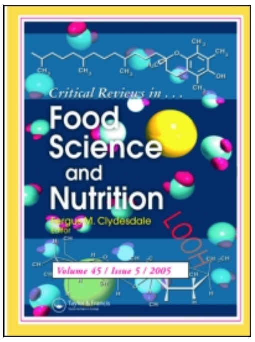

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100% citrus juice: Nutritional contribution, dietary benefits, and association with anthropometric measures

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ABSTRACT
Citrus juices such as 100% orange (OJ) and grapefruit juice (GJ) are commonly consumed throughout the world. This review examines the contributions of OJ and GJ to nutrient intake, diet quality, and fruit intake, and supports citrus juices as nutrient-dense beverages. This review also explores the research examining associations between OJ and GJ intake and anthropometric measures. Citrus juices are excellent sources of vitamin C and contribute other key nutrients such as potassium, folate, magnesium, and vitamin A. OJ intake has been associated with better diet quality in children and adults. OJ intake has not been associated with adverse effects on weight or other body measures in observational studies in children and adults. In adults, some observational studies report more favorable body mass index or body measure parameters in OJ consumers compared to nonconsumers. Intervention studies in adults report no negative impacts of OJ or GJ consumption on anthropometric measures, although these measures were typically not the primary outcomes examined in the studies. Moderate consumption of citrus juices may provide meaningful nutritional and dietary benefits and do not appear to negatively impact body weight, body composition, or other anthropometric measures in children and adults.

KEYWORDS
Citrus; orange juice; grapefruit juice; nutrients; anthropometrics

Introduction

Citrus juices are widely available and commonly consumed beverages in the United States and many parts of the world. One hundred percent orange (OJ) and grapefruit juice (GJ) are naturally nutrient rich and sources of micronutrients and bioactive phytochemicals, particularly polyphenols, and are associated with a variety of nutritional, dietary and health benefits. Overweight/obesity and its comorbidities are arguably the leading health concerns in the United States and globally. This paper explores the past 20 years of research related to 100% OJ and GJ consumption and their nutritional contribution and dietary benefits, as well as their association with anthropometric measures in children, adolescents, and adults.

Nutritional benefits

Citrus juices provide a natural balance and combination of water, vitamins and minerals, sugars and acids, along with phytochemicals such as polyphenols, and various other organic components. The typical nutritional values for OJ and GJ are presented in Table 1. An 8-ounce serving of OJ provides 122 calories and the same serving size of GJ provides 94 calories. The calories in OJ and GJ are provided almost entirely by carbohydrates and more specifically sugars, with OJ and GJ providing 29 and 22 g of total carbohydrates per 8-ounce serving, respectively. The primary sugars in citrus juices are sucrose, fructose and glucose, and they are generally present in a 2:1:1 ratio. As such, 50% of the sugars available for absorption will be free glucose and 50% will be free fructose if all the sucrose is hydrolyzed into its constituent monosaccharides. OJs and GJs provide a small amount of protein (approximately 2 g/8 ounces for OJ and 1 g/8 ounces for GJ) and are fat free, saturated fat free, cholesterol free, and sodium free.

An 8-ounce serving of OJ is an excellent source of vitamin C, as it typically provides 100% or more of the Daily Value (DV) (the U.S. Food and Drug Administration's (FDA) guidance value for food labeling) for this vitamin. It is also a good source of folate and potassium, providing between 10% and 20% of the DV for these nutrients. OJ also supplies vitamin B6, thiamin, niacin, riboflavin and vitamin A (primarily as beta-cryptoxanthin) at less than 10% of the DV. Magnesium, iron, and calcium (unfortified juice) are other minerals present in OJ at less than 10% of the DV.

An 8-ounce serving of GJ is an excellent source of vitamin C, a good source of potassium, and also supplies folate, thiamin, magnesium, vitamin B6, iron, niacin, and calcium (unfortified juice) at amounts less than 10% of the DV. An 8-ounce serving of pink or red GJ is an excellent source of vitamin A, primarily because of its beta-carotene content. Calcium-fortified citrus juices are excellent sources of calcium and vitamin D, as most brands provide at least 300 mg of calcium per 8-ounce serving and more than 20% of the DV for vitamin D.

Hesperidin and naringin are bioactive polyphenolic compounds and the primary flavonoids in citrus, belonging to the subclass of flavonoids called flavanones. Citrus fruit and juice

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Table 1. Nutrient content of 100% orange and grapefruit juice (8 ounces).

Nutrient	Orange juice	Grapefruit juice
Energy (kcal)	122	94
Total carbohydrate (g)	29	22
Total sugars (g)	21	22
Total dietary fiber (g)	0.7	0.2
Protein (g)	1.7	1.3
Total fat (g)	0.30	0.25
Cholesterol (mg)	0	0
Vitamins		
Vitamin C (mg)	84	72
Thiamin (mg)	0.12	0.10
Folate (μg DFE)	47	25
Vitamin B6 (mg)	0.19	0.049
Vitamin A (IU)	105	17/1087[a]
Niacin (mg)	0.70	0.57
Minerals		
Potassium (mg)	443	378
Magnesium (mg)	27	25
Calcium (mg)	27/349[b]	17
Iron (mg)	0.32	0.49
Sodium (mg)	1	2
Polyphenols[c]		
Hesperidin (mg)	150	—
Naringin (mg)	—	300
Narirutin (mg)	10	20
Nobiletin (mg)	0.7	—

