Consumption of grapefruit is associated with higher nutrient intakes and diet quality among adults, and more favorable anthropometrics in women, NHANES 2003–2008

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Abstract

Background: Dietary guidance recommends consumption of a nutrient-dense diet containing a variety of fruits. The purpose of this study was to estimate usual nutrient intakes and adequacy of nutrient intakes among adult grapefruit consumers and non-consumers, and to examine associations between grapefruit consumption and select health parameters.

Methods: The analysis was conducted with data collected in the National Health and Nutrition Examination Survey (NHANES) 2003–2008. Respondents reporting consumption of any amount of grapefruit or 100% grapefruit juice at least once during the 2 days of dietary recall were classified as grapefruit consumers.

Results: Among adults aged 19+ years with 2 days of dietary recall (n = 12,789), 2.5% of males and 2.7% of females reported consumption of 100% grapefruit juice or fresh, canned, or frozen grapefruit during the recalls. Grapefruit consumers were less likely to have usual intakes of vitamin C (males: 0% vs. 47%; females: 0% vs. 43%; P<0.001) and magnesium (P<0.05) below the estimated average requirement (EAR) compared to non-consumers, and they were more likely to meet adequate intake levels for dietary fiber (P<0.05). Potassium and β-carotene intakes were significantly higher among grapefruit consumers (P<0.001). Diet quality as assessed by the Healthy Eating Index-2005 (HEI-2005) was higher in grapefruit consumers (males: 66.2 [95% CI: 61.0–71.5] vs. 55.4 [95% CI: 54.4–56.4]; females: 71.4 [95% CI: 65.1–77.6] vs. 61.2 [95% CI: 59.8–62.6]). Among women, grapefruit consumption was associated with lower body weight, waist circumference, body mass index (BMI), triglycerides, C-reactive protein (CRP), and higher high-density lipoprotein (HDL) cholesterol (P<0.05). However, risk of being overweight/obese was not associated with grapefruit consumption.

Conclusion: Consumption of grapefruit was associated with higher intakes of vitamin C, magnesium, potassium, dietary fiber, and improved diet quality. Grapefruit may provide a healthful option for adults striving to meet fruit recommendations.

Keywords: grapefruit; juice; citrus; nutrient intake; adults; NHANES; anthropometrics; body weight; BMI
magnesium, vitamin B₆, thiamin, and niacin (5). Pink and white grapefruit juice and orange juice were found to have more favorable nutrient density scores compared with other commonly consumed 100% fruit juices, including apple, grape, pineapple, and prune (6). Similarly, fresh grapefruit (white and pink) tended to have higher nutrient density scores when compared to some commonly consumed fresh fruit such as apples, bananas, and peaches (7).

In addition to vitamins and minerals, citrus fruits also contain several phytonutrients. Grapefruit, particularly pink and red varieties, provide the carotenoids β-carotene and lycopene (8). Grapefruit also provides naringin, a flavonoid in the flavanone subclass (9) that may have cardiovascular benefits (10). In animal studies, naringin has been reported to have beneficial effects on neuroinflammation (11), blood lipids (12), and bone mineral content (13).

Findings from observational studies suggest an association between grapefruit consumption and reduced risk for coronary heart disease mortality (14), and between citrus consumption and decreased acute coronary events (15) or ischemic stroke (16).

Food consumption data collected in the mid-1990s showed that grapefruit juice and grapefruit, including grapefruit in fruit salads, were consumed by approximately 7% of the US population aged 2 years and older at least once in 2 days of dietary recall (17). Little is known about recent consumption of grapefruit by adults, nutrient intakes by consumers of this fruit, and potential associations between consumption of grapefruit and select health parameters. The purpose of this study was to identify patterns of grapefruit (whole fruit and juice) consumption among adults in the United States, and associations between consumption and select indicators of nutrition and health.

**Methods**

**Data source and study population**

Data collected as part of the National Health and Nutrition Examination Surveys (NHANES) conducted in the combined periods 2003–2004, 2005–2006, and 2007–2008 were used to complete this cross-sectional study. NHANES is designed to provide nationally representative nutrition and health data and prevalence estimates for nutrition and health status measures in the United States. Approval for the NHANES data collection was provided by the National Center for Health Statistics (NCHS) Research Ethics Review Board. The sample for this analysis was limited to males and non-pregnant, non-lactating females aged 19 years and older (n = 12,789).

**Dietary intake data**

Information on food consumption was collected via two 24-h dietary recalls in the dietary interview component of NHANES, also known as What We Eat in America (WWEIA; 18–20). Trained dietary interviewers collected detailed information on all foods and beverages consumed by respondents in the preceding 24-h time period (midnight to midnight); recalls may have covered any day of the week, including weekends. A second dietary recall was administered by telephone 3 to 10 days after the first dietary interview, but not on the same day of the week as the first interview. Only adults who provided two complete and reliable dietary recalls meeting criteria for completeness as determined by the NCHS were included in the study population (18–20).

