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Impact of orange juice consumption on macronutrient and energy intakes and body composition in the US population

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Abstract

Objective: The present study evaluated the contribution of 100 % orange juice (OJ) consumption to the intakes of macronutrients and energy and its impact on body composition.
Design: A cross-sectional study was conducted. The main exposure was OJ consumption based on two non-consecutive 24 h diet recalls. Macronutrient and energy intakes and body composition parameters were outcome measures. All statistical analyses were carried out using SAS and SUDAAN statistical software packages to allow for multistage sample designs.
Setting: The US population and its subgroups.
Subjects: The US population aged ≥4 years (*n* 13 971) from the National Health and Nutrition Examination Survey 2003–2006, conducted by the National Center for Health Statistics.
Results: In this US population, OJ consumers had lower BMI and healthier lifestyle behaviours (including lower alcohol consumption and smoking as well as higher exercise level) than non-consumers ($P < 0{\cdot}05$). After adjusting for covariates, OJ consumers had higher daily intakes of carbohydrate, total sugar, total fat and energy than non-consumers ($P < 0{\cdot}01$). However, these linear trends still remained even after OJ was removed from the food list of items consumed. Adult OJ consumers had lower BMI, waist circumference and percentage body fat than non-consumers ($P < 0{\cdot}01$), as well as lower odds ratio for overweight and obesity ($P < 0{\cdot}01$). These effects were not seen in children and adolescents, where there was no significant difference in BMI, waist circumference and percentage body fat in OJ consumers compared with non-consumers.
Conclusions: OJ consumption was associated with healthier body composition in adults; while there were no significant associations between OJ consumption and body composition in children and adolescents.

Keywords
100 % Orange juice
Macronutrient intake
Energy intake
Obesity
Waist circumference

Fruit juice consumption has been increasing over the past several decades for a number of reasons, including an increase in the variety of fruit juice produced and an increase in availability[1]. This has prompted concerns from a number of professional groups, including the American Academy of Pediatrics, about fruit juice intake and its potential impact on body weight[2]. The scientific data supporting these concerns regarding fruit juice consumption and body weight have been mixed. Several epidemiological studies observed that excessive fruit juice consumption was correlated with an increased risk of obesity in children[1,3–5]. In addition, Dennison *et al.* reported that high intake of apple juice rather than orange juice or other types of 100 % fruit juice was associated with obesity among a group of 2- and 5-year-old children[4]. Conversely several other studies have documented no association between fruit juice consumption and overweight or obesity in children[6–10] and have shown that compared with non-consumers, those consuming 100 % fruit juice had overall more nutritious diets including significantly higher intakes of vitamins C and B_6, K, riboflavin, Mg, Fe and folate and significantly lower intakes of total fat, SFA, discretionary fat and added sugar[8]. In addition, children consuming 100 % fruit juice also consumed significantly more servings of total whole fruit than non-consumers[8]. These contradictory findings may be partially attributed to some limitations in the scope of previous studies: (i) most of the past studies failed to separate different types of fruit

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juices or separate 100 % fruit juice from juice drinks that contain less than 100 % fruit juice in the evaluation of the impact of juice consumption on body composition[1,5–8,10]; (ii) in some studies a single 24 h diet recall (DR) was used and assumed to reflect usual diet pattern[9,10]; (iii) some studies had a small number of participants[6]; (iv) some studies used outdated national survey data for the analysis[9,10]; and (v) previous studies have not examined the impact of 100 % fruit juice on body composition in adults.

Orange juice is one of the most nutrient-dense fruit juices consumed in the USA and is rich in essential nutrients such as vitamin C, folate, vitamin B_6, thiamin, niacin, riboflavin, K and Mg[11]. In addition, orange juice is a good source of antioxidants including carotenoids and flavonoids such as hesperetin and naringenin[11,12]. While orange juice is a nutrient-dense beverage, it has been speculated that it contributes to obesity risk by adding energy and sugars to US diets. However, information on the impact of orange juice on macronutrient and energy intakes, body composition and risk of obesity is limited. Therefore, we aimed to investigate the association of 100 % orange juice consumption with macronutrient and energy intakes and body composition by utilizing a recently released, nationally representative health and nutrition data set of the free-living US population.

Materials and methods

Data source

The National Health and Nutrition Examination Survey (NHANES) is conducted by the National Center for Health Statistics to obtain nationally representative information on the health and nutritional status of the US population. NHANES is a national survey involving household interviews and clinical examinations. It was changed in 1999 from a periodic annual survey to a continuous annual survey, and the continuous NHANES data have been released in two-year increments for public use[13].

Participants

The NHANES uses a stratified, multistage probability sample design and weighting methodology that allows for unbiased national estimates to be produced for the civilian, non-institutionalized US population. The NHANES sample weights adjust for unequal probabilities of selection, non-response and planned oversampling of young children, the elderly, low-income persons and ethnic minorities[13].