Sources: USDA, 2013 (NDB 09209 for orange juice; NDB 09123 for grapefruit juice) and the Florida Department of Citrus.
[a]Second value is for pink/red grapefruit juice (NDB 09404—Grapefruit juice, pink, raw).
[b]Second value is for calcium-fortified orange juice and taken from NDB 09210—orange juice, chilled, includes from concentrate, fortified with calcium and vitamin D.
[c]Florida Department of Citrus data for polyphenols, average for domestically available commercial juices.
Abbreviations: DFE, dietary folate equivalents; IU, International Units.

have been identified as primary contributors of total flavonoids or specific flavanones in the diets of humans (Chun et al., 2007; Cassidy et al., 2012; Murphy et al., 2012a). Eight ounces of OJ contains approximately 150 mg of hesperidin and a similar amount of GJ contains approximately 300 mg naringin. Citrus and its juices are the only fruit juices and the only commonly consumed foods that provide significant amounts of hesperidin and naringin in the diet. Other flavonoid compounds in citrus include polymethoxylated flavones, the most common of which are tangeretin and nobiletin which are primarily found in orange, tangerine, and sour orange peel (*Citrus aurantium*) (Horowitz and Gentili, 1977).

By FDA definition, anything labeled as 100% citrus juice cannot contain added (extrinsic) sugars unless the juice percentage declaration is accompanied by a statement indicating that a sweetener or other ingredient is added (FDA, 2011a). One hundred percent fruit juices are not included in current definitions of "sugar-sweetened beverages" as defined by the Institute of Medicine and the U.S. Department of Agriculture, as they contain only the intrinsic sugars found in the whole fruit and no extrinsic sugars are added (USDA, 2010a; IOM, 2012). There is considerable controversy over the role of added sugars in the diet, specifically related to the consumption of sugar-sweetened beverages (i.e., those that contain added sugars) and obesity (Allison and Mattes, 2009; van Baak and Astrup, 2009). Government and health organizations have recommended that Americans reduce or limit their intake of added sugars, especially sugar-sweetened beverages (DHHS, 2005; Johnson et al., 2009; Moeller et al., 2009; USDA, 2010b). Beverages that contain added sugars typically are not as nutrient dense as healthier beverage choices, such as unflavored low-fat and nonfat milk, soy beverages, and 100% fruit or vegetable juices, and may contribute to added sugar consumption and excess calories in the American diet. The added sugar content of foods is not listed on the Nutrition Facts panel, although the FDA has expressed interest in assessing consumer responses to including this information in the future (FDA, 2011b). In certain instances, the FDA allows a claim of "no added sugar," "without added sugar," or "no sugar added" to be stated on the food label (FDA, 2011a), which could help consumers identify foods free of added sugars. Replacing sugar-sweetened beverages with moderate amounts of 100% fruit juice, as well as water, coffee, tea, and low-fat or nonfat milk, has been encouraged (Moreno et al., 2009; USDA, 2010b; CDC, 2011; Malik and Hu, 2012).

Contribution of citrus juices to nutrient intake

Citrus juices provide significant amounts of certain nutrients, particularly vitamin C. Vitamin C was identified as a shortfall nutrient in the 2010 Dietary Guidelines for Americans (DGAs), meaning that it is underconsumed by at least one segment of the U.S. population (USDA, 2010b). Vitamin C status has improved over the 15–20 year time period between 1988/1994 and 2003/2004 (Schleicher et al., 2009). The overall prevalence of vitamin C deficiency in National Health and Nutrition Examination Survey (NHANES) 2003–2004 for individuals six years of age and older was 7.1%, and 22% of adults had blood levels indicative of moderate risk of deficiency. Overall, 38% of men and 46% of women had dietary vitamin C intakes that fell below the Estimated Average Requirement. Based on nationally representative data from NHANES and the Continuing Survey of Food Intakes by Individuals, citrus juices were the leading source of dietary vitamin C in the diet of U.S. adults (Cotton et al., 2004; Chun et al., 2010). An analysis of NHANES 2003–2006 reported that all children and adolescents who consumed any amount of OJ on either of two days of dietary recall data met the Estimated Average Requirement for vitamin C, while only 29% of those not consuming OJ met the Estimated Average Requirement for vitamin C (O'Neil et al., 2011). Intake of citrus has been positively correlated with serum vitamin C concentrations in European populations (Dauchet et al., 2008; Wrieden et al., 2000). Clinical intervention studies using OJ reported that blood levels of vitamin C increased significantly from baseline when at least two cups (16 ounces) of OJ were included in the diet for at least two weeks (Kurowska et al., 2000; Johnston et al., 2003; Sanchez-Moreno et al., 2004; Franke et al., 2005; Morand et al., 2011).

In children and adolescents 2–18 years of age, consumption of OJ has been associated with higher dietary intakes of protein, dietary fiber, vitamin C, folate, potassium, magnesium, and vitamin B6 compared to nonconsumers, and consumers are more likely to meet the Estimated Average Requirement or Adequate Intake recommendations for many of these nutrients (O'Neil et al., 2011). Similar results have been reported in adults (O'Neil et al., 2012), as well as in studies where data from children and adults were combined (Yang et al., 2013).

The DGAs identify calcium, vitamin D, potassium, and dietary fiber as nutrients of public health concern and folate, magnesium, and vitamins A, C, and K as nutrients that are underconsumed in the United States (USDA, 2010b) and the results from epidemiological and clinical studies support that citrus juices may help improve the intake of several of these key shortfall nutrients. Children, and in some cases adults, who consumed OJ tended to have significantly higher daily intakes of total energy, total sugars, total fat, and saturated fat compared to nonconsumers (O'Neil et al., 2011; Wang et al., 2012). However, these associations held even when OJ was excluded from the analysis suggesting that OJ was not responsible for the differences between the consumer and nonconsumer groups (Wang et al., 2012).