**Identification of grapefruit consumers**

In this analysis, respondents were classified as grapefruit consumers if they reported consumption of any amount of 100% grapefruit juice or fresh, canned, or frozen grapefruit, including ‘grapefruit & orange sections’, at least once during the 2 days of dietary recall. Individuals reporting intake of a fruit salad that may have contained grapefruit or a juice drink blend containing grapefruit juice were not considered to be grapefruit consumers.

None of the food codes representing 100% grapefruit juice or 100% fresh, canned, or frozen grapefruit identified the type of grapefruit by color (i.e. white, pink, or red).

**Nutrient intake data**

The United States Department of Agriculture (USDA) processes food consumption data collected during each WWEIA cycle using the most up-to-date food composition values available at the time. Nutrient intakes for NHANES 2007–2008 were processed using USDA’s Food and Nutrient Database for Dietary Studies, 4.1 (FNDDS 4.1), intakes from 2005–2006 were processed using FNDDS 3.0, and intakes from 2003–2004 were processed using FNDDS 2.0 (21–23). The USDA data files indicate that nutrient values for raw grapefruit represented an unspecified mixture of white, pink, and red varieties, and nutrient values for grapefruit juice represented nutrient concentration data for white grapefruit juice (21–23). Nutrient intakes assessed included energy, protein, carbohydrate, total sugars, dietary fiber, total and saturated fat, cholesterol, and key nutrients in grapefruit, including vitamin A, β-carotene, lycopene, vitamin B₆, folate, vitamin C, calcium, magnesium, and potassium.

**Healthy Eating Index-2005 and food group equivalents**

Healthy Eating Index-2005 (HEI-2005) scores, a measure of overall diet quality (24), and intakes of food groups (excluding grapefruit) were calculated using food group equivalent intake data as provided by the USDA (25, 26).

**Anthropometric data**

During the examination component of NHANES, participants underwent a physical examination that included measurement of height, weight, and waist circumference.
using standardized data collection methods (27–29). Body mass index (BMI, kg/m²) was calculated as weight (kg) divided by height (m) squared. Individuals were categorized as being of healthy (or underweight) bodyweight status or as being of overweight/obese bodyweight status based on criteria from the Centers for Disease Control and Prevention (CDC).

**Physiologic parameter data**

The physical examination component also included collection of blood pressure measurements and blood samples for laboratory analyses (27–29). Repeated blood pressure measurements (up to three measurements each of systolic and diastolic blood pressure) were collected from each participant after resting quietly in a sitting position for 5 min. Blood samples were collected via standardized procedures for assessment of numerous analytes (30–32), including serum total cholesterol and serum high-density lipoprotein (HDL) cholesterol in blood samples from non-fasting subjects. A subset of survey participants provided fasting blood samples, which were analyzed for triglycerides, plasma glucose, and serum insulin. The NHANES data files provide low-density lipoprotein (LDL) cholesterol levels for participants with fasting blood samples derived from measured values of total cholesterol, triglycerides, and HDL cholesterol according to the Friedewald calculation: [LDL cholesterol] = [total cholesterol] – [HDL cholesterol] – [triglycerides/5]. Additional measures in blood samples from non-fasting subjects included C-reactive protein (CRP) and red blood cell (RBC) folate levels; during NHANES 2003–2006, blood samples also were analyzed for serum vitamin A (retinol) and β-carotene (trans and cis forms), and serum vitamin C.

**Demographics and other participant characteristics**

Demographic information and other characteristics including physical activity were used as covariates in analyses of some parameters in the current study. Demographic characteristics including age, sex, race (categorized as non-Hispanic white, non-Hispanic black, Mexican American, other Hispanic, or other), and education level (categorized as less than high school graduate, high school graduate/GED or equivalent, or beyond high school) were self-reported by participants (33–35). Physical activity information was collected as part of the in-home questionnaire (36–38); the survey included questions about participation in vigorous or moderate physical activity for at least 10 min during the previous 30 days in 2003–2004 and 2005–2006 or during the previous week in 2007–2008. Based on the approach recently reported by Zhang and colleagues (39), we categorized participants as physically inactive if they reported no engagement in at least 10 min of moderate or vigorous activity.

