrient adequacy was determined as percentage below the EAR using the cut-point method [52]. The EAR is the amount of a nutrient that is estimated to meet the requirement for a specific criterion of adequacy of half of the healthy individuals of a specific age, and life stage. Where an EAR was not available the AI cut-points were used to determine the percent at or below a certain level of intake [52]. Regression analyses using the mean OJ consumption of each decile was generated to assess changes across OJ consumption levels. P-values for statistical significance were set at $p < 0.05$.

Results

Demographics of consumers and non-consumers of orange juice (OJ) in adults 19+ y (Table1)

Of the total sample (n = 35,148), approximately 13% reported consuming OJ with an average mean intake (SE) of 39.5 (1.24) g/d

Variables	Total Population			Non-consumers, OJ			Consumers, OJ[1]			Cons vs Non-Cons		
	N	Mean	SE	N	Mean	SE	N	Mean	SE	Beta	SE	P value[2]
Orange Juice Cons (%)	35,148	12.66	0.29	30,504	0.00	0.00	4,644	100.00	0.00	.	.	.
Age (Years)	35,148	47.01	0.25	30,504	46.51	0.24	4,644	50.50	0.50	3.99	0.44	<0.0001
Gender = Male (%)	35,148	49.21	0.31	30,504	48.68	0.36	4,644	52.85	0.97	4.17	1.10	0.0003
Ethnicity												
Mexican American (%)	35,148	8.37	0.69	30,504	8.48	0.69	4,644	7.59	0.79	-0.89	0.45	0.0541
Other Hispanic (%)	35,148	4.89	0.41	30,504	4.80	0.42	4,644	5.48	0.50	0.68	0.40	0.0908
Non-Hispanic White (%)	35,148	68.57	1.32	30,504	68.52	1.34	4,644	68.89	1.45	0.37	0.96	0.7010
Non-Hispanic Black (%)	35,148	11.39	0.72	30,504	11.26	0.72	4,644	12.32	0.85	1.06	0.55	0.0555
Other (%)	35,148	6.79	0.37	30,504	6.94	0.39	4,644	5.71	0.46	-1.23	0.48	0.0125
Poverty Income Ratio (PIR)[3]												
<1.35 (%)	32,446	23.27	0.73	28,171	23.52	0.72	4,275	21.60	1.10	-1.91	0.86	0.0288
1.35<= PIR<= 1.85 (%)	32,446	9.75	0.29	28,171	9.73	0.30	4,275	9.91	0.76	0.17	0.80	0.8283
>1.85 (%)	32,446	66.97	0.86	28,171	66.75	0.86	4,275	68.49	1.46	1.74	1.26	0.1691
Physical Activity												
Sedentary	35,144	25.00	0.50	30,501	25.20	0.52	4,643	23.61	0.95	-1.59	0.92	0.0882
Moderate	35,144	36.16	0.40	30,501	35.95	0.40	4,643	37.64	1.14	1.69	1.13	0.1371
Vigorous	35,144	38.83	0.62	30,501	38.85	0.62	4,643	38.74	1.34	-0.10	1.25	0.9349
Percent Overweight or Obese[4]												
Overweight (%)	34,715	33.05	0.42	30,149	32.73	0.45	4,566	35.26	0.93	2.53	0.97	0.0105
Overweight or Obese (%)	34,715	68.54	0.51	30,149	68.94	0.54	4,566	65.76	0.98	-3.19	1.03	0.0025
Obese (%)	34,715	35.49	0.49	30,149	36.22	0.50	4,566	30.50	1.07	-5.72	1.03	<0.0001
Body Mass Index (kg/m^2)	34,715	28.74	0.08	30,149	28.87	0.08	4,566	27.85	0.13	-1.02	0.12	<0.0001
Kilojoules Consumed (KJ)	35,148	9032	34.64	30,504	8959	35.73	4,644	9536	90.33	576.35	92.63	<0.0001
Grams of Food	35,148	3393.68	23.25	30,504	3400.23	24.00	4,644	3348.51	37.64	-51.72	35.82	0.1516

Table 1: Demographics of Consumers and Non-consumers of Orange Juice in Adults (NHANES 2003-2016).

[1]Orange juice consumption, in grams, was determined using all orange juice food codes from the What We Eat in America; consumers were defined as having any consumption of orange juice in the 24 hour dietary recalls

[2]Significance was defined as p<0.05

[3]Self-reported through the National Health And Nutrition Examination Survey questionnaire

[4]In adults, a BMI between 25 kg/m^2 and 29.9 kg/m^2 is considered overweight; and a BMI of 30 kg/m^2 or higher is considered obese

(1.3fl oz), which was equivalent to 76.1(2.4) KJ (18.2 (0.57) Kcal) or 0.89 (0.03) % of total energy intake. OJ consumers were more likely to be older (p = <0.0001), male (p = 0.0003) and less likely to have a PIR<1.35% (p = 0.0288) and to be obese (p = <0.0001), or overweight or obese combined. However, the per- cent of adults overweight was significantly higher among OJ consumers (p = 0.0105); yet, mean BMI was lower (p = <0.0001) compared to non-consumers. OJ consumers consumed more total KJ than non-consumers (p = <0.0001).

Linear trends in fruits and nutrient intakes among adults from NHANES 2003-2016 (Table 2)

- **Fruits:** Although there was no significant trend over time in consumption of total fruits, there was an increase in consumption of whole fruits (β = 0.02 cup eq/cycle, p = <0.0001) and a decrease in consumption of FJ (β = -0.02 g/cycle, p = 0.0044), specifically for both OJ (β = -3.93 g/cycle, p = <0.0001 and 100% other juices (β = -1.46 g/cycle, p = 0.0368).

- **Macronutrients:** Total energy intake (KJ) decreased from 2003-2016 (β = -54 KJ/cycle, p = 0.0013). This was reflected in a decreased intake of carbohydrate (β = -3.06 g/cycle, p = <0.0001) and total sugars (β = -2.91 g/cycle, p = <0.0001), specifically added sugars (β = -0.59 g/cycle, p = <0.0001). Total fiber intake increased (β = 0.34 g/cycle, p = <0.0001). There was no significant trend in intakes of total protein, total fat and saturated fat.