The DGAs recommend that Americans consume nutrient-dense foods and beverages to obtain the nutrients they need without exceeding daily calorie intake needs. Nutrient-dense foods and beverages have been defined as those that "provide vitamins, minerals, and other substances that may have positive health effects, with relatively few calories" (USDA, 2010b). Additionally, the term "nutrient-dense" indicates the nutrients and other beneficial substances in a food have not been diluted by the addition of calories from solid fats, sugars, or refined starches that have been added, or by the solid fats naturally present in the food. Several analyses quantifying nutrient density reported that OJ or GJ ranked higher with regard to nutrient density when compared to other 100% fruit juices (LaChance and Fisher, 1986; Scheidt and Daniel, 2004; Fulgoni et al., 2009). Rampersaud (Rampersaud, 2007) computed nutrient density scores for several 100% fruit juices commonly consumed in the United States using six methods. Citrus juices, especially pink GJ, consistently ranked the most favorable with regard to nutrient density for all methods. Citrus juices also have been identified as foods with high nutrient density at an affordable cost (Drewnowski, 2010).

Fruit intake recommendations

The consumption of fruits and vegetables is associated with reduced risk of many chronic diseases, including cardiovascular disease (Dauchet et al., 2006). Fruits and vegetables are nutrient-dense and relatively low in calories, which may help adults and children achieve and maintain a healthy weight. For individuals who get less than 30 minutes per day of moderate physical activity, daily recommendations for fruit intake range from 1 to 2 cups for children and adolescents and $1\frac{1}{2}$ to 2 cups for adults depending on age (USDA, 2011). Based on NHANES 2001–2004 data, over 60% of children four to eight years of age, over 78% of older children, and at least 80% of adults have usual intakes of fruit that fall below recommended intake amounts (Krebs-Smith et al., 2010). In the DGAs and U.S. Department of Agriculture's MyPlate, 100% fruit juice counts toward fruit servings although it is advised that the majority of the fruit recommended come from whole fruits (fresh, canned, frozen, and dried) (USDA, 2010b; USDA, 2011).

One hundred percent OJ has been reported to be an important contributor of total fruit intake in all age and sex groups (Kimmons et al., 2009), including children and adolescents (Lorson et al., 2009). The important contribution of OJ toward meeting fruit intake recommendations was demonstrated in an NHANES 2003–2006 analysis (Yang et al., 2013). All children and adults who consumed at least 4.4 ounces per day of OJ met MyPyramid fruit recommendations. However, when OJ was removed from the list of foods consumed, the resulting percentage meeting fruit intake recommendations fell by over one half. There is concern that 100% juice may displace whole fruit or milk from the diet, particularly in children. However, an NHANES analysis reported that children who consumed OJ had higher Healthy Eating Index subscores for whole fruit compared to those not consuming OJ, suggesting that juice was not replacing whole fruit (O'Neil et al., 2011). Dietary fiber intake was also significantly higher in children or adult OJ consumers compared to nonconsumers (O'Neil et al., 2011; O'Neil et al., 2012). Overall Healthy Eating Index scores were higher for OJ consumers versus nonconsumers, and Healthy Eating Index subscores for dairy were not different between OJ consumers and nonconsumers, suggesting that OJ did not displace dairy foods or dairy beverages in the diet (O'Neil et al., 2011), which was confirmed in a similar analysis by another research group (Wang et al., 2012).

The 2005 Dietary Guidelines Advisory Committee addressed the question of how the guidance on the proportion of total fruit supplied by 100% fruit juice would affect meeting nutritional goals (DHHS, 2005). Recommendations in the 2005 DGAs were to consume no more than one-third of the total recommended fruit group intake amount from 100% fruit juice and the rest from whole fruit. Although fiber intake may be enhanced when whole fruit is substituted for 100% fruit juice, other nutrients such as potassium, vitamin C, and folate may be missed and the Committee concluded that the recommended combination of whole fruits and 100% juices would help individuals achieve an optimal balance and that 100% fruit juice is important in helping consumers meet nutritional goals.

Weight management

Excess body weight and associated comorbidities are a paramount health issue in the United States as well as in many developed countries. Based on 2010 NHANES data, 32% of children and adolescents and 69% of adults in the United States are considered overweight or obese (Flegal et al., 2012; Ogden et al., 2012). The causes of increased rates of overweight and obesity are continually debated. The etiology of obesity is multifactorial and complex, likely resulting from the presence of one or more lifestyle, dietary, physical activity, genetic, physiological, or behavioral factors that ultimately result in energy imbalance.

100% fruit juice and weight

Consumption of 100% fruit juice has been marked as a potential contributor to overweight/obesity, particularly in children and adolescents (AAP, 2001; Faith et al., 2006). The DGAs provide no specific quantitative guidance, but state that intake of 100% fruit juice be monitored for children and adolescents, especially for those who are overweight or obese. In 2001, the American Academy of Pediatrics (AAP) published recommendations for fruit juice intake, stating that fruit juice consumption should be limited to 4 to 6 ounces per day for children 1–6 years of age, and 8 to 12 ounces/day for children 7–18 years of age (AAP, 2001). The AAP recognized that while 100% fruit juice can be a healthy part of the diet when consumed as part of a well-balanced diet, it has the potential to be over-consumed by children because of its taste and the willingness of parents to provide juice because of its healthfulness. The rationale for the AAP fruit juice recommendation is based on the recommended fruit servings for each respective age group, allowing for half of the fruit intake to be supplied by 100% fruit juice. The American Heart Association's guidance regarding fruit juice intake in children and adolescents (Gidding et al., 2005) mirrors that of the AAP. Other published beverage guidelines propose limiting 100% fruit juice intake to 8 ounces per day or less for persons with a 2200 kcal daily energy requirement (Popkin et al., 2006). However, no well-defined rationale for this intake amount is provided in that guidance. Other recommendations for healthy beverage choices include those proposed by the Robert Wood Johnson Foundation, which include daily juice intake of up to 4 ounces for children 2–4 years of age, up to 6 ounces for children 5–10 years of age, and up to 8 ounces for children 11 years of age and older as well as all adults (Healthy Eating Research, 2013).