**Statistical analyses**

Adults were classified as consumers or non-consumers of grapefruit based on reported food intakes and the definition of grapefruit consumers in this analysis. Among the population of grapefruit consumers, the proportion of consumers by form of grapefruit (fresh, canned/frozen, or juice) and usual intakes were estimated. Usual total nutrient intakes, excluding nutrient intakes from dietary supplements, were estimated for the populations of grapefruit consumers and non-consumers. Usual nutrient intake estimates were generated using Software for Intake Distribution Estimation (C-SIDE, version 1.02, 1997, Department of Statistics, Iowa State University), which accounted for inter- and intra-individual variations in intake (40, 41). The percentage of a population with usual nutrient intakes below life-stage-specific estimated average requirements (EAR) provides a measure of inadequate intakes, while a mean usual intake at or above life-stage-specific adequate intake (AI) levels implies a low prevalence of inadequate intakes (42). Percentages of each population with usual intakes below the EAR were calculated for vitamin A, vitamin B₉, folate, vitamin C, calcium, and magnesium using the cut-point method (42). For potassium and dietary fiber, nutrients for which EARS were not established, the percentages of adults with usual intakes at or above the AI were estimated.

HEI scores were calculated for populations of adult grapefruit consumers and non-consumers using the HEI-2005 scoring standards and analytical support files provided by the CNPP (24, 43). Estimates of 2-day average food group equivalents were calculated from all foods reported consumed other than grapefruit.

Anthropometric measures including weight, waist circumference, and BMI and the odds ratio of grapefruit consumers being overweight or obese (BMI ≥ 25.0) using a logistic regression were estimated for the subpopulations of grapefruit consumers and non-consumers with adjustments for age, sex, race/ethnicity, education, and physical activity.

Mean levels of physiologic measures including systolic and diastolic blood pressure, serum total, HDL and LDL cholesterol, serum triglycerides, plasma glucose, serum insulin, CRP, serum vitamin C, serum vitamin A (retinol), serum β-carotene (cis and trans forms), and RBC folate were estimated for each subpopulation of grapefruit consumers and non-consumers using the HEI-2005 scoring standards and analytical support files provided by the CNPP (24, 43). Estimates of 2-day average food group equivalents were calculated from all foods reported consumed other than grapefruit.

Comparisons of usual nutrient intakes, percentages below the EAR or above the AI, and mean anthropometric and physiologic parameters between populations of grapefruit consumers and non-consumers were conducted using STATA statistical software package version 10 (Stata-Corp, College Station, TX, USA). All summary statistics and analyses were adjusted for the complex survey design of...
Results

Characteristics of grapefruit consumers and non-consumers and mean intakes of grapefruit among consumers

Using the definition of a grapefruit consumer in this analysis, 333 survey respondents aged 19 years and older, representing 2.5% of males and 2.7% of females, were classified as grapefruit consumers (Table 1). Among both males and females, consumers of grapefruit were older and more likely to have an education beyond high school than non-consumers ($P < 0.005$). The percentage of males across race/ethnicity categories differed between consumers and non-consumers of grapefruit ($P = 0.041$). Among males and females, the percentage of adults identified as physically inactive did not differ between consumers and non-consumers of grapefruit. The estimated usual intake of grapefruit was 162 g/day among male consumers of grapefruit and 151 g/day among female consumers. As shown in Fig. 1, male grapefruit consumers were most likely to consume grapefruit in the form of juice, while female consumers of grapefruit were most likely to consume fresh grapefruit.

Nutrition intakes, adequacy of intake, and diet quality among grapefruit consumers and non-consumers

Usual intakes of energy and select nutrients from the total diet were estimated for the populations of grapefruit consumers and non-consumers (Table 2). Energy intakes did not differ between grapefruit consumers and non-consumers. Male and female grapefruit consumers had higher usual intakes of dietary fiber than non-consumers, while total fat, saturated fat, and cholesterol intakes by female grapefruit consumers were lower than intakes by non-consumers. Usual intakes of β-carotene, vitamin C, magnesium, and potassium were higher among both male and female grapefruit consumers than non-consumers. Male grapefruit consumers had significantly higher usual intakes of vitamin A than non-consumers, and vitamin B$_6$ intakes by female grapefruit consumers were higher than intakes by non-consumers.

Adequacy of nutrient intakes is shown in Figs. 2 and 3. Grapefruit consumers were less likely to have usual intakes of vitamin C or magnesium below the EAR, and female grapefruit consumers were less likely to have intakes of vitamins A and B$_6$ below the EAR compared to grapefruit non-consumers (Fig. 2). A higher percentage of grapefruit consumers had intakes of dietary fiber above the AI compared to non-consumers (Fig. 3).

