Intake of 100% Fruit Juice Is Associated with Improved Diet Quality of Adults: NHANES 2013–2016 Analysis

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Received: 21 August 2019; Accepted: 14 October 2019; Published: 18 October 2019

Abstract: Fruit intake is generally associated with better diet quality and overall health. This report examined the effect of 100% fruit juice (considered a part of total fruit servings) and its replacement with whole fruit equivalents on nutrient intake and diet quality. National Health and Nutrition Examination Survey 2013–2016 data (24-h dietary recall) from adults 19+ years (n = 10,112) were used to assess the diet quality and nutrient intakes and to isocalorically replace with 100% fruit juice intakes whole fruit equivalents in a modeling analysis. About 15.6% adults were 100% fruit juice consumers. Consumers had higher diet quality (10% higher Healthy Eating Index, HEI 2015 score), and higher intakes of energy, calcium, magnesium, potassium, vitamin C and vitamin D than non-consumers. Consumption of 100% fruit juice was also associated with lower risk of being overweight/obese (−22%) and having metabolic syndrome (−27%). Replacing 100% fruit juice with whole fruits equivalents did not affect nutrient intake except for a modest increase (+6.4%) in dietary fiber. Results show that 100% fruit juice intake was associated with better diet quality and higher nutrient intake. Replacement of 100% fruit juice intake with whole fruit equivalents had no significant effect on nutrients except for dietary fiber.

Keywords: nutrients; healthy eating index; health risk factors; dietary modeling

1. Introduction

Increased fruit and vegetable consumption are associated with a reduced risk of CVD, diabetes and stroke, and their low intake is linked with poor health and increased risk of chronic diseases [1–5]. Fruits and vegetables are important sources of a number of key nutrients, including K, Mg, dietary fiber, folate, and vitamins A and C, and an array of bioactive substances [1,6–8]. Due to their nutritional value, they are consistently recommended by public health authorities globally and increasing their consumption is an important public health goal [9]. Dietary Guidelines for Americans 2015–2020 (DGA) recommends consumption of fruits and vegetables as part of healthy eating pattern [1]. Two or more servings of fruits and three or more servings of vegetables per day are recommended by most nutritional guidelines [2]. Increasing the contribution of fruits to the diets of adults and children is also one of the key objectives of Healthy People 2020 [10]. Despite these recommendations, there is a huge gap between recommendations and consumption. In 2015, only 12.2% U.S. adults (9.2% male and 15.1% females) met fruit intake recommendations and 9.3% adults (7.6% male and 10.9% females) met vegetable intake recommendations [11].

ChooseMyPlate recommends that half of the food on a meal plate should be fruit and vegetables and adults should consume 1.5 to 2 cups equivalent fruit per day depending on age, gender, and
physical activity [6]. The fruit requirement can be met by consuming fresh, frozen, or dried whole fruit, or 100% fruit juice. DGA and MyPlate indicated that one cup of 100% fruit juice can be considered as one cup serving from the Fruit Group and 100% fruit juice in moderation can be part of healthy eating patterns [1,6]. However, there is an ongoing scientific debate on the recommendations for 100% fruit juice intake, especially for children. Concerns have been raised that naturally occurring sugars in 100% fruit juices may cause weight gain similar to those of sugar-sweetened beverages, again especially in children [12–14], however, several studies concluded that 100% fruit juice was not associated with meaningful weight gain [14–16]. Several randomized controlled trials have also suggested a positive or null effect of 100% fruit juice on cardiometabolic risk factors and glucose control [17,18]. A few previous cross-sectional studies also reported that children and adults who consumed 100% fruit juice had better diet quality and nutrient intakes than non-consumers [19–25]. The main purpose of this study was to provide an updated evaluation of the association of 100% fruit juice consumption by consumption level and the effect of replacing 100% fruit juice with whole fruit equivalents on nutrient intake and diet quality using the most recent National Health and Nutrition Examination Survey (NHANES) 2013–2016 database. Secondary aim of this study was to evaluate the association of 100% fruit juice consumption with physiological markers of risk.

2. Methods

2.1. Data Collection

The NHANES is a cross-sectional survey of nationally-representative non-institutionalized civilian population conducted by the National Center for Health Statistics (NCHS) of the Centers for Disease Control and Prevention (CDC) on a continual basis to examine nutrition, diet and health relationship. The data are collected using a complex stratified multistage cluster sampling probability design via an in-home interview for demographic and basic health information, and a comprehensive diet and health examination in a mobile examination center. A detailed description of the subject recruitment, survey design, and data collection procedures are available online [26] and all data obtained from this study are publicly available at: http://www.cdc.gov/nchs/nhanes/. NHANES protocol was approved by the NCHS Ethics Review Board and all participants or proxies provided a signed written informed consent. This study was a secondary data analysis which lacked personal identifiers, therefore, did not require Institutional Review Board review.

2.2. Study Population

Data from adults age 19+ years participating in NHANES 2013–2014, and 2015–2016 (n = 11,776) were used; however, those with unreliable data (n = 1461), primarily incomplete recalls, determined by the United States Department of Agriculture (USDA) and pregnant or lactating females (n = 203) were excluded, and the final sample size was 10,112 adults.