All interviewed persons were invited to the mobile examination centre, where the 24 h DR and questionnaires on dietary and lifestyle behaviours were administered. Individuals aged ≥4 years in NHANES 2003–2004[14] and 2005–2006[15] with reliable and complete DR data were included in the present study (*n* 13 971). Participants were grouped into subgroups by sociodemographic and lifestyle variables: age (4–8, 9–13, 14–18, 19–30, 31–50, >50 years); gender; ethnicity (non-Hispanic whites, non-Hispanic blacks, Mexican Americans, others); BMI (<18·5, 18·5–25·0, 25·0–30·0, ≥30·0 kg/m^2); poverty income ratio (PIR; <1·3, 1·3–3·5, >3·5); alcohol consumption (yes or no to 'at least 12 alcoholic drinks/year'); current smoking (yes or no to 'current cigarette smoking'); and exercise levels (0, T1, T2, T3; expressed as the MET (metabolic equivalent of task) score calculated by combining the intensity level of the leisure-time activities reported with their mean duration and frequency).

Dietary intake data

The dietary intake data were estimated from two 24 h DR interviews conducted in the NHANES 2003–2004[14] and 2005–2006[15], which were carried out by trained interviewers using the US Department of Agriculture (USDA) Automated Multiple Pass Method[16]. The day 1 recalls were conducted in person in the NHANES mobile examination centre. The day 2 recalls were conducted by telephone interview approximately 3 to 10 d after the day 1 recall. Food consumption data were coded using the USDA Food and Nutrient Database for Dietary Studies version 3·0 (FNDDS 3·0) to produce energy and macronutrient intake data. Since a food composition table for added sugar is not available in FNDDS 3·0, a special added sugar database was utilized for estimating added sugar intake[17]. In the present study, 100 % orange juice (OJ) included non-sweetened 100 % orange juice and non-sweetened 100 % orange juice fortified with Ca and vitamin D. OJ consumers were then defined as those who reported they consumed OJ as a beverage at least once in the two non-consecutive 24 h DR, while non-consumers were defined as the rest of the participants. OJ consumption was the mean of the two days.

Body composition parameters

Height, weight and waist circumference (WC) were measured by trained technicians using standardized protocols and calibrated equipment. Fat mass was determined by dual-energy X-ray absorptiometry from whole-body scans administered in the NHANES mobile examination centre. Percentage body fat (body fat %) was calculated. BMI was calculated and rounded to the nearest 0·1 kg/m^2. For adults, BMI categories were defined using widely accepted cut-off points, i.e. <18·5 kg/m^2 for underweight, 18·5–24·9 kg/m^2 for normal weight, 25·0–29·9 kg/m^2 for overweight and ≥30·0 kg/m^2 for obesity[18]. As for the definition of obesity in the US children, the Centers for Disease Control and Prevention (CDC) defined that children with BMI-for-age between the 85th and 95th percentiles are overweight and those with BMI-for-age at or above 95th percentile are obese using the databases that were developed in 1997[19]. The present study used the same cut-off points for determining overweight and obesity and BMI-for-age *Z*-scores were calculated based on the 2000 CDC BMI-for-age growth charts for US children[20].

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Statistical analyses

All data analyses was carried out using the SAS statistical software package release 9·2 (2009; SAS Institute Inc., Cary, NC, USA) and the Survey Data Analysis for multistage sample designs professional software package (SUDAAN), release 8·0·2 (2003; Research Triangle Institute, Research Triangle Park, NC, USA). Sample weighting was applied to all analyses to account for the unequal probabilities of selection, non-coverage and non-response bias resulting from oversampling of low-income persons, adolescents, the elderly, African Americans and Mexican Americans. SUDDAN was used to increase the reliability and validity of the results through computing variance estimates and test statistics for a stratified, multistage probability survey design.

The χ^2 test was applied for assessing the distributions of categorical variables. ANOVA was used to compare means for interval scale variables and to test overall differences in percentages of OJ consumption by sociodemographic and lifestyle variables. The analysis was stratified by age to examine the association of macronutrient intakes and body composition with OJ consumption. Arithmetic means and standard errors of macronutrient intake by OJ consumption were calculated by the linearization (Taylor series) variance estimation method. The linear trends of macronutrient intakes and body parameters among OJ non-consumers and tertiles of OJ consumers were tested using linear contrasts after adjustment of age, gender, ethnicity and total energy intake. Where ANOVA results indicated significant difference, the Student t test was conducted to compare macronutrient intakes between OJ non-consumers and consumers in each tertile of OJ consumption with Bonferroni correction, where statistical significance was defined as $P < 0·017$. Prevalence estimates were age-adjusted using the 2000 US Census[21]. In addition to being examined as categories, after testing if BMI (standardized as (raw value – mean)/SD) met the assumption of linearity in the logit, it was also evaluated as a continuous variable; odds ratios are presented for completeness. All P values reported are two-tailed; statistical significance was defined as $P < 0·05$ except for the P values from Bonferroni correction.