Compared to non-consumers of grapefruit, male and female grapefruit consumers had higher intakes of whole grains and total fruit including 100% fruit juice (other than grapefruit or grapefruit juice), and lower intakes of added sugars ($P < 0.05$) (Table 3). Male consumers of grapefruit

Table 1. Demographics of male and female grapefruit consumers and non-consumers aged 19+ years, NHANES 2003–2008

| Demographics       | Males                        | Females                      |
|--------------------|------------------------------|------------------------------|
|                    | Grapefruit consumers*        | Grapefruit non-consumers     | Grapefruit consumers* | Grapefruit non-consumers |
|                    | (n = 153)                    | (n = 6,237)                  | (n = 180)             | (n = 6,219)              |
| Age (years)        | Mean 52.9, SE 1.64           | Mean 45.4, SE 0.44           | Mean 53.8, SE 2.11    | Mean 47.6, SE 0.38       | $P$ | Mean 0.001, SE 0.003 |
| Education (%)      |                              |                              |                          |                          | $P$ | 0.004 |
| Less than high school | 10, 2.4                      | 18, 1.0                      | 19, 3.3                | 18, 0.9                  | $P$ | <0.001 |
| High school        | 18, 3.8                      | 26, 1.1                      | 10, 2.7                | 26, 0.9                  | $P$ | 0.293 |
| More than high school | 72, 3.8                      | 56, 1.5                      | 72, 3.9                | 56, 1.4                  | $P$ | 0.140 |
| Race/ethnicity (%) |                              |                              |                          |                          | $P$ | 0.041 |
| Non-Hispanic White | 85, 3.6                      | 72, 1.9                      | 70, 4.5                | 73, 2.1                  | $P$ | 0.371 |
| Non-Hispanic Black | 9, 2.5                       | 11, 1.0                      | 13, 3.1                | 12, 1.3                  | $P$ | 0.140 |
| Mexican American   | 3, 1.4                       | 9, 1.0                       | 5, 2.0                 | 7, 0.8                   | $P$ | 0.690 |
| Other Hispanic     | 1, 0.6                       | 3, 0.5                       | 5, 1.8                 | 4, 0.5                   | $P$ | 0.004 |
| Other race         | 2, 1.9                       | 5, 0.5                       | 8, 3.9                 | 4, 0.5                   | $P$ | 0.004 |
| Physically inactive (%) | 30, 5.0                      | 36, 1.4                      | 32, 5.0                | 40, 1.3                  | $P$ | 0.004 |

*Grapefruit consumers reported consumption of 100% grapefruit juice or 100% fresh, canned, or frozen grapefruit at least once on the 2 days of dietary recall.
reported eating more vegetables and less poultry compared to non-consumers of grapefruit, while female consumers of grapefruit had lower intakes of meats and solid fat than non-consumers (Table 3). Among both males and females, grapefruit consumers had significantly higher HEI-2005 scores than non-consumers. Mean HEI-2005 scores for male grapefruit consumers and non-consumers were 66.2 [95% confidence interval (CI): 61.0–71.5] and 55.4 [95% CI: 54.4–56.4], respectively; scores for female grapefruit consumers and non-consumers were 71.4 (95% CI: 65.1–77.6) and 61.2 (95% CI: 59.8–62.6), respectively.

Anthropometric measures of grapefruit consumers and non-consumers

Mean anthropometric measures of grapefruit consumers and non-consumers are shown in Table 4. The anthropometric measures including body weight, waist circumference and BMI were lower among female grapefruit consumers as compared to grapefruit non-consumers. There were no significant differences in risk of being overweight or obese (BMI ≥ 25.0) between grapefruit consumers and non-consumers (males: OR = 0.64 [95% CI: 0.35–1.17, 0.001].

Table 2. Usual dietary intake of select nutrients by male and female grapefruit consumers and non-consumers aged 19+ years, NHANES 2003–2008