2.3. Estimates of Dietary Intake

Dietary intake data were obtained from in-person 24-h dietary recall interviews that were administered using an automated, multiple-pass (AMPM) method [27]. While two dietary recalls were collected the first day dietary recall was collected with methods that have been validated and as such only this dietary recall was used in all analyses. 100% fruit juice intakes were assessed from 30 available USDA food codes beginning with 612 and 614 (Table 1). Fruit juices reconstituted from concentrate with water were also considered as 100% fruit juice. Juice cocktails, juice punches, juice drinks, or juice beverages and fruit juices with any added sugars were not considered as 100% fruit juice in this study. Fruit juice consumers were defined as those consuming any amount of 100% fruit juice during the first 24-h recall. Participants were dichotomized into consumers and non-consumers of 100% fruit juice; and consumers were further classified into 4 groups based on 100% fruit juice consumption levels: (>0–4 oz, >4–8 oz, >8–12 oz and >12 oz. Energy and nutrient intake were determined by using
the USDA Nutrient Database for Standard Reference Releases in conjunction with the respective Food and Nutrient Database for Dietary Studies for each NHANES cycle [28,29].

Table 1. Food codes of 100% fruit juices and of whole fruit equivalents used for 100% fruit juice replacement.

| Food Code  | Description                                      | Food Code  | Description          |
|------------|--------------------------------------------------|------------|----------------------|
| 61201010   | Grapefruit juice, 100%, freshly squeezed         | 11010100   | Grapefruit, raw      |
| 61201020   | Grapefruit juice, 100%, NS as to form            | 61201025   | Grapefruit juice, 100%, with calcium added |
| 61201220   | Grapefruit juice, 100%, canned, bottled or in a carton |
| 61210000   | Orange juice, 100%, NFS                           | 61210010   | Orange juice, 100%, freshly squeezed |
| 61210220   | Orange juice, 100%, canned, bottled or in a carton |
| 61210250   | Orange juice, 100%, with calcium added, canned, bottled or in a carton |
| 61210620   | Orange juice, 100%, frozen, reconstituted         | 61213220   | Tangerine juice, 100% |
| 61213800   | Fruit juice blend, citrus, 100% juice             | 61402000   | Cranberry juice blend, 100% juice |
| 64100100   | Fruit juice, NFS                                  | 64104010   | Apple cider          |
| 64100110   | Fruit juice blend, 100% juice                    | 64104030   | Apple juice, 100%    |
| 64104600   | Blackberry juice, 100%                           | 64116020   | Grape juice, 100%    |
| 64105400   | Cranberry juice, 100%, not a blend               | 64116060   | Grape juice, 100%, with calcium added |
| 64120010   | Papaya juice, 100%                               | 64124010   | Pineapple, 100%      |
| 64121000   | Passion fruit juice, 100%                        | 64126000   | Pomegranate juice, 100% |
| 64132010   | Prune juice, 100%                                | 64133100   | Watermelon, 100%     |
| 64132050   | Strawberry juice, 100%                           |           |                      |

2.4. Estimates of Diet Quality

Diet quality scores were determined using the USDA Healthy Eating Index-2015 (HEI-2015) [30]. The HEI-2015 contains 13 subcomponents, each reflecting the DGA’s recommendations. Dietary intake was expressed per 1000 kilocalories for all components except for fatty acid ratios (expressed as ratio of unsaturated to saturated fatty acids), saturated fat (expressed as % energy) and added sugars (expressed as % energy). Total vegetables; greens and beans; total fruit, whole fruit; total protein; and seafoods and plant proteins were scored proportionally from 0 to 5 points and all other components (i.e., whole grains; dairy; fatty acids; sodium; refined grains; saturated fat; and added sugars) were scored proportionally from 0 to 10 points. Four components, sodium, refined grains, saturated fat, and added sugars are reverse scored, so that lower intake leads to a higher score, and thus a greater contribution to overall diet quality. The maximum possible score was 100 [30].
2.5. Estimation of Physiological Markers of Risk

Body weight, body mass index (BMI), waist circumference, blood pressure, total cholesterol, LDL-cholesterol (fasting), HDL-cholesterol, triglycerides (fasting), plasma glucose (fasting), glycohemoglobin, and insulin (fasting) were measured using NHANES standard protocols [26]. Homeostasis model assessment: insulin resistance (HOMA-IR) was calculated as: insulin (mU/L) × plasma glucose (mmol/L)/22.5 [31]. The following criteria were used to define risk factors: elevated waist circumference: waist circumference > 102 cm for males, >88 cm for females; elevated blood pressure: systolic BP ≥ 130 mmHg or diastolic BP ≥ 80 mmHg or taking hypertension medication; reduced HDL-cholesterol: HDL-cholesterol < 40 mg/dL for males, <50 mg/dL for females or taking antihyperlipidemic medication; elevated triglycerides: triglycerides ≥ 150 mg/dL or taking antihyperlipidemic medication; elevated plasma glucose: plasma glucose > 100 mg/dL or taking antidiabetic medication; metabolic syndrome: positive diagnosis for 3 or more of the risk factors described above; overweight or obese: BMI ≥ 25 kg/m²; elevated LDL-cholesterol: LDL ≥ 100 mg/dL or taking antihyperlipidemic medication [32,33].

2.6. Dietary Modeling

Intake 100% fruit juice in consumers was isocalorically replaced by whole fruit equivalents (food codes beginning with 611, 631, 632 and 633; Table 1) in the juice modeling analysis. Usual intakes (UI) of nutrients was estimated using the National Cancer Institute (NCI) Method V. 2.1 [34]; the percentage of the population below the Estimated Average Requirement (EAR) or above Adequate Intake (AI) were estimated with two days of intake data in 100% fruit juice consumers before and after replacement.