	2003-2004		2005-2006		2007-2008		2009-2010		2011-2012		2013-2014		2015-2016		Linear Trend		
Variable	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Beta[3]**	**SE**	**P value[4]**
Total fruits (cup eq)	0.93	0.05	0.93	0.04	0.96	0.04	1.07	0.02	0.97	0.04	0.89	0.03	0.92	0.04	0.00	0.01	0.6576
Whole fruits (cup eq)	0.56	0.03	0.58	0.02	0.66	0.03	0.74	0.02	0.67	0.02	0.65	0.03	0.69	0.04	0.02	0.01	<0.0001
Fruit juices (cup eq)	0.38	0.03	0.35	0.02	0.30	0.02	0.34	0.01	0.31	0.03	0.26	0.01	0.25	0.01	-0.02	0.00	0.0044
Orange Juice (g)	52.00	4.02	50.90	3.63	38.40	2.62	42.46	2.52	35.27	5.03	30.06	1.86	30.10	2.20	-3.93	0.60	<0.0001
Other 100% Juice (g)	32.55	4.88	31.38	3.59	34.48	2.36	35.87	2.63	35.86	4.34	25.55	1.75	22.97	2.66	-1.46	0.69	0.0368
Total Energy (KJ)	9280	67	9196	142	8883.0	117	8937	84	9209	54	8958	75	8799	88	-54	17	0.0013
Protein (g)	82.87	1.12	85.46	1.32	81.56	1.20	83.10	0.99	83.45	0.69	83.65	0.72	82.39	1.22	-0.11	0.22	0.6024
Carbohydrate (g)	269.69	2.44	261.57	4.14	256.55	3.12	259.37	2.24	266.90	2.08	252.74	2.14	243.82	2.48	-3.06	0.51	<0.0001
Total sugars (g)	127.26	1.68	119.37	2.58	117.48	2.51	117.09	1.27	117.71	1.36	111.41	1.37	105.38	1.70	-2.91	0.35	<0.0001
Added sugars (g)	20.87	0.48	18.81	0.58	18.71	0.72	17.95	0.33	18.34	0.40	17.61	0.38	16.25	0.42	-0.59	0.09	<0.0001
Total fat (g)	83.98	0.83	83.91	1.68	80.86	1.36	79.29	1.01	82.75	0.73	82.79	0.83	84.01	1.14	0.02	0.21	0.9356
Saturated fat (g)	27.61	0.33	28.12	0.59	26.83	0.51	25.97	0.41	26.62	0.37	26.73	0.27	27.49	0.47	-0.11	0.08	0.1814
Dietary fiber (g)	15.51	0.36	15.79	0.29	15.92	0.49	17.00	0.24	18.08	0.33	16.99	0.26	17.17	0.38	0.34	0.07	<0.0001
Folate, DFE (µg)	537.44	10.32	540.10	7.79	535.79	12.88	546.25	7.30	570.77	8.96	527.87	8.29	512.16	9.41	-2.53	1.79	0.1601
Niacin (mg)	24.44	0.33	26.06	0.47	24.95	0.37	25.92	0.30	26.35	0.37	26.56	0.24	26.14	0.52	0.26	0.08	0.0012
Riboflavin (mg)	2.25	0.04	2.30	0.04	2.20	0.05	2.16	0.03	2.18	0.03	2.18	0.03	2.16	0.04	-0.02	0.01	0.0156
Thiamin (mg)	1.66	0.02	1.70	0.03	1.63	0.03	1.66	0.02	1.65	0.02	1.62	0.02	1.58	0.02	-0.01	0.00	0.0014
Vitamin A, RAE (µg)	597.35	15.67	627.24	15.76	611.02	15.84	638.55	12.00	672.82	37.98	635.59	12.34	626.38	13.39	5.71	2.96	0.0561
Vitamin B6 (mg)	1.86	0.03	2.04	0.04	1.97	0.04	2.11	0.03	2.20	0.04	2.21	0.03	2.14	0.05	0.05	0.01	<0.0001
Vitamin C (mg)	86.89	3.30	86.94	2.26	84.02	3.83	88.72	1.71	84.20	3.95	78.48	1.66	79.26	2.56	-1.44	0.53	0.0082
Vitamin D (D2 + D3) (µg)	4.49	0.17	4.59	0.12	4.34	0.12	5.13	0.14	4.70	0.14	4.74	0.15	4.64	0.14	0.04	0.03	0.1666
Calcium (mg)	877.0	17.0	954.0	19.0	933.0	22.0	1016.0	11.0	995.0	15.0	965.0	12.0	948.0	19.0	10.0	3.0	0.0024
Iron (mg)	15.72	0.18	16.18	0.20	15.14	0.32	15.24	0.15	15.77	0.16	14.55	0.13	13.97	0.16	-0.29	0.03	<0.0001
Magnesium (mg)	280.12	4.44	303.85	4.44	293.63	6.91	306.35	2.91	313.93	4.70	304.70	3.29	305.44	5.26	3.41	0.91	0.0003
Phosphorus (mg)	1331.43	17.55	1362.29	20.86	1328.72	23.26	1415.45	14.48	1424.99	11.44	1398.81	12.09	1383.46	21.62	11.37	3.54	0.0017
Potassium (mg)	2720.72	35.46	2744.67	35.54	2634.96	49.60	2774.67	24.85	2792.92	35.59	2653.62	30.29	2626.48	38.89	-11.40	6.92	0.1022
Sodium (mg)	3624.66	33.77	3692.93	51.05	3591.95	57.97	3594.55	31.06	3615.72	25.77	3528.74	31.02	3537.45	41.18	-20.33	7.55	0.0082
Zinc (mg)	12.05	0.20	12.84	0.23	12.04	0.26	11.97	0.16	11.57	0.13	11.19	0.09	11.21	0.19	-0.23	0.04	<0.0001

Table 2: Linear Trends in Fruits[1] and Nutrient Intakes[2] among Adults (19+) from NHANES 2003 to 2016.

[1]Intake of fruits was determined using food codes from the What We Eat In America.

[2]Usual Intake (UI) of nutrients was determined using the National Cancer Institute Method

[3]Linear regression coefficients were generated to access changes over time (2003-2016).

[4]Significance was defined as $p<0.05$.

- **Vitamins:** There was a significant decrease in intakes of folate (β = -2.64 µg/cycle, p = 0.0015, riboflavin (β = -0.02 mg/cycle, p = 0.0156), thiamin (β = -0.01 mg/cycle, p < 0.0014), and vitamin C (β = -1.44 mg/cycle, p < 0.01). In contrast, intakes of niacin (β = 0.26 mg/cycle, p < 0.0012) and vitamin B6 (β = 0.05 mg/cycle, p = <0.0001) increased.
- **Minerals:** Intakes of iron (β = -0.29 mg/cycle, p = <0.0001), sodium (β = -20.33 mg/cycle, p = 0.0082) and zinc (β = -0.23 mg/cycle, p = <0.0001) decreased from 2003-2016. In contrast, intakes of calcium (β = 10.0 mg/cycle, p = 0.0024), magnesium (β = 3.41 mg/cycle, p = 0.0003) and phosphorus (β = 11.37 mg/cycle, p = 0.0017) increased.

Linear trends in nutrient adequacy among adults from NHANES 2003-2016 (Table 3)

	Cutoff	2003-2004		2005-2006		2007-2008		2009-2010		2011-2012		2013-2014		2015-2016		Linear Trend		
Variable[1]	**%[2]**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Beta[3]**	**SE**	**P value[4]**
Protein (g)	EAR (% Below)	2.67	0.57	2.39	0.54	2.07	0.70	1.38	0.46	1.40	0.25	2.18	0.39	1.82	0.34	-0.10	0.10	0.3661
Carbohydrate (g)	EAR (% Below)	0.86	0.15	0.75	0.21	0.85	0.23	0.46	0.11	0.51	0.16	1.14	0.21	1.15	0.30	0.00	0.06	0.9509
Dietary fiber (g)	AI (% Above)	4.01	0.61	4.17	0.54	5.42	0.88	7.40	0.66	9.97	1.15	7.60	0.82	8.37	1.06	0.91	0.20	0.0061
Niacin (mg)	EAR (% Below)	2.20	0.81	2.19	0.71	2.04	0.60	0.93	0.38	1.03	0.19	1.30	0.19	1.99	0.44	-0.05	0.13	0.7359
Thiamin (Vitamin B1) (mg)	EAR (% Below)	7.06	0.84	8.26	0.87	6.56	1.43	4.72	0.65	5.69	0.73	7.53	0.99	8.11	0.96	-0.04	0.31	0.9117
Vitamin A, RAE (mcg)	EAR (% Below)	52.89	1.87	47.34	1.62	48.16	2.51	44.33	1.95	42.62	2.74	45.34	1.44	45.92	1.82	-0.96	0.42	0.0722
Vitamin B6 (mg)	EAR (% Below)	18.01	1.98	13.52	1.30	14.11	1.99	9.22	1.09	8.85	0.73	10.15	0.77	13.19	1.32	-0.73	0.59	0.2660
Vitamin C (mg)	EAR (% Below)	43.12	2.22	42.91	1.69	45.95	3.30	40.89	1.41	46.07	1.85	48.93	1.72	47.35	2.21	1.04	0.54	0.1121
Vitamin D (D2 + D3) (µg)	EAR (% Below)	95.80	0.76	94.17	0.85	95.40	0.55	94.47	0.95	94.94	0.52	94.13	0.79	95.66	0.64	-0.03	0.14	0.8419
Calcium (mg)	EAR (% Below)	53.47	1.67	45.78	1.45	46.44	2.25	38.30	0.95	41.49	1.35	43.91	1.24	45.14	1.48	-0.95	1.00	0.3875
Iron (mg)	EAR (% Below)	4.86	0.30	4.50	0.35	5.40	0.72	4.63	0.37	4.06	0.35	5.73	0.39	6.17	0.51	0.12	0.13	0.3701
Magnesium (mg)	EAR (% Below)	64.75	1.76	55.11	1.47	57.79	3.09	52.43	1.10	50.27	1.55	53.71	1.26	53.34	1.83	-1.40	0.72	0.1071
Phosphorus (mg)	EAR (% Below)	1.98	0.38	1.87	0.39	1.43	0.50	0.42	0.13	0.65	0.13	0.72	0.21	0.79	0.20	-0.11	0.11	0.3543
Potassium (mg)	AI (% Above)	33.42	1.66	34.46	1.16	30.09	2.19	36.40	1.32	36.82	1.50	30.26	1.39	29.55	1.59	-0.58	0.57	0.3562
Riboflavin (Vitamin B2) (mg)	EAR (% Below)	2.60	0.48	2.71	0.38	2.58	0.46	2.56	0.35	2.61	0.39	3.23	0.54	3.14	0.35	0.09	0.04	0.0675
Sodium (mg)	AI (% Above)	99.10	0.35	99.02	0.20	99.16	0.36	99.54	0.24	99.67	0.08	99.20	0.22	98.90	0.22	0.04	0.09	0.6676
Zinc (mg)	EAR (% Below)	13.39	1.37	10.97	0.94	12.93	1.93	13.12	1.31	14.59	1.60	18.95	1.61	17.13	1.40	1.07	0.32	0.0203