| Nutrient | Males | | | | | Females | | | |
|----------|-------|-----|-----|-----|-----|-------|-----|-----|-----|
|          | Grapefruit consumers | | | | | | Grapefruit non-consumers | | | |
|          | (n = 153) | | | | | | (n = 6,237) | | | |
| Energy (kcal) | 2,591 | 83.5 | 2,584 | 14.6 | 0.933 | 1,734 | 34.5 | 1,789 | 8.4 | 0.139 |
| Protein (g) | 98 | 3.57 | 99.7 | 0.57 | 0.714 | 69.3 | 1.64 | 67.8 | 0.39 | 0.393 |
| Carbohydrate (g) | 308 | 8.1 | 306 | 1.8 | 0.825 | 221 | 5.7 | 221 | 1.2 | 0.986 |
| Total sugars (g) | 146 | 4.3 | 140 | 1.3 | 0.209 | 105 | 3.6 | 103 | 0.9 | 0.622 |
| Dietary fiber (g) | 21.9 | 1.02 | 17.5 | 0.19 | <0.001 | 17.1 | 0.60 | 13.9 | 0.17 | <0.001 |
| Total fat (g) | 98.2 | 3.99 | 98.0 | 0.70 | 0.960 | 63.2 | 1.83 | 69.1 | 0.46 | 0.005 |
| Saturated fat (g) | 30.8 | 1.48 | 32.6 | 0.24 | 0.240 | 19.8 | 0.67 | 22.9 | 0.16 | <0.001 |
| Cholesterol (mg) | 368 | 27.2 | 355 | 2.5 | 0.650 | 208 | 7.3 | 230 | 1.5 | 0.003 |
| Vitamin A (mcg RAE) | 906 | 77.5 | 664 | 7.8 | 0.003 | 596 | 20.2 | 570 | 6.7 | 0.189 |
| β-carotene (mcg) | 3,025 | 162.6 | 1,935 | 34.9 | <0.001 | 3,259 | 196.2 | 1,926 | 43.9 | <0.001 |
| Lycopene (mcg) | 2,675 | 1440.1 | 6,860 | 171.9 | 0.203 | 5,145 | 692.2 | 4,924 | 148.6 | 0.759 |
| Vitamin B6 (mg) | 2.38 | 0.076 | 2.32 | 0.017 | 0.518 | 1.79 | 0.056 | 1.62 | 0.014 | 0.004 |
| Folate (mcg DFE) | 635 | 21.6 | 619 | 5.0 | 0.430 | 478 | 20.5 | 464 | 4.7 | 0.527 |
| Vitamin C (mg) | 187.0 | 7.97 | 91.5 | 1.33 | <0.001 | 145.1 | 3.86 | 75.6 | 1.24 | <0.001 |
| Calcium (mg) | 1,038 | 36.2 | 1,036 | 9.5 | 0.945 | 831 | 27.0 | 812 | 7.7 | 0.465 |
| Magnesium (mg) | 381 | 10.6 | 333 | 2.7 | <0.001 | 286 | 9.3 | 252 | 2.6 | 0.001 |
| Potassium (mg) | 3,590 | 58.4 | 3,087 | 20.2 | <0.001 | 2,680 | 52.1 | 2,314 | 17.2 | <0.001 |

*Grapefruit consumers reported consumption of 100% grapefruit juice or 100% fresh, canned, or frozen grapefruit at least once on the 2 days of dietary recall.

Table 2. Usual dietary intake of select nutrients by male and female grapefruit consumers and non-consumers aged 19+ years, NHANES 2003–2008
Physiologic parameters of grapefruit consumers and non-consumers

Mean levels of select physiologic measures among grapefruit consumers and non-consumers also are shown in Table 4. Among adult females, HDL cholesterol was significantly higher among grapefruit consumers compared to non-consumers, and female grapefruit consumers had significantly lower triglyceride and CRP levels than non-consumers. Male grapefruit consumers had significantly higher levels of vitamins C and \( \beta \)-carotene (\( \text{cis} \) and \( \text{trans} \) forms) and significantly lower RBC folate levels than non-consumers.

Discussion

This was the first study to our knowledge to assess grapefruit intake and associations with nutrient intake and nutrient intake adequacy, diet quality, and health parameters in a nationally representative sample of adults. Results from this assessment show that grapefruit is consumed by a relatively small fraction of adults, as slightly fewer than 3% of adults reported consumption of either 100% grapefruit juice or 100% fresh, canned, or frozen grapefruit at least once on 2 days of dietary recall. Among the adults who did report consumption of grapefruit, findings from this cross-sectional study suggest that grapefruit consumption was associated with some positive shifts in nutrient intake, nutrient intake adequacy, and diet quality as measured by the HEI-2005.

The Dietary Guidelines identify, among others, magnesium and vitamins A and C as under-consumed nutrients, and potassium and dietary fiber as nutrients of public concern (1). Mean intakes of magnesium, vitamin C, and potassium were higher among grapefruit consumers than non-consumers. A lower percentage of grapefruit consumers versus non-consumers had intakes of magnesium and vitamin C below the EAR, and grapefruit consumers in this study were more likely to have fiber intakes above the AI level. Grapefruit consumers also had higher intakes of potassium than non-consumers, though the increased intake did not result in a greater proportion of adults meeting recommended potassium intakes. In addition to increased intakes of nutrients to encourage, grapefruit consumers had lower intakes compared to non-consumers of components to limit, namely added sugars (men and women) and saturated fat (women only). Overall, diet quality was higher among grapefruit consumers than non-consumers, including higher intake of fruits other than...
grapefruit. Similar findings were reported in a recent cross-sectional study of nutrient intakes by adult consumers of 100% orange juice; in that study, usual intakes of total fruit, whole grains, folate, magnesium, potassium, fiber, and vitamins A, B6, and C were higher among consumers of 100% orange juice; in that study, usual intakes of grapefruit and white grapefruit juice and contains no lycopene, 686 mcg β-carotene, and 58 mcg vitamin A (45). In contrast, the nutrient composition data of grapefruit used by USDA was based exclusively on the nutrient profile of white grapefruit juice and contains no lycopene, 14 mcg β-carotene, and 2 mcg vitamin A (46). Pink or red grapefruit juice accounted for well over half of total annual retail sales of grapefruit juice since 2004 (Florida Department of Citrus, personal communication), therefore estimates of carotenoid and vitamin A intakes by consumers of grapefruit juice are likely underestimated.