2.7. Statistics

All analyses were performed using SAS 9.4 (SAS Institute, Cary, NC, USA) software. The data were adjusted for the complex sampling design of NHANES, using appropriate survey weights, strata, and primary sampling units. Day1 dietary/examination weights were used in all analysis except where the outcome was a fasting laboratory variable in which case fasting subsample weights were used.

Mean descriptive data were determined for consumers and non-consumers of 100% fruit juice; differences in groups were determined via t-tests. Least square means (LSM) and standard errors (SE) were generated via regression analyses for energy and nutrient intakes; diet quality; and physiological risk markers in non-consumers and 100% fruit juice consumers (including consumers by consumption level). Analyses were adjusted for age, gender, ethnicity, physical activity level, poverty income ratio level, current smoking status, alcohol and energy intake (except for energy and diet quality) for energy, nutrients and diet quality. BMI was also added to covariate list for all physiological and risk variables except for body weight, BMI, waist circumference, overweight or obese status, elevated waist circumference status and metabolic syndrome. The p-values for trend across fruit juice consumption level in the LSM and odds ratios (OR) analyses were based on models with 100% fruit juice (oz) as a continuous variable. Significant differences before and after isocaloric replacement of 100% fruit juice intakes by whole fruit equivalents in modeling analysis were accessed by a Z-statistic being compared to a normal distribution table.

3. Results

3.1. Demographics

Approximately 15.6% of adults consumed 100% fruit juice and about 1.2%, 4.6%, 4.2%, and 5.7% of adults consumed > 0 to 4 oz/day, >4 to 8 oz/day, >8 to 12 oz/day, and >12 oz/day, respectively. Adult consumers of 100% fruit juice were older, and had lower BMI compared to non-consumers (P < 0.05). A significantly higher proportion of 100% fruit juice consumers were male, Hispanic, non-Hispanic blacks, and lower proportion were non-Hispanic white, of other ethnicity, smokers, obese compared
to non-consumers ($P < 0.05$). All other demographic characteristics evaluated were similar among consumers and non-consumers of 100% fruit juice (Table 2).

### Table 2. Demographics associated with 100% fruit juice consumption in adults (19+ years of age)—NHANES 2013–2016 *

| Variables                  | Non-Consumers | Consumers | P Value | 100% Fruit Juice Consumption Levels (Oz/Day) |
|-----------------------------|---------------|-----------|---------|------------------------------------------------|
|                             |               |           |         | >0 to 4 | >4 to 8 | >8 to 12 | >12 |
| Population (%)              | 84.4 ± 0.5    | 15.6 ± 0.5| 1.16 ± 0.15 | 4.65 ± 0.31 | 4.16 ± 0.20 | 5.67 ± 0.31 |
| Age (years)                 | 47.3 ± 0.4    | 49.8 ± 0.7| 0.0009 | 53.3 ± 2.2 | 55.6 ± 1.1 | 49.4 ± 1.0 | 44.4 ± 1.2 |
| Gender (% Male)             | 48.8 ± 0.7    | 52.6 ± 1.5| 0.0469 | 28.5 ± 6.0 | 46.8 ± 2.8 | 54.9 ± 3.1 | 60.7 ± 2.3 |
| Ethnicity                   |               |           |         |         |         |         |      |
| Non-Hispanic White (%)      | 14.6 ± 1.7    | 17.3 ± 1.9| 0.0077 | 13.9 ± 3.6 | 11.2 ± 2.1 | 17.4 ± 2.6 | 23.0 ± 3.0 |
| Non-Hispanic Black (%)      | 10.6 ± 1.3    | 14.8 ± 1.7| <0.0001 | 15.1 ± 4.0 | 10.8 ± 2.1 | 16.5 ± 2.4 | 16.8 ± 1.8 |
| Asian (%)                   | 5.72 ± 0.80   | 4.76 ± 0.79| 0.0505 | 5.07 ± 1.78 | 4.30 ± 0.98 | 4.86 ± 1.19 | 4.99 ± 0.88 |
| Other (%)                   | 3.50 ± 0.39   | 2.00 ± 0.37| 0.0079 | 2.79 ± 1.49 | 0.81 ± 0.39 | 2.43 ± 0.84 | 2.51 ± 0.58 |
| Physical Activity           |               |           |         |         |         |         |      |
| Sedentary (%)               | 22.1 ± 0.8    | 21.0 ± 1.6| 0.5052 | 27.5 ± 6.3 | 25.2 ± 2.7 | 21.7 ± 2.9 | 15.7 ± 1.8 |
| Moderate (%)                | 35.2 ± 0.7    | 38.2 ± 1.9| 0.1364 | 40.7 ± 6.2 | 39.9 ± 2.9 | 38.3 ± 2.8 | 36.2 ± 3.2 |
| Vigorous (%)                | 42.7 ± 1.0    | 40.8 ± 1.9| 0.3296 | 31.8 ± 5.5 | 34.9 ± 3.0 | 39.9 ± 3.0 | 48.1 ± 3.0 |
| Poverty Income Ratio        |               |           |         |         |         |         |      |
| <1.35 (%)                   | 23.7 ± 1.5    | 24.6 ± 2.4| 0.6397 | 23.6 ± 5.9 | 19.3 ± 2.8 | 24.9 ± 2.8 | 28.9 ± 3.4 |
| 1.35–1.85 (%)               | 10.2 ± 0.7    | 11.3 ± 1.2| 0.4042 | 4.1 ± 1.7 | 13.7 ± 2.3 | 10.4 ± 1.7 | 11.6 ± 1.7 |
| >1.85 (%)                   | 66.1 ± 1.9    | 64.1 ± 2.8| 0.3324 | 72.3 ± 6.4 | 67.0 ± 3.5 | 64.7 ± 3.1 | 59.5 ± 3.6 |
| Smoking Current (% Yes)     | 20.2 ± 0.9    | 11.8 ± 1.3| <0.0001 | 8.2 ± 2.9 | 10.5 ± 2.2 | 10.5 ± 1.6 | 14.5 ± 1.8 |
| Obese (%)                   | 39.5 ± 1.0    | 34.2 ± 1.8| 0.0111 | 27.0 ± 4.8 | 32.1 ± 3.3 | 32.3 ± 2.4 | 38.9 ± 3.0 |
| Overweight (%)              | 32.2 ± 0.6    | 34.4 ± 1.3| 0.1485 | 44.4 ± 7.4 | 34.9 ± 2.9 | 39.7 ± 2.3 | 28.0 ± 2.4 |
| Body Mass Index (kg/m²)     | 29.4 ± 0.2    | 28.4 ± 0.3| 0.0027 | 28.1 ± 0.6 | 28.2 ± 0.5 | 28.7 ± 0.4 | 28.5 ± 0.5 |