Table 3: Linear Trends in percent below the Estimated Average Requirement (EAR) or percent above the Adequate Intake (AI) among adults from NHANES 2003-2016.

[1]Usual Intake (UI) of nutrients was determined using the National Cancer Institute Method

[2]Nutrient adequacy was determined based on the percent below the Estimated Average Requirement (EAR) or above the Adequate Intake (AI)

[3] Linear regression coefficients were generated to access changes over time (2003-2016)

[4]Significance was defined as p<0.05.

The percentage of adults above the AI for dietary fiber increased (β = 0.91g/cycle, p = 0.0061) and the percentage below the EAR for zinc increased (β = 1.07 mg/cycle, p = 0.0203). No significant trend in nutrient adequacy were found among the other nutrients studied.

Percent below EAR or above AI by decile of OJ consumption

Deciles of OJ consumption were determined based on dietary intake data with non-consumers in the first decile and consumers of OJ separated into nine relatively equal groups; mean OJ consumptions of decile 1, decile 5 and decile 10 were 0.216, and 788 g/d. All regression coefficients for assessing change in percentage below the EAR/above the AI across deciles of OJ consumption are presented in supplemental table 1.

- **Folate:** For every gram of OJ consumed the percent of the population with inadequate intake of folate decreased 0.02 percentage units (Figure 1). In other words, for every 120 g (4 fl oz) of OJ consumed the percent of the population with inadequate intake decreased 2.4 percentage points.

Nutrients with an EAR	Beta	SE	p-value
Calcium	-0.06	0.01	0.0001
Folate, DFE	-0.02	0.003	0.0014
Iron	-0.005	0.002	0.0238
Magnesium	-0.05	0.004	<0.0001
Niacin	-0.002	0.001	0.0645
Phosphorus	-0.002	0.001	0.0228
Riboflavin	-0.004	0.002	0.0235
Thiamin	-0.01	0.002	0.0090
Vitamin A	-0.01	0.01	0.0943
Vitamin B6	-0.01	0.003	0.0005
Vitamin C	-0.0001	0.001	0.9137
Vitamin D	-0.01	0.004	0.0165
Zinc	-0.01	0.002	0.0021
Nutrients with an AI			
Dietary Fiber	0.004	0.002	0.0260
Potassium	0.01	0.01	0.4425
Sodium	0.001	0.0003	0.0158

Supplemental Table 1: Regression coefficient for assessing change in % below the EAR/above the AI* across deciles of orange juice consumption-Adults 19+ years.
*EAR: Estimated Average Requirement; AI: Adequate Intake.

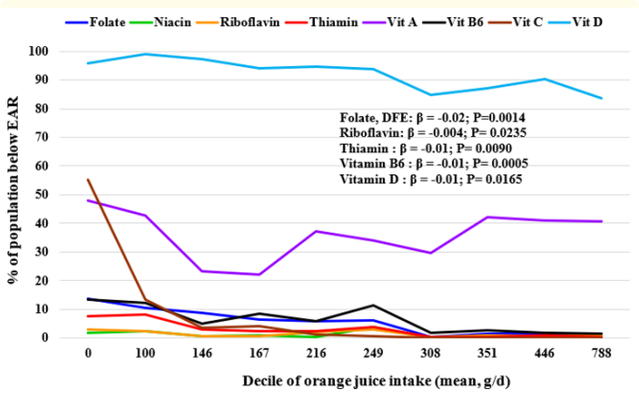

Figure 1: Percentage of Adults 19+ y (National Health And Nutrition Examination Survey 2003–2016) with Intakes Below the Estimated Average Requirement (EAR) for Select Vitamins by Decile of Orange Juice (OJ) Consumption. Regression Analysis (ß: regression coefficient) was Used to Assess if a Linear Association Existed with OJ Consumption. Only Associations Significant at $p < 0.05$ are Presented.

- **Riboflavin:** For every gram of OJ consumed the percent of the population with inadequate intake of riboflavin decreased 0.004 percentage units (Figure 1). In other words, for every 120 g (4 fl oz) of OJ consumed the percent of the population with inadequate intake decreased 0.48 percentage points.

- **Thiamin, vitamins B6 and D**: For all three vitamins, for every gram of OJ consumed the percent of the population with inadequate intake of all three vitamins: decreased 0.01 percentage units (Figure 1). In other words, for every 120g (4 fl oz) of OJ consumed the percent of the population with inadequate intake of each of the three vitamins decreased 1.2 percentage points.

- **Calcium:** For every gram of OJ consumed, the percent of the population with inadequate intake of calcium decreased 0.06 percentage units (Figure 2). In other words, for every 120 g (4 fl oz) of OJ consumed the percent of the population with inadequate intake decreased 7.2 percentage points.

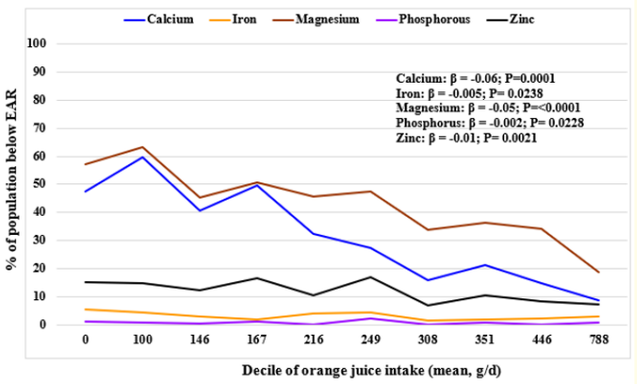

Figure 2: Percentage of Adults 19+ y (National Health And Nutrition Examination Survey 2003–2016) with Intakes Below the Estimated Average Requirement (EAR) for Select Minerals by Decile of Orange Juice (OJ) Consumption. Regression Analysis ß: regression coefficient) was Used to Assess if a Linear Association Existed with OJ Consumption. Only Associations Significant at $p < 0.05$ are Presented.

- **Phosphorus**: For every gram of OJ consumed the percent of the population with inadequate intake of phosphorus decreased 0.002 percentage units (Figure 2). In other words, for every 120 g (4 fl oz) of OJ consumed the percent of the population with inadequate intake decreased 0.24 percentage points.