Differences in anthropometric measures and physiologic measures were observed between some adult populations of grapefruit consumers and non-consumers. Female grapefruit consumers had a lower mean body weight, waist circumference, and BMI than non-consumers. These differences in anthropometric measures were not observed among males. Findings from a preliminary intervention study in 91 obese men and women reported that consumption of half of a fresh grapefruit before meals for 12 weeks resulted in significant weight loss and improved insulin resistance among participating adults with metabolic syndrome (47). In a randomized controlled trial of overweight men and women who consumed ½ of a ruby red grapefruit before each of three daily meals for 6 weeks (n = 39, mean age 39.4 years), no effects on body weight or anthropometric measures when compared to a control condition (no grapefruit, n = 32, mean age 44.0 years) were reported (48). However, when compared with baseline values, significant decreases in waist circumference and waist-to-hip ratio were demonstrated in grapefruit consumers. These data suggest that fresh grapefruit or grapefruit juice may not independently affect weight or body composition parameters but when included as part of a reduced calorie diet may provide additional nutritional and health benefits.

Significantly higher levels of HDL cholesterol were observed in the subpopulation of female grapefruit consumers compared to non-consumers. Clinical studies report similar effects of grapefruit on HDL cholesterol. In a study of 85 obese men and women, consumption of 127 g of grapefruit juice daily for 12 weeks as a preload to each of three main meals was associated with a mean HDL cholesterol increase of 4.9 ± 7.5 mg/dL versus a decrease of 2.0 ± 7.2 mg/dL in participants consuming a water preload (P = 0.017); HDL cholesterol also increased by

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**Table 3.** Two-day average intake of food components from foods other than grapefruit by male and female grapefruit consumers and non-consumers aged 19+ years, NHANES 2003–2008

| Food component                        | Males                      | Females                    |
|---------------------------------------|----------------------------|----------------------------|
|                                       | Grapefruit consumers<sup>a</sup> (n = 153) | Grapefruit non-consumers (n = 6,237) | Grapefruit consumers<sup>a</sup> (n = 180) | Grapefruit non-consumers (n = 6,219) |
|                                       | Mean  | SE   | Mean  | SE   | P       | Mean  | SE   | Mean  | SE   | P       |
| Total fruit (cup eq/day)              | 1.6   | 0.14 | 1.0   | 0.03 | <0.001  | 1.3   | 0.08 | 1.0   | 0.03 | <0.001  |
| Total vegetables (cup eq/day)         | 2.1   | 0.11 | 1.8   | 0.02 | 0.026   | 1.7   | 0.11 | 1.5   | 0.02 | 0.097   |
| Total grains (ounce eq/day)           | 7.4   | 0.36 | 7.8   | 0.07 | 0.210   | 5.2   | 0.23 | 5.6   | 0.05 | 0.138   |
| Whole grains (ounce eq/day)           | 1.3   | 0.26 | 0.8   | 0.03 | 0.031   | 0.9   | 0.12 | 0.7   | 0.03 | 0.039   |
| Total dairy (cup eq/day)              | 1.6   | 0.11 | 1.7   | 0.04 | 0.101   | 1.3   | 0.09 | 1.4   | 0.03 | 0.357   |
| Meat/franks (ounce eq/day)            | 3.6   | 0.47 | 3.7   | 0.07 | 0.877   | 1.4   | 0.14 | 2.1   | 0.04 | <0.001  |
| Poultry (ounce eq/day)                | 1.2   | 0.15 | 1.7   | 0.05 | 0.003   | 1.5   | 0.16 | 1.3   | 0.04 | 0.097   |
| Total fish (ounce eq/day)             | 1.1   | 0.26 | 0.7   | 0.04 | 0.158   | 0.9   | 0.20 | 0.5   | 0.03 | 0.080   |
| Eggs (ounce eq/day)                   | 0.7   | 0.10 | 0.6   | 0.01 | 0.298   | 0.4   | 0.04 | 0.4   | 0.01 | 0.982   |
| Nuts/seeds/soy/legumes                | 1.2   | 0.27 | 0.9   | 0.04 | 0.274   | 1.0   | 0.22 | 0.7   | 0.03 | 0.172   |
| Discretionary oil (g/day)             | 23.5  | 1.94 | 21.3  | 0.39 | 0.237   | 15.4  | 1.45 | 16.6  | 0.22 | 0.414   |
| Discretionary solid fat (g/day)        | 48.4  | 3.00 | 53.0  | 0.57 | 0.132   | 30.9  | 1.77 | 37.1  | 0.44 | 0.002   |
| Added sugars (teaspoon/day)            | 17.0  | 1.21 | 21.3  | 0.40 | 0.002   | 12.3  | 0.87 | 15.0  | 0.29 | 0.008   |

<sup>a</sup>Grapefruit consumers reported consumption of 100% grapefruit juice or 100% fresh, canned, or frozen grapefruit at least once on the 2 days of dietary recall.