* Data is presented as Mean ± Standard Error (SE).

#### 3.2. 100% Fruit Juice Intake

Per capita mean usual intake (a measure of long-term intake) of 100% fruit juice was 0.26 ± 0.01 cups eq/day with a 95th percentile of intake of 1.11 cups eq/day. 100% fruit juice provided on average of 153 ± 4 kcal/day or 7% energy, 138 ± 6 mg/day or 14% calcium, 30.3 ± 0.7 mg/day or 10% magnesium, 480 ± 11 mg/day or 16% potassium, 94.4 ± 1.9 mg/day or 61% vitamin C, 0.83 ± 0.02 g/day or 5% dietary fiber and 29.1 ± 0.7 g/day or 23% total sugars (by definition 100% fruit juice provides zero added sugars) to the consumers on the day of recall.

#### 3.3. Effect of Intake of 100% Fruit Juice on Energy and Nutrients Intake

There were significant differences in energy and nutrient intakes between the 100% fruit juice consumers and the non-consumers (Table 3). Consumers had a significantly higher intake of energy (+8.3%), and energy adjusted carbohydrates (+8.6%), total sugar (+18.1%), calcium (+8.0%), magnesium (+3.3%), potassium (+13.2%), thiamin (+5.1%), folate (+10.1%), vitamins B6 (+6.6%), vitamin C (+143%), Vitamin D (+17.8%) and beta-cryptoxanthin (+70.7%), and lower intakes for added sugars (−14.5%), total fat (−8.9%), protein (−3.9%) and sodium (−4.4%) compared to non-consumers. The intakes of energy, carbohydrates, total sugars, calcium, magnesium, potassium, folate, vitamin B6, vitamin C, vitamin D and beta-cryptoxanthin also increased while the intakes of added sugars, total fat, protein, sodium, riboflavin, niacin, decreased with increasing 100% fruit juice consumption level (Table 3).
Table 3. Energy and nutrients intake associated with 100% fruit juice consumption in adults (19+ years of age, n = 9152)—NHANES 2013-2016 *