A comprehensive review published in 2008 evaluated the results of 21 cross-sectional and longitudinal studies and concluded that the preponderance of evidence did not support an association between higher fruit juice intake and increased risk of overweight or obesity, while noting that consumption should be in moderate amounts (O'Neil C and Nicklas, 2008). Of the 21 studies, 6 studies (3 cross-sectional and 3 longitudinal) showed a relationship between fruit juice intake and weight measures and were conducted in small or convenience populations not considered representative of a national population sample. Of note, two longitudinal studies reported positive associations between fruit juice intake and adiposity in children from low-income families who were overweight or at risk of overweight at baseline (Welsh et al., 2005; Faith et al., 2006). Cross-sectional studies cannot be used to determine cause and effect. Longitudinal studies evaluate participants over time, with baseline information and changes occurring during the study period by collecting data at multiple intervals, which provides more robust data compared to cross-sectional studies. Other epidemiological-based studies in children published since the 2008 review help support the review's overall conclusions (Nicklas et al., 2008; Vanselow et al., 2009; O'Neil et al., 2010; Danyliw et al., 2012; Taber et al., 2012). Children 2–11 years of age (Nicklas et al., 2008) or adolescents 12–18 years of age (O'Neil et al., 2010) who consumed 100% fruit juice had no differences in various weight measures compared to fruit juice non-consumers. No correlations between juice consumption and weight gain in adolescents over a 5-year period were found in the Project EAT (Eating Among Teens) cohort (Vanselow et al., 2009). A cross-sectional analysis of the Canadian Community Health Survey reported no significant association between overweight/obesity and children with a fruit juice beverage cluster pattern (Danyliw et al., 2012). A study of data collected as part of the cross-sectional Youth Risk Behavior Survey reported that higher intakes of 100% fruit juice were associated with lower BMI percentile in girls (Taber et al., 2012).

Fewer epidemiological studies of 100% juice intake and weight parameters have been conducted in adult populations. These studies evaluated the aggregate intake of 100% fruit juices and not the intake of any specific juice. Two studies using several large U.S. cohorts such as the Nurses' Health Study and Health Professionals' Follow-up Study reported that weight gain in adults was significantly and positively associated with 100% fruit juice intake (Mozaffarian et al., 2011; Pan et al., 2013). An analysis of NHANES 1999–2004 data reported that 100% fruit juice consumers had significantly lower mean BMI and waist circumference (WC) compared to nonconsumers (Pereira and Fulgoni, 2010). An inverse association between fruit juice consumption and BMI in adults was reported in the Canadian Community Health Survey (Akhtar-Danesh and Dehghan, 2010). A study of a large European cohort of adults reported no association between the combined intake of fruit juice and fruit nectars and BMI (InterAct Consortium, 2013).

Citrus juice and weight

In vitro and animal studies suggest that citrus or its components may have certain antiobesity characteristics. Several studies have reported favorable effects of citrus or components of citrus on the ability to induce lipolysis (Choi 2006; Tsujita and Takaku, 2007; Dallas et al., 2008; Kang et al., 2012) or reduce fat accumulation (Titta et al., 2010; Takayanagi, 2011). Citrus flavonoids also have been associated with reducing adiposity and regulating enzymes related to obesity (Mulvihill et al., 2009; Nichols et al., 2011). The clinical significance of these results is unclear in large part because those are in vitro and animal studies and the effect has been observed at doses higher than those that would be normally ingested by humans as part of the usual diet. Various supplements made from citrus extracts (components from *C. aurantium*) are available as herbal weight loss remedies. These products are marketed based on the potential stimulant effects of alkaloid chemicals found in bitter orange, such as synephrine, which are reputed to be metabolic stimulants (Manore, 2012) or have lipolytic properties (Mercader et al., 2011). Synephrine is an adrenergic agonist that may potentially increase resting energy expenditure or decrease food intake (Haaz et al., 2006), purported mechanisms for weight loss. Synephrine may also adversely affect the cardiovascular system and its safety has been questioned (Haaz et al., 2006). Clinical weight loss studies using synephrine supplements have been of small sample size and short duration, making their interpretation challenging.

Vitamin C, provided in high amounts in OJ and GJ, may play a role in affecting fat storage or oxidation. Vitamin C is needed as a cofactor for the function of two enzymes associated with the synthesis of carnitine, the compound that transports long chain fatty acids into the mitochondria of cells where they can undergo beta-oxidation for ultimate conversion into adenosine-5′-triphosphate, or ATP. Vitamin C has been associated with increased or activated lipolysis in animal models (Garcia-Diaz et al., 2009; Ji et al., 2010). Plasma vitamin C may also impact fat oxidation and physical activity performance in humans (Johnston, 2005) and vitamin C status has been inversely associated with BMI or other anthropometric measures in epidemiological studies (Canoy et al., 2005; Johnston et al., 2007).

Studies reporting 100% OJ or GJ intake and body weight parameters are presented in Table 2. Seven observational

Table 2. Observational and clinical studies evaluating 100% citrus juice intake and anthropometric measures.