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### Table 4. Anthropometric and physiologic measures of male and female grapefruit consumers and non-consumers aged 19+ years, NHANES 2003–2008

| Parameterb | Males                      | Females                     |
|-------------|----------------------------|-----------------------------|
|             | Grapefruit consumersa     | Grapefruit non-consumers    | Grapefruit consumersa | Grapefruit non-consumers |
|             | n  | Mean | SE | n  | Mean | SE | n  | Mean | SE | n  | Mean | SE | P  |
| Weight (kg) | 151 | 85.8 | 2.07 | 6,162 | 88.4 | 0.39 | 180 | 70.9 | 1.63 | 6,120 | 75.4 | 0.49 | 0.008 |
| WC (cm)     | 148 | 101.5 | 1.62 | 6,013 | 103.0 | 0.28 | 171 | 90.5 | 1.29 | 5,962 | 94.8 | 0.40 | 0.001 |
| BMI (kg/m²) | 151 | 27.9 | 0.61 | 6,144 | 28.7 | 0.12 | 180 | 27.0 | 0.57 | 6,104 | 28.6 | 0.18 | 0.007 |
| SBP (mm Hg) | 143 | 122 | 1.6 | 6,039 | 124 | 0.4 | 175 | 122 | 1.8 | 5,935 | 122 | 0.3 | 0.957 |
| DBP (mm Hg) | 141 | 72 | 0.9 | 6,015 | 72 | 0.3 | 169 | 72 | 1.3 | 5,894 | 70 | 0.3 | 0.158 |
| Total-C (mmol/L) | 148 | 5.12 | 0.093 | 5,974 | 5.09 | 0.020 | 170 | 5.23 | 0.085 | 5,891 | 5.20 | 0.022 | 0.733 |
| HDL-C (mmol/L) | 148 | 1.26 | 0.042 | 5,974 | 1.23 | 0.007 | 170 | 1.64 | 0.047 | 5,890 | 1.51 | 0.008 | 0.009 |
| LDL-C (mmol/L)e | 57  | 2.92 | 0.121 | 2,600 | 3.00 | 0.019 | 81  | 2.85 | 0.109 | 2,580 | 2.98 | 0.023 | 0.258 |
| Triglyceride (mmol/L)e | 59  | 1.59 | 0.211 | 2,687 | 1.72 | 0.032 | 82  | 1.19 | 0.065 | 2,615 | 1.46 | 0.028 | 0.001 |
| Glucose (mmol/L)e | 59  | 5.66 | 0.229 | 2,699 | 5.88 | 0.038 | 82  | 5.59 | 0.156 | 2,642 | 5.62 | 0.036 | 0.864 |
| Insulin (pmol/L)c | 59  | 59 | 7.2 | 2,679 | 71 | 1.6 | 0.107 | 81  | 57 | 5.6 | 2,596 | 64 | 1.5 | 0.266 |
| CRP (mg/dL) | 148 | 5.12 | 0.093 | 5,974 | 5.09 | 0.020 | 170 | 5.23 | 0.085 | 5,891 | 5.20 | 0.022 | 0.733 |
| Vitamin C (umol/L)d | 97  | 56 | 2.9 | 3,796 | 50 | 0.9 | 98  | 68 | 4.9 | 3,655 | 58 | 1.0 | 0.079 |
| Vitamin A (retinol, umol/L)d | 98  | 2.3 | 0.09 | 3,804 | 2.2 | 0.01 | 98  | 2.1 | 0.09 | 3,658 | 2.0 | 0.01 | 0.123 |
| trans-β-carotene (umol/L)e | 98  | 0.40 | 0.045 | 3,804 | 0.27 | 0.006 | 98  | 0.60 | 0.121 | 3,658 | 0.39 | 0.015 | 0.092 |
| cis-β-carotene (umol/L)d | 90  | 0.03 | 0.003 | 3,627 | 0.02 | 0.000 | 95  | 0.04 | 0.008 | 3,516 | 0.03 | 0.001 | 0.111 |
| Folate, RBC (nmol/L) | 147 | 733 | 44.3 | 5,961 | 830 | 16.3 | 171 | 932 | 68.0 | 5,927 | 891 | 18.5 | 0.576 |

aGrapefruit consumers reported consumption of 100% grapefruit juice or 100% fresh, canned, or frozen grapefruit at least once on the 2 days of dietary recall.
bEstimates adjusted for age, sex, race/ethnicity, and education; weight, WC, and BMI also adjusted for physical activity. Estimates based on small sample sizes may be less statistically reliable. All estimates were generated with statistical weights provided by the National Center for Health Statistics (NCHS).
cLimited to individuals with a fasting blood sample.
dParameter assessed only in NHANES 2003–2006 (males: 100 grapefruit consumers and 3,984 non-consumers; females: 104 grapefruit consumers and 3,884 non-consumers).