| Nutrient                  | Non-Consumers | Consumers | P Value | 100% Fruit Juice Consumption Levels (Oz/Day) |
|---------------------------|---------------|-----------|---------|---------------------------------------------|
|                           |               |           |         | >0 to 4 | >4 to 8 | >8 to 12 | >12     | P group trend |
| Energy (kcal)             | 2088 ± 11     | 2262 ± 31 | <0.0001 | 2021 ± 74 | 2198 ± 63 | 2267 ± 62 | 2366 ± 45 | <0.0001 |
| Carbohydrate (g)          | 243 ± 1       | 264 ± 2   | <0.0001 | 241 ± 5 | 263 ± 4 | 260 ± 3 | 272 ± 4 | <0.0001 |
| Total sugars (g)          | 105 ± 1       | 124 ± 2   | <0.0001 | 95.2 ± 5.2 | 120 ± 4 | 123 ± 3 | 134 ± 3 | <0.0001 |
| Added sugars (tsp eq)     | 17.2 ± 0.3    | 14.7 ± 0.4| <0.0001 | 13.8 ± 1.1 | 17.0 ± 1.0 | 15.4 ± 0.6 | 12.5 ± 0.7 | <0.0001 |
| Dietary fiber (g)         | 17.0 ± 0.2    | 17.3 ± 0.3| 0.4661 | 16.7 ± 0.8 | 17.9 ± 0.6 | 16.3 ± 0.4 | 17.6 ± 0.5 | 0.4908 |
| Total fat (g)             | 84.2 ± 0.4    | 76.7 ± 0.9| <0.0001 | 85.8 ± 2.0 | 77.3 ± 1.3 | 77.2 ± 1.2 | 73.8 ± 1.6 | <0.0001 |
| Cholesterol (mg)          | 296 ± 3       | 289 ± 8   | 0.4742 | 317 ± 16 | 284 ± 1.3 | 274 ± 13 | 300 ± 17 | 0.5822 |
| Protein (g)               | 83.0 ± 0.6    | 79.8 ± 0.7| 0.0024 | 80.9 ± 2.1 | 79.4 ± 1.8 | 82.4 ± 2.0 | 78.0 ± 1.9 | 0.0050 |
| Calcium (mg)              | 940 ± 8       | 1015 ± 11 | <0.0001 | 840 ± 37 | 948 ± 31 | 1083 ± 31 | 1059 ± 24 | <0.0001 |
| Iron (mg)                 | 14.1 ± 0.1    | 14.5 ± 0.3| 0.3345 | 14.1 ± 0.7 | 15.1 ± 0.5 | 14.6 ± 0.4 | 13.9 ± 0.4 | 0.5799 |
| Magnesium (mg)            | 302 ± 2       | 312 ± 4   | 0.0285 | 297 ± 10 | 307 ± 7 | 313 ± 9 | 320 ± 8 | 0.0163 |
| Phosphorus (mg)           | 1384 ± 9      | 1370 ± 10 | 0.2844 | 1310 ± 22 | 1372 ± 24 | 1402 ± 28 | 1358 ± 28 | 0.4451 |
| Potassium (mg)            | 2578 ± 19     | 2918 ± 28 | <0.0001 | 2606 ± 79 | 2749 ± 55 | 2886 ± 65 | 3158 ± 50 | <0.0001 |
| Sodium (mg)               | 3540 ± 17     | 3386 ± 41 | 0.0014 | 3842 ± 255 | 3412 ± 62 | 3398 ± 96 | 3251 ± 65 | <0.0001 |
| Vitamin A, RAE (µg)       | 626 ± 9       | 640 ± 19  | 0.5025 | 708 ± 82 | 660 ± 39 | 691 ± 21 | 570 ± 30 | 0.9135 |
| Thiamin (Vitamin B1) (mg) | 1.58 ± 0.01   | 1.66 ± 0.02| 0.0124 | 1.54 ± 0.05 | 1.64 ± 0.04 | 1.70 ± 0.04 | 1.66 ± 0.05 | 0.0135 |
| Riboflavin (Vitamin B2) (mg) | 2.17 ± 0.01       | 2.13 ± 0.03| 0.1409 | 2.15 ± 0.12 | 2.17 ± 0.06 | 2.24 ± 0.07 | 2.00 ± 0.05 | 0.0418 |
| Niacin (mg)               | 26.2 ± 0.2    | 25.4 ± 0.4| 0.0831 | 25.3 ± 1.2 | 25.7 ± 0.6 | 27.1 ± 0.8 | 23.8 ± 0.8 | 0.0461 |
| Folate, DFE (µg)          | 507 ± 6       | 558 ± 14  | 0.0024 | 493 ± 27 | 574 ± 27 | 588 ± 18 | 558 ± 21 | 0.0021 |
| Vitamin B6 (mg)           | 2.13 ± 0.02   | 2.27 ± 0.05| 0.0115 | 2.15 ± 0.13 | 2.22 ± 0.08 | 2.40 ± 0.09 | 2.23 ± 0.08 | 0.0147 |
| Vitamin C (mg)            | 64.3 ± 1.4    | 156 ± 4   | <0.0001 | 77.6 ± 3.1 | 112 ± 5 | 145 ± 4 | 218 ± 6 | <0.0001 |
| Vitamin D (D2 + D3) (µg)  | 4.56 ± 0.09   | 5.37 ± 0.35| 0.0308 | 4.55 ± 0.39 | 5.05 ± 0.53 | 5.51 ± 0.45 | 5.73 ± 0.78 | 0.0406 |
| Vitamin E as α-tocopherol (mg) | 9.28 ± 13    | 9.08 ± 0.26| 0.4773 | 9.26 ± 0.39 | 9.22 ± 0.43 | 9.35 ± 0.44 | 8.72 ± 0.60 | 0.4171 |
| Total choline (mg)        | 336 ± 2       | 338 ± 6   | 0.7196 | 336 ± 16 | 335 ± 7 | 330 ± 10 | 351 ± 15 | 0.5612 |
| Beta-carotene (mcg)       | 2207 ± 73     | 2359 ± 166| 0.3958 | 3041 ± 575 | 2634 ± 349 | 2456 ± 216 | 1898 ± 256 | 0.9688 |
| Beta-cryptoxanthin (µg)   | 77.9 ± 3.2    | 133 ± 6   | <0.0001 | 85.5 ± 12.9 | 98.3 ± 7.5 | 132 ± 11 | 173 ± 11 | <0.0001 |
| Lycopene (µg)             | 5118 ± 167    | 4743 ± 319| 0.3470 | 4902 ± 898 | 4981 ± 446 | 4632 ± 484 | 4587 ± 618 | 0.3229 |
| Lutein + zeaxanthin (µg)  | 1603 ± 69     | 1696 ± 99 | 0.4927 | 1926 ± 571 | 1510 ± 126 | 1698 ± 159 | 1802 ± 234 | 0.4134 |

* Data adjusted for age, gender, ethnicity, physical activity level, poverty income ratio level, smoking current status, alcohol and kcal (except for energy); and presented as Least Square Mean (LSM) ± Standard Error (SE).
3.4. Effect of Intake of 100% Fruit Juice on Diet Quality

Adult consumers of 100% fruit juice as compared to non-consumers had a 5.0 point or 10% higher ($P < 0.0001$) HEI-2015 (a measure of diet quality) total score and there was a significant group trend ($P < 0.0001$) for increasing HEI-2015 total score with increasing consumption level (Table 4). The HEI 2015 total score of adult consumers were also significantly higher compared to non-consumers when the data was analyzed separately for males and females and for age groups 19–30, 19–50, 31–50, 51–70, 51–99 and 71–99 years (data not presented). The HEI 2015 subcomponent scores for total fruit, whole fruit, whole grain, sodium, saturated fat and added sugar were also significantly higher ($P < 0.05$ for whole grain and $P < 0.01$ for other variables) for consumers compared to non-consumers with a significant group trend ($P < 0.01$) for increasing HEI-2015 subcomponent scores (total fruit, whole fruit, sodium, saturated fat, and added sugar) with increasing 100% fruit juice consumption level (Table 4).