Reference	Study type	Study/subject description	Diet/intake	Results
Orange juice: Observational studies				
Dennison et al. (1999)	Cross-sectional	Primary care health center in upstate New York $n = 163$ children 2–5 years of age	OJ intake based on a seven-day diet record	OJ intake was not associated with child height ($p = 1.0$), weight, BMI ($p = 0.9$) or ponderal index
Forshee and Storey (2003)	Cross-sectional	Continuing Survey of Food Intake by Individuals 1994–96, 1998 $n = 3{,}311$ children 6–19 years of age	Citrus juice intake	No association between citrus juice intake and BMI in boys or girls ($p \geq 0.05$)
Vanselow et al. (2009)	Longitudinal	Project EAT (Eating Among Teens) $n = 2{,}294$ middle school and high school students from the Minneapolis/St. Paul metro area	OJ intake based on food frequency questionnaire	No significant association between OJ intake and change in BMI over 5 years ($p = 0.28$)
O'Neil et al. (2011)	Cross-sectional	NHANES 2003–2006 $n = 7{,}250$ children 2–18 years of age	OJ usual intake; consumers versus nonconsumers with consumers defined as those consuming any amount of OJ on any of the two nonconsecutive days of dietary recall	No differences in body weight or BMI in consumers versus nonconsumers ($p \geq 0.05$) Smaller WC in consumers versus non-consumers (68.77 $\pm$ 0.14 vs. 69.10 $\pm$ 0.10 cm; $p = 0.04$) No association with risk of being overweight or obese (OR = 0.86; 95% CI 0.70–1.05; $p = 0.15$) in consumers versus nonconsumers
O'Neil et al. (2012)	Cross-sectional	NHANES 2003–2006 $n = 8{,}861$ adults 19+ years of age	OJ usual intake Consumers versus nonconsumers with consumers defined as those consuming any amount of OJ on any of the two nonconsecutive days of dietary recall	Lower BMI in consumers versus nonconsumers (27.6 $\pm$ 0.2 vs. 28.5 $\pm$ 0.1; ($p < 0.0001$) No difference in body weight ($p = 0.51$) or WC ($p = 0.44$) in consumers versus nonconsumers Lower risk of being obese (OR = 0.79 $\pm$ 0.08 95% CI 0.65–0.95; $p = 0.0116$) in OJ consumers versus nonconsumers
Wang et al. (2012)	Cross-sectional	NHANES 2003–2006; $n = 13{,}971$ children and adults 4+ years of age	OJ intake Consumers (in tertiles of intake) versus nonconsumers with consumers defined as those consuming any amount of OJ at least once in the two nonconsecutive days of dietary recall	Children age 4–18 years: no significant trend across tertiles of intake for weight-for-age z-score, BMI, WC, triceps skinfold thickness, and body fat percentage ($p \geq 0.05$); no significant trend across tertiles of intake for BMI-for-age percentile ($p \geq 0.05$); age subgroup analysis identified increased odds ratio for obesity in the third tertile of intake for children aged 4–8 years (data not presented) Adults age 19+: significant trend for lower weight, BMI, WC, triceps skinfold thickness and body fat percentage across tertiles of intake ($p \leq 0.05$); in highest tertile of OJ intake odds ratio of having a BMI $\geq$ 25: OR = 0.69; 95% CI 0.56–0.84; $p < 0.001$ or BMI $\geq$ 30: OR = 0.68; 95% CI 0.53–0.87; $p < 0.01$ compared to nonconsumers as reference
Yang et al. (2013)	Cross-sectional	NHANES 2003–2006 $n = 13{,}971$ children and adults 4+ years of age	OJ intake Consumers (in tertiles of intake) versus. nonconsumers with consumers defined as those consuming any amount of OJ at least once in the two nonconsecutive days of dietary recall	The percent of individuals who consumed 100% OJ was higher in those with lower BMI ($p < 0.05$)
Orange juice: clinical studies				
Kurowska et al. (2000)	Clinical trial	$n = 25$ healthy men and women with elevated plasma total and LDL-cholesterol and normal plasma triacylglycerol concentrations Mean 55 $\pm$ 11 years of age Study duration 17 weeks	Participants consumed 1, 2, or 3 cups (250 mL each) of OJ sequentially into an AHA Step I diet, each dose over 4 weeks, followed by a 5-week washout period	No change in body weight or BMI ($p \geq 0.05$)

(Continued on next page)

Table 2. (Continued)