- **Zinc:** For every gram of OJ consumed the percent of the population with inadequate intake of zinc decreased 0.01 percentage units (Figure 2). In other words, for every 120 g (4 fl oz) of OJ consumed the percent of the population with inadequate intake decreased 1.2 percentage points.

- **Dietary Fiber:** For every gram of OJ consumed the percent of the population above the AI for dietary fiber increased 0.004 percentage units (Figure 3). Thus, for every 120 g (4 fl oz) of OJ consumed the percent of the population with adequate intake increased 0.48 percentage units.

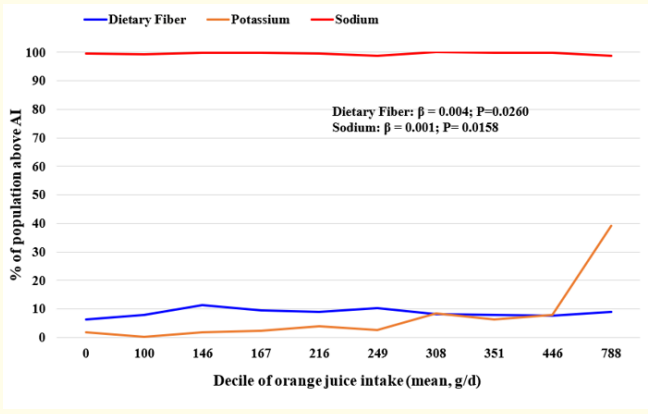

Figure 3: Percentage of Adults 19+ y (National Health And Nutrition Examination Survey 2003–2016) with Intakes Above Adequate Intake (AI) of Orange Juice (OJ) Consumption. Regression Analysis (ß: regression coefficient) was Used to Assess if a Linear Association Existed with OJ Consumption. Only Associations Significant at $p < 0.05$ are Presented.

- **Sodium:** For every gram of OJ consumed the percent of the population above the AI for sodium increased 0.001 percent units (Figure 3). Thus, for every 120 g (4 fl oz) of OJ consumed the percent of the population with adequate intake increased 0.12 percentage units. For other nutrients evaluated (Supplemental Table 1) there were no significant associations of changes in the percentage of the population below the EAR/ above the AI across deciles of OJ intake.

Major food sources of energy and nutrient intake by orange juice consumption and survey year

- **Energy:** The food sources of energy intake by OJ consumption that were significantly different for NHANES survey years 2003-2004 and 2015-2016 are presented in table 4. Only the food sources of energy intake that were significantly different among OJ consumers and non-consumers are presented. Of the increased energy in 2003-2004 among OJ consumers (593 KJ) as compared to non-consumers, mostly was due to consumption of OJ (556 KJ) and other 100% juices (554 KJ),

	2003-2004 Energy Intake (KJ) of Adults 19+ Years of Age						
Significant food groups[1]	**OJ consumers**		**OJ non-consumers[2]**		**OJ consumers vs OJ non-consumers**		
	Mean	**SE**	**Mean**	**SE**	**Beta[3]**	**SE**	**P value[4]**
All Foods	9775	178.78	9182	75.10	593.50	195.56	0.0084
Orange Juice	556	20.92	0	0.00	555.55	20.92	<0.0001
Fruits	294	20.38	170	9.00	123.39	19.62	<0.0001
100% Juice	618	31.25	64	12.01	554.05	31.05	<0.0001
Sweetened Beverages	593	50.46	777	31.30	-184.26	46.48	0.0012
Diet Beverages	6	0.79	11	1.38	-4.81	1.38	0.0032
Meats	283	27.36	358	24.27	-74.73	28.87	0.0205
Breads, Rolls, Tortillas	737	47.11	628	23.89	109.45	44.56	0.0267
Mixed Dishes - Mexican	116	22.38	247	52.51	-130.16	58.91	0.0432
2015-2016 Energy Intake (KJ) of Adults 19+ Years of Age							
All Foods	9663	249.41	8704	98.28	958.47	278.36	0.0036
Orange Juice	598	24.06	0	0.00	597.77	24.06	<0.0001
100% Juice	645	26.28	43	5.31	602.12	26.36	<0.0001
Diet Beverages	3	0.71	8	0.84	-5.19	1.00	0.0001
Flavored or Enhanced Water	1	0.42	3	0.59	-2.59	0.67	0.0018
Ready-to-Eat Cereals	243	33.76	155	10.71	88.12	34.02	0.0205
Candy	93	14.98	140	13.10	-47.57	19.46	0.0273

Breads, Rolls, Tortillas	562	35.94	459	15.31	102.63	43.14	0.0310
Coffee and Tea	122	24.89	183	16.44	-61.00	26.57	0.0364
Fruits	274	27.28	214	12.18	59.45	26.36	0.0395

Table 4: Significant Food Sources of Energy Intake (KJ) of Adults 19+ y of Age by OJ Consumption and by Survey Year.

[1]Intakes of foods was determined using all appropriate food codes from the What We Eat In America

[2]OJ consumption in grams was determined using all orange juice codes from the What We Eat In America

[3]Linear regression coefficients were generated to determine differences between OJ consumers and OJ non-consumers

[4]Significance was defined as $p<0.05$.

whole fruits (123 KJ) and breads/rolls/tortillas (109 KJ) with a concomitant decrease in consumption of sweetened beverages (-184 KJ) and mixed dishes-Mexican (-130 KJ). In 2015-2016, the increased energy intake among OJ consumers (959 KJ) as compared to non-consumers was mostly due to consumption of OJ (598 KJ), other 100% juice (602 KJ) and breads/rolls/tortillas (103 KJ) with a concomitant decrease in consumption of candy (-48 KJ) and coffee/tea (61 KJ).

Significant food sources for all nutrients that showed a significant association of changes in percentage of the population below the EAR/above the AI across deciles of OJ consumption are presented by survey year in supplemental tables 2-13: The significant differences in food sources of iron, magnesium, riboflavin, thiamin, vitamins B6 and D, zinc and dietary fiber among OJ consumers and non-consumers were very small. The most notable differences were found in the food sources of calcium, folate, phosphorus, and sodium. In both survey years, OJ and other 100% juices were the major food sources of calcium, folate, and phosphorus among OJ consumers compared to non-consumers. In 2015-2016, ready-to-eat cereals were a major food source of folate among OJ consumers compared to non-consumers in both survey years, breads/rolls/tortillas were the primary food source of sodium among OJ consumers compared to non-consumers.

	2003-2004 Calcium (mg) of Adults 19+ Years of Age						
Significant food groups	**OJ consumers**		**OJ non-consumers**		**OJ consumers vs OJ non-consumers**		
	Mean	SE	Mean	SE	Beta	SE	P value
All Foods	1028.80	31.68	845.91	18.62	182.90	32.17	<0.0001
Orange Juice	155.13	11.82	0.00	0.00	155.13	11.82	<0.0001
100% Juice	158.21	11.88	2.69	0.45	155.51	11.83	<0.0001
Coffee and Tea	8.68	1.21	15.18	1.93	-6.49	1.76	0.0022
Fruits	10.51	0.91	7.15	0.36	3.36	0.96	0.0033
Mixed Dishes - Mexican	12.93	2.47	30.97	6.21	-18.04	6.14	0.0101
Breads, Rolls, Tortillas	72.61	4.35	61.30	1.95	11.30	4.35	0.0202
Mixed Dishes - Sandwiches (single code)	19.04	4.22	28.72	2.41	-9.68	4.01	0.0290
2015-2016 Calcium (mg) of Adults 19+ Years of Age							
All Foods	1137.08	28.73	926.80	21.30	210.28	35.08	<0.0001
Orange Juice	178.29	14.81	0.00	0.00	178.29	14.81	<0.0001
100% Juice	182.80	14.47	3.48	0.66	179.32	14.43	<0.0001

Diet Beverages	1.30	0.32	4.72	0.44	-3.42	0.52	<0.0001
Crackers	1.80	0.45	3.67	0.32	-1.88	0.55	0.0037
Candy	3.59	0.78	5.84	0.61	-2.25	0.90	0.0241
Alcoholic Beverages	6.72	0.82	9.15	0.54	-2.43	0.98	0.0251
Milk	150.92	15.16	103.93	8.18	46.98	19.30	0.0279
Fruits	13.83	2.25	9.42	0.68	4.41	1.84	0.0303
Ready-to-Eat Cereals	22.39	4.08	12.34	0.89	10.05	4.23	0.0315
Cheese	131.64	9.54	110.04	6.97	21.59	9.17	0.0326

Supplemental Table 2: Significant Food Sources of Calcium (mg) of Adults 19+ Years of Age by Orange Juice (OJ) Consumption and by Survey Year.