3.5. Effect of Intake of 100% Fruit Juice on Physiological Markers

100% fruit juice adult consumers as compared to non-consumers had a significantly lower BMI (28.3 ± 0.3 vs. 29.5 ± 0.2 kg/m², $P = 0.0009$), body weight (80.4 ± 1.0 vs. 84.0 ± 0.5 kg, $P = 0.0019$), waist circumference (97.9 ± 0.8 vs. 101 ± 0.3 cm, $P = 0.0025$), plasma glucose 106 ± 1 vs. 109 ± 1 mg/dL, $P = 0.0491$), and glycohemoglobin (5.59 ± 0.03% vs. 5.68 ± 0.01%, $P = 0.0035$). Adult consumers of 100% fruit juice also had a significantly lower risk for being overweight or obese (OR = 0.78; 95% CI = 0.65, 0.95; $P = 0.0147$), having an elevated waist circumference (OR = 0.69; 95% CI = 0.56, 0.85; $P = 0.0012$) and metabolic syndrome (OR = 0.73; 95% CI = 0.58, 0.93; $P = 0.0115$) as compared to non-consumers.

3.6. Effect of Isocaloric Replacement of 100% Fruit Juice with Whole Fruit Equivalents

When 100% fruit juice was isocalorically replaced by whole fruit equivalents, there was a significant increase (+6.4%, $P = 0.0008$) in usual intake of fiber (Table 5) for consumers. There was also a significant increase ($P = 0.0102$) % of population with intakes above AI for dietary fiber with replacement. However, the replacement did not significantly affect ($P > 0.05$) usual intake or inadequacy (% population below EAR) or % population above AI for any other nutrients (Table 5).
Table 4. Healthy Eating Index (HEI) 2015 and sub-component scores associated with 100% fruit juice consumption in adults (19+ years of age, \( n = 9152 \))—NHANES 2013–2016 *.

| HEI 2015 Components       | Non-Consumers | Consumers   | \( P \) Value | 100% Fruit Juice Consumption Levels (Oz/Day) |  
|---------------------------|---------------|-------------|---------------|---------------------------------------------|
|                           |               |             |               | >0 to 4 | >4 to 8 | >8 to 12 | >12 | \( P_{\text{group trend}} \) |
| Total score               | 50.4 ± 0.3    | 55.4 ± 0.4  | <0.0001       | 51.9 ± 0.9 | 54.9 ± 0.8 | 54.3 ± 0.9 | 57.4 ± 0.6 | <0.0001 |
| Component 1 (total vegetables) | 3.07 ± 0.03 | 3.05 ± 0.06 | 0.7784        | 3.22 ± 0.22 | 3.34 ± 0.12 | 2.93 ± 0.11 | 2.93 ± 0.09 | 0.3500 |
| Component 2 (greens and beans) | 1.62 ± 0.05 | 1.67 ± 0.11 | 0.6911        | 1.23 ± 0.28 | 1.68 ± 0.18 | 1.73 ± 0.16 | 1.72 ± 0.14 | 0.5074 |
| Component 3 (total fruit)  | 1.63 ± 0.05   | 4.03 ± 0.04 | <0.0001       | 2.63 ± 0.23 | 3.53 ± 0.11 | 4.02 ± 0.07 | 4.76 ± 0.04 | <0.0001 |
| Component 4 (whole fruit) | 2.03 ± 0.05   | 2.35 ± 0.09 | 0.0007        | 2.04 ± 0.34 | 2.59 ± 0.18 | 2.19 ± 0.14 | 2.34 ± 0.14 | 0.0015 |
| Component 5 (whole grains) | 2.61 ± 0.04   | 2.95 ± 0.13 | 0.0125        | 3.91 ± 0.39 | 3.00 ± 0.23 | 2.94 ± 0.24 | 2.69 ± 0.18 | 0.0513 |
| Component 6 (dairy)       | 5.05 ± 0.06   | 4.92 ± 0.09 | 0.2091        | 4.32 ± 0.46 | 5.04 ± 0.22 | 5.24 ± 0.24 | 4.71 ± 0.17 | 0.2301 |
| Component 7 (total protein foods) | 4.25 ± 0.02 | 4.17 ± 0.04 | 0.1083        | 4.40 ± 0.14 | 4.17 ± 0.07 | 4.09 ± 0.09 | 4.18 ± 0.07 | 0.0665 |
| Component 8 (seafood and plant protein) | 2.40 ± 0.05 | 2.34 ± 0.09 | 0.5048        | 2.06 ± 0.26 | 2.28 ± 0.13 | 2.13 ± 0.15 | 2.61 ± 0.15 | 0.9908 |
| Component 9 (fatty acid ratio) | 5.04 ± 0.07 | 4.93 ± 0.12 | 0.4197        | 5.06 ± 0.51 | 5.17 ± 0.27 | 4.67 ± 0.27 | 4.89 ± 0.24 | 0.2866 |
| Component 10 (sodium)    | 4.08 ± 0.05   | 4.79 ± 0.12 | <0.0001       | 3.94 ± 0.61 | 4.53 ± 0.18 | 4.80 ± 0.28 | 5.20 ± 0.18 | <0.0001 |
| Component 11 (refined grain) | 6.26 ± 0.06 | 6.49 ± 0.14 | 0.1517        | 5.87 ± 0.35 | 6.37 ± 0.26 | 6.22 ± 0.25 | 6.94 ± 0.24 | 0.0520 |
| Component 12 (saturated fat) | 5.62 ± 0.06 | 6.38 ± 0.13 | <0.0001       | 5.37 ± 0.36 | 6.44 ± 0.20 | 6.23 ± 0.24 | 6.67 ± 0.21 | <0.0001 |
| Component 13 (added sugar) | 6.72 ± 0.06 | 7.35 ± 0.11 | <0.0001       | 7.83 ± 0.49 | 6.90 ± 0.19 | 7.15 ± 0.17 | 7.77 ± 0.20 | <0.0001 |