Reference	Study type	Study/subject description	Diet/intake	Results
Franke et al. (2005)	Clinical trial	$n = 13$ healthy men and women 28–51 years of age Study duration 3 weeks	710 mL/day OJ as part of the habitual diet	No change in body weight
Cesar et al. (2010a)	Controlled trial	$n = 53$ men and women 36–44 years of age (mean) Study duration 60 days	Experimental: $n = 31$ with normal cholesterol and $n = 14$ with elevated cholesterol Consumed 750 mL/day OJ as part of habitual diet; control: $n = 8$ no OJ	No change in BMI or WC ($p \geq 0.05$)
Aptekmann et al. (2010)(Ce: Not in ref. list)	Randomized controlled trial	$n = 26$ overweight women 30–48 years of age Study duration 90 days	Experimental: $n = 13$ consumed 500 mL/day OJ as part of habitual diet + aerobic training 3 days/week Control: $n = 13$ no OJ + aerobic training 3 days/week	No difference in change in body weight, BMI, or body fat percentage between control and experimental groups ($p \geq 0.05$)
Basile et al. (2010)	Clinical trial	$n = 41$ healthy men and women 20–53 years of age Study duration 8 weeks	Consumed 500 mL/day (women) or 750 mL/day OJ (men)	No difference in body weight, BMI, mid-arm circumference, or triceps skin-fold thickness with OJ consumption ($p \geq 0.05$) Significant reduction in WC in women consuming OJ ($p < 0.05$) No change in WC in men
Cesar et al. (2010b)	Clinical trial	$n = 29$ healthy men and women 25–55 years of age Study duration 60 days	Consumed 750 mL/day OJ	No change in BMI, body fat, or WC ($p \geq 0.05$)
Morand et al. (2011)	Randomized controlled crossover	$n = 24$ healthy overweight men 50–65 years of age Study duration 4 weeks	Experimental: consumed 500 mL/day OJ or 500 mL/day control drink + hesperidin capsule Control group: 500 mL/day control drink + placebo capsule 3-week washout	No change in body weight or BMI ($p \geq 0.05$)
Simpson et al. (2012) (abstract)	Randomized controlled trial	$n = 32$ overweight women with mild fasting insulin resistance 20–45 years of age Study duration 12 weeks	Experimental: $n = 16$ consumed 250 mL/day OJ Control: $n = 16$ consumed 250 mL/day orange-flavored drink	No change in body weight, lean body mass, gynoid fat percentage, or android fat percentage in any group ($p \geq 0.05$)
Niv et al. (2012) (Ce: Not in ref. list)	Randomized controlled trial	$n = 48$ healthy men and women 18–60 years of age Study duration 8 weeks	Experimental: $n = 29$ consumed 500 mL/day OJ + Levan (fructan dietary fiber) Control: $n = 19$ consumed 500 mL/day OJ	No change in BMI by treatment or time ($p \geq 0.05$)
Grapefruit juice: clinical studies				
Fujioka et al. (2006)	Randomized controlled trial	$n = 91$ obese adult men and women Study duration 12 weeks	Experimental: $n = 24$ grapefruit capsule and 207 mL apple juice; $n = 21$ placebo capsule and 237 mL GJ; $n = 24$ placebo capsule and ½ fresh grapefruit; control: $n = 22$ placebo capsule and 207 mL apple juice Treatments consumed three times per day prior to meals	GJ group lost 1.5 kg (3.3 pounds; not significantly different from the other treatment groups) No significant difference among the treatment groups in body fat percentage or WC In subgroup analysis, those with metabolic syndrome had a significantly greater weight loss in the grapefruit, grapefruit capsule, and GJ groups compared with control ($p < 0.02$)
Silver et al. (2011)	Randomized controlled trial	$n = 85$ obese men and women 21–50 years of age Study duration 12 weeks	Experimental: $n = 29$ fresh grapefruit preload; $n = 28$ GJ preload; control: $n = 28$ water preload; Consumed 381 g/day (~12 ounces, ~370 mL) preloads to a calorie restricted diet	Significant decrease in BMI, WC, body fat%, trunk fat%, android fat%, gynoid fat% in all groups ($p < 0.05$) Changes in BMI, WC, fat tissue mass, body fat percentage, trunk fat%, android fat%, gynoid fat%, or lean tissue mass was not significantly different among experimental groups

Abbreviations: OJ, orange juice; BMI, body mass index; NHANES, National Health and Nutrition Examination Survey; WC, waist circumference; OR, odds ratio; CI, confidence interval; AHA, American Heart Association; GJ, grapefruit juice.

studies evaluated associations between OJ (six studies) or citrus juice (one study) intake and anthropometric measures. Studies in young children (Dennison et al., 1999), children 6–19 years of age (Forshee and Storey, 2003), middle and high school students (Vanselow et al., 2009), children 4–18 years of age (Wang et al., 2012), and children of 2–18 years of age (O'Neil et al.,

2011) generally report no significant association between OJ or citrus juice intake and anthropometric measures. The exception was an increased odds for obesity reported for the highest tertile of OJ intake in children four to eight years of age although no specific information for that finding is presented in the publication (Wang et al., 2012).

Several studies report favorable associations between OJ intake and anthropometric measures. An analysis of NHANES 2003–2006 reported that WC in children and adolescents was modestly but significantly smaller in OJ consumers compared to non-consumers (O'Neil et al., 2011). In adults, a study using NHANES 2003–2006 data reported a significant trend for decreasing body weight, BMI, WC, and body fat percentage across increasing tertiles of OJ intake (Wang et al., 2012). Adults consuming at least 7.5 ounces of OJ daily had at least a 31% reduced risk for overweight or obesity compared to nonconsumers. A similar analysis of NHANES data reported that adult OJ consumers had a lower BMI compared to nonconsumers (27.6 ± 0.2 vs. 28.5 ± 0.1; $p < 0.0001$) and a 21% lower risk of being obese (O'Neil et al., 2012).

Results from epidemiological studies are strengthened by a number of clinical studies that report no deleterious effects on anthropometric measurements when 100% OJ is included as an intervention to the usual or study diet (Table 2). While most of these studies were not designed to monitor and evaluate weight loss as a primary outcome, they include secondary outcome data that clearly demonstrate that the chronic consumption of OJ was not associated with significant changes in anthropometric changes under the study conditions. OJ intake in these studies ranged from 250 to 750 mL/day for periods ranging from 4 to 17 weeks. Two studies reported higher energy intakes in the OJ intervention group at the end of the study compared to baseline, yet anthropometric measures were not adversely affected (Basile et al., 2010; Cesar et al., 2010a). Although changes in weight or BMI were not observed, WC significantly decreased in women following 8 weeks of consuming 500 mL OJ per day, although no such changes were noted in men (Basile et al., 2010).