	2003-2004 Folate (DFE, mcg) of Adults 19+ Years of Age						
Significant food groups	**OJ consumers**		**OJ non-consumers**		**OJ consumers vs OJ non-consumers**		
	Mean	SE	Mean	SE	Beta	SE	P value
All Foods	637.59	20.22	517.30	10.14	120.29	18.61	<0.0001
Orange Juice	73.04	4.00	0.00	0.00	73.04	4.00	<0.0001
100% Juice	74.71	3.97	2.10	0.42	72.61	3.91	<0.0001
Snack/Meal Bars	1.48	0.52	6.02	0.81	-4.54	0.94	0.0002
Fruits	12.74	1.39	7.60	0.45	5.14	1.30	0.0013
Coffee and Tea	10.39	0.91	14.23	0.81	-3.84	1.38	0.0142
Condiments and Sauces	4.70	0.78	2.73	0.27	1.97	0.75	0.0185
Breads, Rolls, Tortillas	99.40	6.15	83.67	3.11	15.72	6.29	0.0244
Ready-to-Eat Cereals	124.42	18.22	86.42	6.51	38.00	17.09	0.0420
2015-2016 Folate (DFE, mcg) of Adults 19+ Years of Age							
All Foods	637.58	28.93	498.12	10.47	139.47	32.74	0.0007
Orange Juice	58.41	2.16	0.00	0.00	58.41	2.16	<0.0001
100% Juice	59.83	2.11	1.34	0.26	58.49	2.03	<0.0001
Protein and Nutritional Powders	1.78	1.06	9.37	2.15	-7.59	2.71	0.0135
Fruits	13.80	1.83	10.21	0.74	3.59	1.44	0.0249
Ready-to-Eat Cereals	139.39	23.09	80.99	6.59	58.41	24.18	0.0289
Seafood	2.35	0.57	3.27	0.50	-0.91	0.39	0.0334
Cured Meats/Poultry	0.59	0.12	1.12	0.19	-0.53	0.23	0.0348
Sweet Bakery Products	29.13	2.62	23.71	1.09	5.42	2.40	0.0391

Supplemental Table 3: Significant Food Sources of Folate (DFE, mcg) of Adults 19+ Years of Age by Orange Juice (OJ) Consumption and by Survey Year.

	2003-2004 Iron (mg) of Adults 19+ Years of Age						
Significant food groups	**OJ consumers**		**OJ non-consumers**		**OJ consumers vs OJ non-consumers**		
	Mean	SE	Mean	SE	Beta	SE	P value
All Foods	17.87	0.67	15.29	0.17	2.57	0.68	0.0019
Orange Juice	1.14	0.06	0.00	0.00	1.14	0.06	<0.0001
100% Juice	1.24	0.06	0.11	0.02	1.13	0.07	<0.0001
Fruits	0.28	0.02	0.16	0.01	0.12	0.02	0.0002
Sweetened Beverages	0.40	0.03	0.54	0.02	-0.14	0.03	0.0006
Coffee and Tea	0.10	0.01	0.13	0.01	-0.03	0.01	0.0050
Breads, Rolls, Tortillas	2.19	0.13	1.79	0.06	0.40	0.14	0.0130
Ready-to-Eat Cereals	3.22	0.55	1.99	0.13	1.23	0.56	0.0436
2015-2016 Iron (mg) of Adults 19+ Years of Age							
All Foods	15.76	0.60	13.77	0.19	1.98	0.69	0.0112
Orange Juice	0.39	0.01	0.00	0.00	0.39	0.01	<0.0001
100% Juice	0.45	0.03	0.05	0.01	0.40	0.03	<0.0001
Diet Beverages	0.03	0.01	0.08	0.01	-0.05	0.01	0.0020
Coffee and Tea	0.07	0.01	0.10	0.01	-0.03	0.01	0.0036
Protein and Nutritional Powders	0.04	0.03	0.22	0.05	-0.18	0.06	0.0122
Ready-to-Eat Cereals	3.11	0.43	1.83	0.13	1.28	0.46	0.0142
Milk	0.03	0.00	0.02	0.00	0.01	0.00	0.0291
Cured Meats/Poultry	0.18	0.02	0.24	0.02	-0.06	0.03	0.0436

Supplemental Table 4: Significant Food Sources of Iron (mg) of Adults 19+ Years of Age by Orange Juice (OJ) Consumption and by Survey Year.

	2003-2004 Magnesium (mg) of Adults 19+ Years of Age						
Significant food groups	**OJ consumers**		**OJ non-consumers**		**OJ consumers vs OJ non-consumers**		
	Mean	SE	Mean	SE	Beta	SE	P value
All Foods	322.15	8.11	271.67	4.45	50.48	7.23	<0.0001
Orange Juice	33.83	1.28	0.00	0.00	33.83	1.28	<0.0001
100% Juice	36.66	1.65	2.29	0.38	34.37	1.61	<0.0001
Fruits	14.90	1.34	8.15	0.52	6.75	1.34	0.0001
Coffee and Tea	14.14	0.70	20.66	1.25	-6.52	1.35	0.0002
Mixed Dishes - Mexican	3.09	0.46	7.33	1.51	-4.23	1.38	0.0077
Plant-based Protein Foods	28.03	3.15	19.66	1.25	8.36	3.35	0.0247
Breads, Rolls, Tortillas	20.87	1.37	17.79	0.99	3.08	1.27	0.0281
Ready-to-Eat Cereals	12.56	1.85	8.49	0.77	4.07	1.72	0.0321
Meats	6.36	0.68	7.70	0.48	-1.34	0.61	0.0446

2015-2016 Magnesium (mg) of Adults 19+ Years of Age							
All Foods	343.21	10.68	301.21	5.51	42.00	11.01	0.0017
Orange Juice	32.94	1.31	0.00	0.00	32.94	1.31	<0.0001
100% Juice	34.97	1.29	1.74	0.22	33.23	1.28	<0.0001
Diet Beverages	0.34	0.09	1.06	0.10	-0.72	0.13	0.0001
Coffee and Tea	12.75	1.24	20.48	1.50	-7.73	2.16	0.0028
Fruits	14.16	1.55	10.45	0.73	3.71	1.41	0.0192
Breads, Rolls, Tortillas	21.91	2.28	16.16	0.52	5.75	2.23	0.0211
Milk	13.63	1.37	9.36	0.74	4.27	1.72	0.0250

Supplemental Table 5: Significant Food Sources of Magnesium (mg) of Adults 19+ Years of Age by Orange Juice (OJ) Consumption and by Survey Year.