* Data adjusted for age, gender, ethnicity, physical activity level, poverty income ratio level, smoking current status, and alcohol; and presented as Least Square Mean (LSM) ± Standard Error (SE).
100% juice in a healthy eating pattern [1]. The rationale for limiting 100% fruit juice intake to only half whole fruit and whole grain are indicative of their higher intakes while higher score for sodium, were significantly higher than that those of non-consumers. A higher HEI-2015 score for total fruit, total fruit, whole fruit, whole grain, sodium, saturated fat and added sugar of 100% fruit juice consumers NHANES 2013–2016 data, we found that the HEI-2015 total scores as well as subcomponent scores for using 13 subcomponents (nine for adequacy and four for moderation) [1]. In the present analysis of HEI-2015 is an indication of better compliance between nutrients [1].

Table 5. Effect of isocaloric replacement of 100% fruit juice with whole fruit equivalents on usual intakes of nutrients and population adequacy for adult (19+ years of age, n = 10,112)—NHANES 2013–2016 *

| Nutrients with EAR | Usual Intakes | P Value (z stat) | % Adults Below EAR | Nutrients with AI | Usual Intakes | P Value (z stat) | % Adults Above AI |
|-------------------|--------------|-----------------|--------------------|-------------------|--------------|-----------------|-------------------|
| Calcium (mg)      | 959 ± 9      | 4.985           | 44.5 ± 1.0         | 45.2 ± 1.0        | 6.273        |
| Carbohydrate (g)  | 249 ± 1      | 0.8444          | 1.17 ± 0.17        | 1.15 ± 0.17       | 0.9556       |
| Folate, DFE (µg)  | 525 ± 5      | 0.6513          | 14.6 ± 0.9         | 14.1 ± 0.9        | 0.7338       |
| Iron (mg)         | 14.5 ± 0.1   | 0.9657          | 5.99 ± 0.32        | 6.05 ± 0.35       | 0.9903       |
| Magnesium (mg)    | 305 ± 3      | 0.8929          | 53.5 ± 1.1         | 53.6 ± 1.1        | 0.919        |
| Niacin (mg)       | 26.3 ± 0.2   | 0.9296          | 1.63 ± 0.22        | 1.63 ± 0.21       | 0.9969       |
| Phosphorus (mg)   | 1393 ± 10    | 0.8442          | 0.74 ± 0.14        | 0.76 ± 0.15       | 0.9214       |
| Protein (g)       | 83.1 ± 0.6   | 0.8694          | 1.97 ± 0.27        | 1.97 ± 0.26       | 0.9987       |
| Riboflavin (B12)  | 2.17 ± 0.02  | 0.8926          | 3.23 ± 0.3         | 3.17 ± 0.29       | 0.8766       |
| Thiamin (B1) (mg)| 1.61 ± 0.01  | 0.3465          | 7.78 ± 0.7         | 7.45 ± 0.7        | 0.7411       |
| Vitamin A, RAE (µg)| 633 ± 8    | 0.6554          | 45.7 ± 1.1         | 44.9 ± 1.2        | 0.6217       |
| Vitamin B6 (mg)   | 2.16 ± 0.02  | 0.9752          | 11.7 ± 0.7         | 11.6 ± 0.7        | 0.9284       |
| Vitamin C (mg)    | 79.4 ± 1.4   | 0.0599          | 48.0 ± 1.4         | 46.3 ± 1.4        | 0.5767       |
| Vitamin D (D2 + D3) (µg) | 4.68 ± 0.08 | 0.4371          | 94.9 ± 0.6         | 95.3 ± 0.5        | 0.5733       |
| Vitamin E as alpha-tocopherol (mg) | 9.25 ± 0.13 | 0.6416          | 79.0 ± 1.2         | 78.4 ± 1.2        | 0.729        |

4. Discussion

In the present analysis of NHANES 2013–2016 using the most recent nationally representative sample of US adults, 100% fruit juice consumption was associated with better nutrient intake and better diet quality, and replacing 100% fruit juice with whole fruits equivalents resulted in only a limited impact on nutrient intake, except for a small increase in dietary fiber.

Approximately 16% of the population consumed 100% fruit juice on the day of recall and the mean per capita usual intake was 0.26 cups equivalent per day. Although there are no specific recommendations for adults for 100% fruit juice consumption, DGA recognized one cup of 100% fruit juice as one cup serving of fruit and indicated that up to half the daily fruit intake may come from 100% juice in a healthy eating pattern [1]. The rationale for limiting 100% fruit juice intake to only half daily fruit intake was that the juice is lower in fiber than whole fruit [1]. In our dietary modeling study, isocaloric replacement of 100% fruit juice with whole fruit equivalents resulted in only a modest (6.4%) increase in usual intake of dietary fiber. An earlier modeling study conducted by USDA for the 2005 Dietary Guidelines Advisory Committee also reported improved fiber intake by replacing juices with fruit for children [35]. The Committee concluded that 100% fruit juice provided higher amounts of several important vitamins and minerals than whole fruits. However, we did not find any significant changes in the usual intakes as well as percentage of the population below the EAR/above the AI of any other nutrients due to replacement of 100% fruit juice with whole fruit equivalents.