3.0 ± 5.2 mg/dL in subjects consuming a fresh grapefruit preload though the change was not significantly different from the water preload group (49). Female grapefruit consumers also had decreased levels of triglycerides and CRP compared to non-consumers of grapefruit. Lower serum triglycerides have been observed in a clinical trial with 57 hyperlipidemic men and women aged between 39 and 72 years consuming a heart-healthy diet including one fresh red grapefruit daily for 30 days (50). The lower CRP levels in female grapefruit consumers observed in our study is consistent with data from the Nurses’ Health Study where the consumption of at least one serving per day of grapefruit (including 100% grapefruit juice) was associated with significantly lower CRP concentrations compared to intake of less than one serving per month (51). The lower blood folate levels observed in male grapefruit consumers compared to non-consumers may have been related to other food choices in the diet, as grapefruit and grapefruit juice provide modest levels of folate (6% of the DV for eight ounces of grapefruit juice and 4% of the DV for ½ of a medium fresh grapefruit). Although several intervention trials have reported beneficial effects on blood pressure with consumption of fresh grapefruit by normotensive overweight men and women (48), grapefruit juice by normotensive and hypertensive men and women (52), or high flavonoid grapefruit–pummelo hybrid ‘sweetie’ fruit juice by men and women with Stage I hypertension (53), grapefruit consumption as such was not associated with lower blood pressure in the current observational study. We also did not observe an association between grapefruit consumption and LDL or total cholesterol. Clinical studies have reported significantly lower LDL or total cholesterol concentrations in adults consuming fresh grapefruit who did not have high cholesterol (defined as ≥225 mg/dL) (48), who were hyperlipidemic (50), or hypercholesterolemic men and women who consumed ‘sweetie’ juice (54). In our NHANES analysis, it is unknown whether there were
beneficial associations between grapefruit consumption and blood pressure or blood lipids in individuals with elevated levels since the data were not stratified by blood pressure or blood lipid status.

Diet quality was higher among consumers of grapefruit, which could impact the observed associations between grapefruit consumers and anthropometric and physiologic measures. In order to account for the potential effect of differences in diet quality, analyses of anthropometric and physiologic measures were repeated with an adjustment for each food group with statistically significant differences between grapefruit consumers and non-consumers (fruit excluding grapefruit, whole grains, vegetables, dairy, meat/franks, poultry, fish, discretionary solid fat, added sugars). The adjustment for food group intakes did not affect the significant associations observed between grapefruit consumption and anthropometric and physiologic parameters in women, while the few associations observed among men were largely unchanged with the adjustment; hence, our overall conclusions did not change. Differences in food group intakes between grapefruit consumers and non-consumers could also affect differences in usual nutrient intakes though we did not examine this issue.

There are several strengths to this analysis, including a large, nationally representative sample and calculation of usual nutrient intakes that are more representative of day-to-day intakes than intakes based on a single day of recall. As with all dietary surveys, however, the accuracy of the intake estimates is limited by the accuracy of recalls provided by survey participants. An additional limitation of this study is that grapefruit consumption was identified based on just 2 days of dietary recall. Adults who occasionally consume grapefruit but did not consume the fruit or juice during the recalls were classified as non-consumers in this assessment, and thus the estimated percentage of adults consuming grapefruit is likely underestimated. The analysis also is limited by the small number of NHANES adult participants reporting grapefruit consumption. One cannot rule out uncertainty due to the potential lack of representativeness of the consumption patterns of the sample number of grapefruit consumers. In addition, it is important to note that the findings are based on cross-sectional data; consequently no conclusions of the causal relationship between grapefruit consumption and improved nutrition status, diet quality, or metabolic health can be made.

In summary, a small percentage of adults reported consumption of grapefruit. Males were more likely to consume juice, and women were more likely to consume the fruit. Consumption of grapefruit was associated with improved adequacy of intake of key nutrients including vitamin C and magnesium, and a greater proportion of adults meeting recommended intakes of dietary fiber. In addition, grapefruit consumers had significantly better diet quality compared to non-consumers. Among women in this cross-sectional study, grapefruit consumption was associated with lower body weight, waist circumference, BMI, triglycerides, and CRP, and higher HDL cholesterol. Grapefruit consumption was not, however, associated with reduced risk of being overweight or obese. This is a cross-sectional study; therefore, causality of the observed effects cannot be determined. Dietary guidance encourages consumption of a nutrient-dense diet rich in fruits and vegetables. Currently, a small proportion of the population consumes grapefruit. Grapefruit, including both the fruit and 100% juice, may provide an additional option for many adults striving to consume a healthful diet with increased levels of fruits.

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