	2003-2004 Phosphorus (mg) of Adults 19+ Years of Age						
Significant food groups	**OJ consumers**		**OJ non-consumers**		**OJ consumers vs OJ non-consumers**		
	Mean	SE	Mean	SE	Beta	SE	P value
All Foods	1402.38	34.82	1317.16	18.95	85.22	36.01	0.0318
Orange Juice	45.16	1.73	0.00	0.00	45.16	1.73	<0.0001
100% Juice	49.51	1.95	3.35	0.56	46.17	1.86	<0.0001
Fruits	19.24	1.69	10.49	0.61	8.75	1.70	0.0001
Coffee and Tea	10.75	1.10	18.41	1.98	-7.66	1.90	0.0011
Diet Beverages	7.01	1.05	12.07	1.32	-5.07	1.57	0.0056
Mixed Dishes - Mexican	19.05	3.54	41.19	8.27	-22.14	8.85	0.0245
Ready-to-Eat Cereals	39.77	6.33	26.08	2.19	13.68	5.73	0.0305
Mixed Dishes - Sandwiches (single code)	28.44	6.10	41.51	3.85	-13.07	5.79	0.0394
Breads, Rolls, Tortillas	76.48	5.34	65.86	3.76	10.63	4.81	0.0431
2015-2016 Phosphorus (mg) of Adults 19+ Years of Age							
All Foods	1506.78	39.37	1369.65	23.15	137.13	43.09	0.0062
Orange Juice	85.65	4.40	0.00	0.00	85.65	4.40	<0.0001
100% Juice	88.61	4.11	2.48	0.34	86.13	4.11	<0.0001
Diet Beverages	3.15	0.82	7.82	0.95	-4.68	1.07	0.0006
Milk	116.84	11.74	79.76	6.30	37.08	14.71	0.0235
Crackers	6.39	1.71	10.70	0.71	-4.31	1.74	0.0257
Ready-to-Eat Cereals	41.00	5.46	27.14	2.10	13.86	5.89	0.0326
Fruits	17.81	1.99	13.73	0.87	4.08	1.84	0.0420
Breads, Rolls, Tortillas	75.12	7.54	59.77	2.44	15.35	6.97	0.0438

Supplemental Table 6: Significant Food Sources of Phosphorus (mg) of Adults 19+ Years of Age by Orange Juice (OJ) Consumption and by Survey Year.

	2003-2004 Riboflavin (mg) of Adults 19+ Years of Age						
Significant food groups	**OJ consumers**		**OJ non-consumers**		**OJ consumers vs OJ non-consumers**		
	Mean	SE	Mean	SE	Beta	SE	P value
All Foods	2.37	0.06	2.23	0.04	0.14	0.04	0.0058
Orange Juice	0.08	0.00	0.00	0.00	0.08	0.00	<0.0001
Fruits	0.05	0.00	0.03	0.00	0.02	0.00	<0.0001
100% Juice	0.09	0.00	0.01	0.00	0.08	0.00	<0.0001
Coffee and Tea	0.17	0.01	0.26	0.02	-0.09	0.02	0.0016
Diet Beverages	0.02	0.00	0.03	0.00	-0.01	0.00	0.0058
Breads, Rolls, Tortillas	0.19	0.01	0.16	0.01	0.03	0.01	0.0105
2015-2016 Riboflavin (mg) of Adults 19+ Years of Age							
All Foods	2.25	0.08	2.16	0.04	0.10	0.08	0.2379
Orange Juice	0.12	0.00	0.00	0.00	0.12	0.00	<0.0001
100% Juice	0.12	0.01	0.00	0.00	0.12	0.00	<0.0001
Diet Beverages	0.01	0.00	0.05	0.01	-0.04	0.01	0.0012
Coffee and Tea	0.18	0.02	0.26	0.01	-0.08	0.02	0.0029
Mixed Dishes - Mexican	0.05	0.01	0.07	0.01	-0.02	0.01	0.0101
Sweetened Beverages	0.04	0.01	0.08	0.01	-0.04	0.01	0.0130
Candy	0.01	0.00	0.01	0.00	0.00	0.00	0.0154
Milk	0.23	0.02	0.16	0.01	0.07	0.03	0.0332
Fruits	0.04	0.00	0.03	0.00	0.01	0.00	0.0403

Supplemental Table 7: Significant Food Sources of Riboflavin (mg) of Adults 19+ Years of Age by Orange Juice (OJ) Consumption and by Survey Year.

	2003-2004 Thiamin (mg) of Adults 19+ Years of Age						
Significant food groups	**OJ consumers**		**OJ non-consumers**		**OJ consumers vs OJ non-consumers**		
	Mean	SE	Mean	SE	Beta	SE	P value
All Foods	1.89	0.04	1.61	0.02	0.28	0.04	<0.0001
Orange Juice	0.20	0.01	0.00	0.00	0.20	0.01	<0.0001
100% Juice	0.21	0.01	0.01	0.00	0.20	0.01	<0.0001
Fruits	0.04	0.00	0.02	0.00	0.02	0.00	0.0002
Coffee and Tea	0.03	0.00	0.04	0.00	-0.01	0.00	0.0022
Diet Beverages	0.00	0.00	0.01	0.00	0.00	0.00	0.0057
Meats	0.05	0.01	0.08	0.01	-0.03	0.01	0.0060
Breads, Rolls, Tortillas	0.28	0.02	0.23	0.01	0.05	0.02	0.0103
2015-2016 Thiamin (mg) of Adults 19+ Years of Age							

All Foods	1.84	0.06	1.55	0.02	0.28	0.07	0.0010
Orange Juice	0.15	0.01	0.00	0.00	0.15	0.01	<0.0001
100% Juice	0.15	0.01	0.01	0.00	0.15	0.01	<0.0001
Diet Beverages	0.00	0.00	0.00	0.00	0.00	0.00	0.0008
Coffee and Tea	0.03	0.00	0.04	0.00	-0.01	0.00	0.0033
Sweet Bakery Products	0.08	0.01	0.06	0.00	0.02	0.01	0.0329
Alcoholic Beverages	0.01	0.00	0.01	0.00	0.00	0.00	0.0345
Fruits	0.04	0.01	0.03	0.00	0.01	0.00	0.0355
Ready-to-Eat Cereals	0.18	0.03	0.12	0.01	0.06	0.03	0.0394

Supplemental Table 8: Significant Food Sources of Thiamin (mg) of Adults 19+ Years of Age by Orange Juice (OJ) Consumption and by Survey Year.

	2003-2004 Vitamin B6 (mg) of Adults 19+ Years of Age						
Significant food groups	**OJ consumers**		**OJ non-consumers**		**OJ consumers vs OJ non-consumers**		
	Mean	SE	Mean	SE	Beta	SE	P value
All Foods	2.18	0.06	1.80	0.03	0.38	0.05	<0.0001
Orange Juice	0.24	0.01	0.00	0.00	0.24	0.01	<0.0001
Fruits	0.15	0.01	0.08	0.01	0.07	0.01	<0.0001
100% Juice	0.27	0.01	0.02	0.00	0.25	0.01	<0.0001
Coffee and Tea	0.00	0.00	0.01	0.00	0.00	0.00	0.0005
Mixed Dishes - Mexican	0.02	0.00	0.05	0.01	-0.02	0.01	0.0338
Ready-to-Eat Cereals	0.31	0.04	0.21	0.01	0.09	0.04	0.0360
Mixed Dishes - Sandwiches (single code)	0.04	0.01	0.05	0.00	-0.02	0.01	0.0404
2015-2016 Vitamin B6 (mg) of Adults 19+ Years of Age							
All Foods	2.40	0.09	2.11	0.05	0.29	0.09	0.0059
Orange Juice	0.22	0.01	0.00	0.00	0.22	0.01	<0.0001
100% Juice	0.23	0.01	0.01	0.00	0.22	0.01	<0.0001
Diet Beverages	0.00	0.00	0.06	0.02	-0.06	0.02	0.0070
Plant-based Protein Foods	0.04	0.00	0.06	0.01	-0.02	0.01	0.0145
Flavored or Enhanced Water	0.00	0.00	0.01	0.00	-0.01	0.00	0.0202
Other	0.00	0.00	0.00	0.00	0.00	0.00	0.0276
Milk	0.05	0.00	0.03	0.00	0.01	0.01	0.0281
Candy	0.00	0.00	0.00	0.00	0.00	0.00	0.0301
Fruits	0.13	0.01	0.10	0.01	0.03	0.01	0.0341

Supplemental Table 9: Significant Food Sources of Vitamin B6 (mg) of Adults 19+ Years of Age by Orange Juice (OJ) Consumption and by Survey Year.