Consumers of 100% fruit juice had a better diet quality, as assessed by HEI-2015, in the present analysis. HEI is a validated marker of diet quality commonly used to evaluate diets and dietary interventions [36–38], to validate other nutrition research tools [39] and to understand relationships between nutrients/foods/dietary patterns and health-related outcomes [40–42]. A higher score of HEI-2015 is an indication of better compliance/adherence to key dietary recommendations of the DGA using 13 subcomponents (nine for adequacy and four for moderation) [1]. In the present analysis of NHANES 2013–2016 data, we found that the HEI-2015 total scores as well as subcomponent scores for total fruit, whole fruit, whole grain, sodium, saturated fat and added sugar of 100% fruit juice consumers were significantly higher than that of those non-consumers. A higher HEI-2015 score for total fruit, whole fruit and whole grain are indicative of their higher intakes while higher score for sodium,
saturated fat and added sugars are indicative of their lower intakes [30]. These results are in agreement with earlier cross-sectional studies analyzing older versions of NHANES 2003–2006 [19,20] as well as other data sets [21,22]. In our present analysis, we additionally found a significant trend towards higher HEI 2015 score (total score and specific subcomponents scores) with increasing consumption of 100% fruit juice from <4 oz to >12 oz suggesting that diet quality increased with increasing 100% fruit juice intake. The fact that 100% fruit juice was also associated with increased sub-component scores for whole grain, sodium, and saturated fat suggests fruit juice consumers consume healthier foods/diets.

100% fruit juice consumers had significantly higher intake of calcium, magnesium, potassium, thiamin, folate, vitamins B6, vitamin C, vitamin D and beta-cryptoxanthin and intake of these nutrients (except thiamin) increased with increasing level of 100% fruit juice intake. Many of these nutrients are currently under-consumed and have been identified as “shortfall nutrients” by the DGA [1]. Additionally, the DGA has classified calcium, potassium, and vitamin D as “nutrients of public health concern” due to the fact that their current intakes are low enough to pose a public health concern [1]. Thus, foods containing these nutrients need to be promoted for children and adults. Similar improved intakes of many vitamin and minerals among 100% fruit juice consumers were also reported in earlier cross-sectional studies [19–22]. The consumers of 100% fruit juice had a 154 mg less sodium than non-consumers. High sodium intake has been linked to blood pressure and therefore limiting dietary sodium is an important public health improvement target [1]. The consumers of 100% fruit juice also had a higher energy intake and higher intake total sugar than non-consumers in the present analysis. However, the intake of added sugars was significantly lower in 100% fruit juice consumers, indicating that consumers are probably not consuming as much sugar sweetened beverages. Although 100% fruit juice contains naturally occurring sugars, it has no added sugar. DGA also recommended limiting added sugar to 10% total daily energy intake [1].

Additionally, adult consumers of 100% fruit juice also had lower BMI/body weight and certain metabolic markers, and a reduced risk for obesity and metabolic syndrome. Consumers of 100% orange juice also had lower BMI and cardiometabolic markers in earlier analysis with NHANES 1999–2004 and 2003–2006 [20,43,44], and another database [45]. However, some cross-sectional studies reported no association between 100% fruit juice and BMI among French adults [22], or a positive association among postmenopausal women [46]. It is interesting to note that although compared to non-consumers, 100% fruit juice consumers had 8% more energy intake on the day of the recall, they had about 4% lower BMI/body weight and were at 22% less risk for being overweight/obese in the present analysis. However, as noted above, juice consumers had better diet quality (10% higher HEI-2015 score) than non-consumers. Diet quality may play a significant role in body weight metabolism. However, more research especially using randomized controlled trials are needed to confirm this.

A major limitation of this study is the use of cross-sectional study design, which cannot be used to determine cause and effect. The dietary intake data were self-reported recalls relying on memory, and are potentially subject to reporting bias. While dietary recalls in NHANES were collected using one of the best available and validated methodology, the AMPM method, there are still limitations with it [47]. Finally, a single 24-h recall only provides consumption patterns of the day of recall and may not be sufficient to separate regular consumers from non-consumers [48]. It is also important to recognize that the results from this study do not specifically reflect the effect of fruit juice consumption only, but rather reflect the consumption of fruit juice within the context of the total diet. While we used a number of covariates to adjust our results, we cannot rule out that residual confounding may explain some of the reported associations.

5. Conclusions

Results from this study show that the consumption of 100% fruit juice was associated with better nutrient intake and diet quality and the association was also related to the consumption level. Isoenergetic replacement of 100% fruit juice with whole fruits equivalents had no effect on nutrient intake, except for a small increase in dietary fiber.
**Author Contributions:** The authors' responsibilities were as follows: intellectual conception, S.A., V.L.F.III and D.W.; interpretation of the research, S.A., V.L.F.III and D.W.; and writing and approval of the final manuscript version of the present research, S.A., V.L.F.III and D.W.

**Funding:** The present research was funded and supported by Juice Products Association.

**Acknowledgments:** The views expressed in this manuscript are those of the authors and do not necessarily reflect the position or policy of Juice Products Association.

**Conflicts of Interest:** Sanjiv Agarwal and Victor L. Fulgoni, III are nutrition consultants and provide services to industry. Diane Welland is an employee of Juice Products Association.

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