Two clinical studies have been conducted regarding GJ intake and weight (Table 2). In one study, 91 obese subjects consumed GJ, fresh grapefruit, a capsule containing freeze-dried and compressed whole grapefruit (including the peel), or a placebo control tablet for 12 weeks as part of their usual diet (Fujioka et al., 2006). They were also encouraged to walk 20–30 minutes three or four times per week. The GJ group lost 1.5 kg, which was significantly more than the 0.3 kg the placebo control group lost. Physical activity levels were not monitored in the study, which could have affected outcomes. In another intervention study, overweight subjects were randomized to consume between 4 to 5 ounces of GJ, one-half of a fresh grapefruit, or water as a pre-load prior to each of three daily reduced-calorie meals (Silver et al., 2011). Although all study groups lost weight, weight loss was not significantly different among the three treatment groups. Clinical studies have reported that the addition of fresh grapefruit to the diet was not incrementally beneficial toward weight loss when compared to a control group that did not consume grapefruit (Silver et al., 2011; Dow et al., 2012). Preliminary data from a cross-sectional NHANES analysis reports that women who consumed any amount of grapefruit (fresh, juice, or frozen) had significantly lower body weight, BMI, and WC compared to nonconsumers (Murphy et al., 2012b).

Data on the role of citrus juices and weight are limited and there is a lack of clinical intervention studies that include weight parameters as a primary outcome. Observational studies have limitations because they rely on self-reported food intake and some may use self-reported weight or other anthropometric measures, and differences exist among studies in the inclusion or measurement of confounding variables. Finally, results of cross-sectional studies may not be attributable to the intake of citrus juices because of the nature of the research.

Citrus juice, dietary sugars and fructose

There are conflicting opinions about the potential adverse health effects of excess sugar or fructose in the diet, and fructose has been implicated in the pathogenesis of a variety of chronic diseases or conditions including obesity, dyslipidemia, insulin resistance, metabolic syndrome, and diabetes (Johnson et al., 2007; Bray 2010; Dekker et al., 2010; Lustig, 2010; Ruxton et al., 2010; Aller et al., 2011; Samuel, 2011; Lustig et al., 2012). An 8-ounce serving of OJ and GJ provides approximately 29 and 22 g of total carbohydrates, respectively (USDA, 2013). The calories provided by OJ and GJ come from the carbohydrates sucrose, fructose, and glucose. In the small intestine, sucrose is hydrolyzed by the enzyme sucrase into its monosaccharide constituents, glucose and fructose. Each is then absorbed and transported into the bloodstream, glucose by the sodium dependent SGLT1 transporter and fructose by the GLUT5 transporter. The body metabolizes fructose via a different pathway than glucose and is insulin independent while glucose metabolism is insulin dependent. In the blood stream, glucose is diverted to various tissues and can serve as a direct energy source, or can be stored in the liver or skeletal muscle as glycogen. Most of the absorbed fructose is carried by the portal vein to the liver where it is metabolized. Tracer studies suggest that approximately 30–54% of ingested fructose is ultimately converted to glucose, approximately 28% is converted to lactate, and less than 1% may be converted to lipids, although more data is needed with regard to lipid conversion (Sun and Empie, 2012). Regardless of the original source of ingested sugars (i.e., intrinsic or extrinsic), the body processes them the same.

Mean intakes of fructose in the United States are reported to be 49 g/day with 90th and 95th percentile intakes of 75 and 87 g/day, respectively (Marriott et al., 2009). It is estimated that more than 99% of the U.S. population consumes less than 150 g fructose per day (Livesey and Taylor, 2008). Fructose intake of 50 g/day or less has been defined as moderate intake and greater than 50–100 g/day has been defined as high intake (Livesey and Taylor, 2008). OJ would be expected to provide approximately equal amounts of glucose and fructose for absorption assuming that 100% of ingested sucrose is hydrolyzed to its monosaccharide constituents. Although OJ or 100% fruit juices have been categorized as fructose-rich beverages (Choi and Curhan, 2008; Sartorelli et al., 2009; Choi et al., 2010), a term not quantitatively defined in these studies, the contribution to the diet of fructose from an 8-ounce portion of

OJ is only expected to be approximately 10 g. The dietary contribution of fructose from all fruit juices is substantially less than sugar-sweetened beverages or grain foods (Vos et al., 2008). Fruit and fruit products, including 100% fruit juice, contributed 13% of total fructose in the diet, less than grain products (17%) and nonalcoholic beverages (not including fruit juice) (46%) (Marriott et al., 2009).

Potential mechanisms put forth with respect to the association between fructose intake and obesity include differential effects of fructose on plasma leptin concentrations (Stanhope, 2012), cerebral blood flow changes that may regulate appetite (Page et al., 2013), and simply the overconsumption of calories associated with fructose-containing foods and beverages (Tappy and Le, 2010). Interpretation of fructose studies is confounded by the use of pure fructose in clinical studies when pure fructose is not typically consumed as part of the normal diet; the use of fructose amounts that are greater than the 95th percentile of intake in the United States; and differential results when fructose is fed under isocaloric versus hypercaloric conditions (Sievenpiper et al., 2012). A meta-regression analysis of clinical trials reported that oral fructose intakes of $\leq$ 100 g/day had no significant effect on body weight when fructose was used as a replacement for other carbohydrates in the diet such as starch, glucose, or sucrose (Livesey and Taylor, 2008). Dolan et al. (Dolan et al., 2010) concluded that the intake of up to 100 g/day fructose instead of glucose or sucrose did not result in an increase in food intake or body weight in healthy normal weight individuals. A systematic review and meta-analysis of the effect of fructose on body weight in controlled feeding trials concluded that fructose does not appear to cause weight gain when it is substituted for other carbohydrates in isocaloric diets; however, when given as excess calories fructose modestly increased body weight (Sievenpiper et al., 2012). In this instance, it is unknown whether the fructose or excess energy intake was responsible for the weight gain. Well controlled and long-term clinical trials are needed to fill these research gaps.