	2003-2004 Vitamin D (D2 + D3) (µg) of Adults 19+ Years of Age						
Significant food groups	**OJ consumers**		**OJ non-consumers**		**OJ consumers vs OJ non-consumers**		
	Mean	SE	Mean	SE	Beta	SE	P value
All Foods	4.82	0.33	4.42	0.17	0.40	0.33	0.2467
Orange Juice	0.00	0.00	0.00	0.00	.	.	.
Mixed Dishes - Mexican	0.01	0.00	0.03	0.01	-0.02	0.01	0.0085
Coffee and Tea	0.02	0.01	0.07	0.02	-0.05	0.02	0.0136
White Potatoes	0.02	0.00	0.04	0.00	-0.01	0.00	0.0157
Cooked Grains	0.00	0.00	0.00	0.00	0.00	0.00	0.0182
Sweetened Beverages	0.03	0.01	0.05	0.01	-0.02	0.01	0.0266
Poultry	0.04	0.01	0.05	0.00	-0.01	0.01	0.0413
2015-2016 Vitamin D (D2 + D3) (µg) of Adults 19+ Years of Age							
All Foods	5.49	0.23	4.54	0.16	0.95	0.30	0.0060
Orange Juice	0.70	0.07	0.00	0.00	0.70	0.07	<0.0001
100% Juice	0.70	0.07	0.00	0.00	0.70	0.07	<0.0001
Alcoholic Beverages	0.00	0.00	0.01	0.00	-0.01	0.00	0.0054
Mixed Dishes - Sandwiches (single code)	0.12	0.02	0.17	0.01	-0.05	0.02	0.0134
Protein and Nutritional Powders	0.02	0.01	0.11	0.03	-0.09	0.04	0.0191
Milk	1.54	0.16	1.07	0.08	0.47	0.21	0.0371

Supplemental Table 10: Significant Food Sources of Vitamin D (D2 + D3) (µg) of Adults 19+ Years of Age by Orange Juice (OJ) Consumption and by Survey Year.

	2003-2004 Zinc (mg) of Adults 19+ Years of Age						
Significant food groups	**OJ consumers**		**OJ non-consumers**		**OJ consumers vs OJ non-consumers**		
	Mean	SE	Mean	SE	Beta	SE	P value
All Foods	12.63	0.48	11.94	0.19	0.69	0.43	0.1278
Orange Juice	0.20	0.01	0.00	0.00	0.20	0.01	<0.0001
100% Juice	0.23	0.01	0.02	0.00	0.21	0.01	<0.0001
Fruits	0.12	0.01	0.07	0.00	0.06	0.01	0.0004
Coffee and Tea	0.09	0.01	0.13	0.01	-0.05	0.01	0.0008
Diet Beverages	0.01	0.00	0.01	0.00	-0.01	0.00	0.0035
Snack/Meal Bars	0.03	0.01	0.07	0.01	-0.04	0.01	0.0045
Breads, Rolls, Tortillas	0.59	0.04	0.49	0.02	0.10	0.04	0.0150
Ready-to-Eat Cereals	1.29	0.22	0.82	0.06	0.46	0.21	0.0425
2015-2016 Zinc (mg) of Adults 19+ Years of Age							
All Foods	11.54	0.42	11.17	0.20	0.38	0.47	0.4363

Orange Juice	0.21	0.01	0.00	0.00	0.21	0.01	<0.0001
100% Juice	0.24	0.02	0.02	0.00	0.22	0.02	<0.0001
Diet Beverages	0.00	0.00	0.01	0.00	0.00	0.00	0.0013
Mixed Dishes - Mexican	0.44	0.10	0.65	0.09	-0.21	0.06	0.0032
Breads, Rolls, Tortillas	0.55	0.05	0.42	0.01	0.13	0.05	0.0183
Plain Water	0.07	0.01	0.08	0.00	-0.02	0.01	0.0299
Milk	0.54	0.05	0.37	0.03	0.16	0.07	0.0304
Coffee and Tea	0.10	0.02	0.15	0.01	-0.04	0.02	0.0422

Supplemental Table 11: Significant Food Sources of Zinc (mg) of Adults 19+ Years of Age by Orange Juice (OJ) Consumption and by Survey Year.

	2003-2004 Dietary Fiber (g) of Adults 19+ Years of Age						
Significant food groups	**OJ consumers**		**OJ non-consumers**		**OJ consumers vs OJ non-consumers**		
	Mean	SE	Mean	SE	Beta	SE	P value
All Foods	17.66	0.63	15.07	0.34	2.59	0.48	0.0001
Orange Juice	0.64	0.02	0.00	0.00	0.64	0.02	<0.0001
100% Juice	0.71	0.03	0.05	0.01	0.66	0.03	<0.0001
Fruits	2.20	0.18	1.30	0.07	0.91	0.16	0.0001
Coffee and Tea	0.01	0.00	0.03	0.01	-0.02	0.01	0.0090
Breads, Rolls, Tortillas	2.18	0.14	1.78	0.09	0.40	0.14	0.0095
Mixed Dishes - Mexican	0.24	0.03	0.62	0.16	-0.38	0.14	0.0152
Ready-to-Eat Cereals	1.10	0.17	0.71	0.06	0.39	0.16	0.0255
2015-2016 Dietary Fiber (g) of Adults 19+ Years of Age							
All Foods	19.48	0.80	16.92	0.40	2.56	0.82	0.0068
Orange Juice	0.89	0.04	0.00	0.00	0.89	0.04	<0.0001
100% Juice	0.94	0.04	0.06	0.01	0.88	0.04	<0.0001
Eggs	0.01	0.00	0.02	0.00	-0.02	0.00	0.0002
Cheese	0.00	0.00	0.02	0.00	-0.01	0.00	0.0039
Alcoholic Beverages	0.00	0.00	0.01	0.00	-0.01	0.00	0.0042
Yogurt	0.02	0.01	0.05	0.01	-0.03	0.01	0.0099
Breads, Rolls, Tortillas	1.99	0.18	1.56	0.05	0.43	0.18	0.0303

Supplemental Table 12: Significant Food Sources of Dietary Fiber (g) of Adults 19+ Years of Age by Orange Juice Consumption and by Survey Year.

	2003-2004 Sodium (mg) of Adults 19+ Years of Age						
Significant food groups	**OJ consumers**		**OJ non-consumers**		**OJ consumers vs OJ non-consumers**		
	Mean	SE	Mean	SE	Beta	SE	P value
All Foods	3725.38	84.92	3604.40	38.70	120.98	95.69	0.2254
Orange Juice	6.09	0.23	0.00	0.00	6.09	0.23	<0.0001
Coffee and Tea	11.02	0.86	16.43	1.25	-5.41	1.53	0.0030
Alcoholic Beverages	7.20	0.90	17.06	2.73	-9.86	2.82	0.0033
Breads, Rolls, Tortillas	343.58	20.01	280.61	8.91	62.97	19.59	0.0058
100% Juice	15.49	3.48	6.08	1.67	9.41	3.72	0.0231
Fruits	2.52	0.35	1.65	0.15	0.87	0.37	0.0314
Ready-to-Eat Cereals	79.29	11.00	56.24	3.50	23.05	10.28	0.0405
2015-2016 Sodium (mg) of Adults 19+ Years of Age							
All Foods	3662.01	88.87	3523.51	47.83	138.50	112.96	0.2390
Orange Juice	6.35	0.35	0.00	0.00	6.35	0.35	<0.0001
Diet Beverages	2.72	0.68	11.98	1.36	-9.26	1.35	<0.0001
Breads, Rolls, Tortillas	234.03	14.46	187.04	7.30	46.99	17.06	0.0148
Plain Water	36.07	2.52	43.41	1.89	-7.33	2.70	0.0160
Ready-to-Eat Cereals	63.96	9.30	39.47	2.47	24.49	9.98	0.0268
Coffee and Tea	14.65	1.86	19.79	1.02	-5.14	2.12	0.0286
Milk	56.67	5.52	39.50	3.07	17.17	7.14	0.0295
Sweetened Beverages	30.87	4.30	40.87	2.62	-10.01	4.51	0.0426
Candy	5.72	1.34	9.52	0.98	-3.79	1.71	0.0428
Protein and Nutritional Powders	3.23	1.77	11.48	2.77	-8.25	3.74	0.0435
Plant-based Protein Foods	46.15	9.15	70.10	6.08	-23.95	11.10	0.0476

Supplemental Table 13: Significant Food Sources of Sodium (mg) of Adults 19+ Years of Age by Orange Juice (OJ) Consumption and by Survey Year.

Discussion

Approximately 13% of adults reported consuming OJ with a mean intake of 39.5 g/d (1.3 fl oz) which was equivalent to 76 KJ (18.2 kcal) or 0.89% of total energy intake. On average adults consumed 0.92 cup eq of total fruits (2015-2016); 65% were from whole fruit and 27% from FJ (50% was from OJ). The recommended amount of fruits in the Healthy US-Style Eating Pattern at the 2,000-calorie level is 2 cup eq/d. given that FJ can be part of healthy eating patterns, at least half of the recommended amount of fruits should come from whole fruits because it is higher in fiber than FJ [7] Based on the newly release recommendation the mean amount of total fruits consumed is far below the recommended amount and the proportion of whole fruit compared to FJ consumed is well within the recommended distribution.

The intake of fruits have significantly changed in the diets of adults from 2003-2016. Despite no significant change in consumption of fruits, the consumption of whole fruits increased with a concomitant decrease in consumption of FJ, specifically both OJ and other 100% juices. This is consistent with the latest vital signs report by the Centers for Disease Control and Prevention [51,53].

Nutrient intake in adults has also changed from 2003-2016. Total energy intake decreased along with a decrease in intake of carbohydrates, specifically total sugars and added sugars. Total fiber intake increased with no significant trends in intakes of total protein, total fat, and saturated fat. Intakes of niacin and vitamin B6 increased while intakes of riboflavin, thiamin, and vitamin C decreased. Intakes of calcium, magnesium, and phosphorus increased while intakes of iron, sodium, and zinc decreased. Given that adults are currently under-consuming several nutrients (i.e. vitamins A,D, E, and C, folate, calcium, magnesium, fiber, and potassium), the percent of adults below the EAR or percent above the AI did not change from 2003-2016. The only positive trends were a significant increase in fiber and zinc intakes.

Given that a major focus of this study was on trends in OJ consumption and nutrient adequacy from 2003-2016, the most notable trends were found in the percent below the EAR or above the AI in 12 nutrients across the deciles of OJ consumption, the percent of adults with inadequate intake of folate, riboflavin, thiamin, vitamins B6 and D, calcium, iron, magnesium, phosphorus, and zinc decreased. The largest drop in the percent of adults with inadequate intake was between decile 1 (0 g of OJ consumed) and decile 2 (100-145 g of OJ consumed). The percent of adults above the AI increased for dietary fiber and sodium. Studies have confirmed that OJ consumption increased nutrient adequacy in adults [8-13], specifically that of vitamin C, folate, potassium, and magnesium; all of which are key nutrients in OJ. The trends in nutrient adequacy across the deciles of OJ consumption was shown in nutrients for which OJ is not a significant source; thus, it was important to look at significant food sources of all 12 nutrients (including total energy intake) for OJ consumers compared to non-consumers.

Many studies have looked at differences in nutrient intakes of OJ consumers compared to non-consumers with the implication that any differences were solely from the contribution of OJ consumption [11,12,14,20,28,30,31,34]. Although this was recognized as a limitation, no further analyses were conducted to identify differences in other food sources of nutrients coming from the total diet. Results from this study clearly demonstrate differences in food patterns among OJ consumers and non-consumers which partially explains the differences in nutrient adequacy among the two groups that were part of this study. It is also interesting that the food sources of nutrients among OJ consumers versus non-consumers has also varied over time.

In an effort to better understand the trends in nutrient adequacy by OJ consumption, food sources of the significantly different nutrients were explored for survey year 2003-2004 compared to the survey year 2015-2016. The increased intake of energy in 2003-2004 among OJ consumers as compared to non-consumers was mostly due to consumption of OJ, other 100% juices, fruits, and breads/rolls/tortillas with a concomitant decrease in consumption of sweetened beverages, meats, and mixed dishes-Mexican. In 2015-2016 the increase in energy consumption among OJ consumers compared to non-consumers was mostly due to consumption of OJ, 100% juices, ready-to-eat cereals, bread/rolls/tortillas and fruits with a concomitant decrease in consumption of flavored or enhanced water, candy, and coffee/tea.

The significant food sources of iron, riboflavin, thiamin, vitamins B6 and D, zinc, and fiber among OJ consumers compared to non-consumers were very small for both survey years. The most notable differences were found in the food sources of calcium, folate, phosphorus, and magnesium. For both survey years, the increase in calcium, folate, phosphorus, and magnesium was mostly due to increased consumption of OJ and other 100% juices. The predominant food sources of sodium was from bread/rolls/tortillas for both survey years; higher intakes among OJ consumers.

Strengths of this study include that it encompassed a large nationally representative sample achieved through combining several sets of NHANES releases, use of 2-days of intake and the NCI method to assess UI of OJ and the percentage of the population below recommended levels over time and across levels of OJ consumption. Identifying food sources of energy and nutrients for 2003-2004 and 2015-2016 for OJ consumers and non-consumers provided greater insight into the dietary patterns of these groups and strengthened the identification of OJ as the likely sources of changes in intake while also identify major pattern shifts (e.g., lower sweetened beverage consumption in OJ consumers).

Limitations of this study are that NHANES is a cross-sectional study; thus, cause and effect relationships cannot be determined. Intake was self-reported, and subjects relied on memory of what they ate and underreporting or over-reporting of intake could have occurred. The possibility that self-reported data may include other juice cocktails and drinks that are not in the definition of 100% juice is possible and it is also well documented that energy intakes are under-reported, particularly among over-weight individuals

[54-57]. Finally, examining linear trends in nutrient intake and nutrient adequacy across OJ deciles does not imply that OJ consumption was solely associated with nutrient adequacy of some nutrients. It can be seen that there were differences in other food sources of nutrients among OJ consumers.

In conclusion, there were changes in intake and nutrient adequacy from 2003-2004 to 2015-2016. There were also changes in nutrient adequacy of adults below EAR/above AI across levels of OJ consumption for several key nutrients. These results suggest that consumption of OJ and other 100% juices were major sources of calcium, folate, phosphorus, and magnesium. Finally, food patterns varied among OJ consumers and non-consumers. This finding suggests that studies looking at consumption versus non-consumption of foods need to look at food patterns within the context of the total diet.

Acknowledgements

This work is a publication of the United States Department of Agriculture (USDA/ARS) Children's Nutrition Research Center, Department of Pediatrics, Baylor College of Medicine, Houston, Texas. The contents of this publication do not necessarily reflect the views or policies of the USDA, nor does mention of trade names, commercial products, or organizations imply endorsement from the US government. This research project was supported by the Florida Department of Citrus, and USDA–Agricultural Research Service through specific cooperative agreement 58-3092-5-001.

Authors' Contributions

T.A.N, C.O'N. and V.L.F contributed to the concept development and the overall research plan; V.L.F. contributed to the methodological and statistical aspects of the work; TAN wrote the initial draft; CO'N. and V.L.F. critically reviewed and edited the manuscript; TAN has primary responsibility for the final content. R.S contributed to the technical logistics and editing of the manuscript. All authors read and approved the final manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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