Emerging research is demonstrating that the intrinsic sugars found in OJ do not seem to manifest the negative health effects sometimes associated with the excess intake of added sugars, including obesity. Clinical studies often test the effects of sugars in isolation in contrast to OJ which is most often consumed with other foods. As previously summarized in Table 2, clinical studies using OJ report no significant adverse effects on anthropometric measures, suggesting that subjects may compensate for the additional calories provided by OJ with other dietary choices. Animal studies suggest that citrus flavonoids such as hesperidin (found primarily in oranges) and naringin (found primarily in grapefruit) may increase fatty acid oxidation in the liver thereby reducing fatty acid transport to adipose and muscle tissue (Mulvihill and Huff, 2012; Assini et al., 2013). However, a clinical trial reported that OJ consumed as part of breakfast limited postmeal fat oxidation compared to when water was consumed with breakfast (Stookey et al., 2012).

Other adverse health effects associated with excess fructose intake include the metabolic syndrome and insulin resistance. A study using NHANES 2003–2006 data reported a 36% reduced risk for the metabolic syndrome in men who consumed OJ compared to non-consumers, while no association was reported for women (O'Neil et al., 2012). Preliminary data from a clinical study in 32 overweight women with mild insulin resistance reported no effects on markers of insulin sensitivity or metabolic syndrome, including the homeostasis model assessment-insulin resistance measure, with the daily consumption of 250 ml of OJ for 3 months (Simpson et al., 2012). Similarly, several epidemiological studies report no association between 100% fruit juice intake and indicators of metabolic syndrome (Yoo et al., 2004; Duffey et al., 2010; Pereira and Fulgoni, 2010). Cross-sectional studies reported no association between OJ consumption and elevated fasting plasma glucose or insulin levels in children (O'Neil et al., 2011) or adults (O'Neil et al., 2012). In clinical studies, consumption of OJ was associated with a decrease in fasting glucose in men (Basile et al., 2010) and no change in plasma glucose or insulin (Cesar et al., 2010b; Morand et al., 2011). Of interest, consumption of OJ was associated with the suppression of the short-term rise in postprandial plasma glucose observed by the consumption of a high-fat, high-carbohydrate meal (Ghanim et al., 2010).

Summary

One hundred percent orange and GJs are nutrient-dense beverages that can contribute substantially to the intake of a number of key nutrients that are under-consumed in the United States, including vitamin C, potassium, folate, magnesium, and vitamin A. Citrus juices are also a source of flavonoids that may be associated with health benefits. Compared to other commonly consumed 100% fruit juices, OJ and GJ provide more favorable amounts of nutrients on a per calorie basis which can help contribute to meeting nutrient intake recommendations. Consumption of OJ has been associated with enhanced diet quality and does not appear to displace whole fruit or dairy beverages from the diet. One hundred percent OJ and GJ contain no added sugars and 100% juices are included in the healthier beverage replacement options for sugar-sweetened beverages in the diet. Because total fruit intake by adults and children is low, citrus juices can help supplement whole fruit intake to help individuals meet daily fruit intake recommendations. Moderate intake of citrus juices is warranted to help achieve and maintain balance in daily calorie intake.

Epidemiological evidence suggests a null association between OJ intake and anthropometric measures in children and adolescents. Longitudinal studies reporting on 100% fruit juice (aggregate intake) suggest there may be some concern among children who are overweight or obese, although the lack of clinical trial data does not allow for the determination of cause and effect. In adults, a limited number of epidemiological studies support an inverse association between 100% OJ intake and anthropometric measures. Based on clinical intervention studies, the addition of OJ or GJ to a habitual or study diet did not result in weight change, suggesting that individuals likely compensated with other dietary choices. Studies suggest that including moderate amounts of OJ or GJ in the diet does not appear to be detrimental toward weight or other anthropometric measures in adults, assuming that energy balance is maintained. Well-controlled clinical trials are needed in both children and adults.

Although dietary fructose intake has been targeted as a primary contributor to obesity, moderate intakes of OJ contribute relatively small amounts of fructose to the diet (approximately 10 g per 8 ounce serving) and OJ is not considered a major delivery system for fructose in the diet. There is little evidence to support negative impacts of OJ or its sugars on health concerns otherwise associated with fructose intakes generally exceeding 100 g/day. Some benefits of OJ consumption have been reported, particularly with respect to associations with the risk for metabolic syndrome.

Conclusion

A review of the research suggests that including moderate amounts of citrus juice as part of a healthy diet and lifestyle can help meet several DGA recommendations related to the intake of key nutrients, choosing nutrient-dense foods and beverages, and improving fruit intake as a complement to whole fruit. Moderate amounts of OJ or GJ can be recommended for children, adolescents, and adults without detrimental effects on weight, provided intakes are balanced with respect to the total diet and physical activity levels. The parents of younger children or children who are overweight or obese should monitor the intake of 100% fruit juice and be advised of the appropriate amounts as recommended by the AAP and that do not contribute to an imbalance in daily caloric intake. Research documents the nutrition and health benefits of moderate citrus juice consumption in a variety of age and demographic groups that may provide benefits throughout the lifespan.

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