Results

Characteristics of orange juice consumers

Sociodemographic, lifestyle and dietary characteristics of the 13 971 participants by OJ consumption are described in Table 1. In the present study, 25 % of the participants consumed OJ as a beverage during at least one of the two non-consecutive recall days. Percentages of OJ consumption were different by gender, age, ethnicity, BMI and income level ($P < 0·05$). Prevalence of OJ consumption was also different among those having different lifestyle or dietary behaviours including alcohol consumption, smoking, supplement use and regular exercise ($P < 0·05$). Although OJ consumers overall drank more milk and less soft drinks than OJ non-consumers in our recent study[22], in the present study OJ consumers in the highest tertile of OJ consumption (≥222 ml/d; ≥7·5 fl oz/d) had higher intakes of milk ($P < 0·001$) and soft drinks ($P < 0·01$) than OJ consumers in the lowest tertile (<121 ml/d; <4·1 fl oz/d).

Macronutrient intakes by orange juice consumption

Compared with participants who did not consume OJ or those in lower tertiles of OJ consumption, after adjusting for age, gender, ethnicity and energy intake, OJ consumers in the highest tertile group with ≥222 ml/d (≥7·5 fl oz/d) had higher intakes of total energy, carbohydrate, total sugar, total fat and fatty acids (SFA, MUFA and PUFA; $P < 0·01$; Tables 2 and 3). However, these linear trends for energy and macronutrient intakes remained unchanged in both children and adult groups when excluding OJ from the food list of items consumed ($P < 0·05$). Percentages of energy from total fat were decreased by OJ consumption in both age groups ($P < 0·001$). In addition, added sugar intake and percentage of energy from added sugar were not associated with OJ consumption in both age groups.

Body composition by orange juice consumption

Among children aged 4–18 years, after adjusted for age, gender, ethnicity and energy intake, OJ consumption had no association with BMI, WC, body fat % or odds ratio for overweight and obesity (Table 4). Taking a further look at age subgroups, children aged 4–8 years did show increased odds ratio for obesity in the third tertile (data not shown), but age groups 9–13 years and 14–18 years had consistent results with the whole group of 4–18 years (data not shown). On the contrary, adults over 19 years who consumed more OJ had lower BMI, WC and body fat % than non-consumers (Table 5). They also had lower odds ratio for overweight and obesity than non-consumers ($P < 0·01$). In age subgroups, this negative association occurred mainly in the 31–50 years group (data not shown).

Discussion

The present study showed that OJ consumption had a negative association with BMI, WC, body fat % and odds ratio for overweight and obesity in adults. In children aged 4–18 years, OJ consumption had no association with BMI, WC, body fat % or odds ratio for overweight and obesity. Nicklas *et al.*[8] reported similar data for 100 % fruit juice in children 2–11 years of age. Although numerous previous studies have evaluated the association between growth parameters of children and 100 % fruit juice consumption, few of them evaluated the impact of specific types of fruit juices. When OJ is specifically

Table 1 Sociodemographic, dietary and lifestyle characteristics according to OJ consumption among the US population aged ≥4 years, NHANES 2003–2006*

		OJ non-consumers (%)		OJ consumers, T1 (%)		OJ consumers, T2 (%)		OJ consumers, T3 (%)		
	n	Mean	SE	Mean	SE	Mean	SE	Mean	SE	*P*†
OJ consumption range										
ml/d		0		<121		121–222		≥222		
fl oz/d		0		<4·1		4·1–7·5		≥7·5		
All	13 971	74·8	0·6	8·3	0·4	8·3	0·4	8·6	0·4	
Gender										
Men	6975	74·2	0·7	6·6	0·3	8·1	0·5	11·0	0·5	<0·001
Women	6996	75·3	0·8	9·9	0·6	8·5	0·5	6·2	0·4	
Age (years)										
4–8	1534	69·3	1·5	17·0	1·3	9·0	0·9	4·7	0·8	<0·001
9–13	1911	73·9	1·4	9·7	0·8	8·7	1·0	7·7	0·8	
14–18	2411	74·5	1·4	4·8	0·7	8·4	0·9	12·3	1·0	
19–30	1776	76·9	1·2	4·9	0·6	7·3	0·7	10·9	0·9	
31–50	2579	79·6	1·1	6·0	0·5	6·3	0·5	8·1	0·8	
>50	3760	70·3	1·2	11·0	0·6	10·7	0·7	8·0	0·5	
Ethnicity										
Non-Hispanic whites	5850	76·3	0·8	8·0	0·4	7·8	0·5	7·9	0·4	<0·01
Non-Hispanic blacks	3731	69·3	1·0	10·0	0·6	10·5	0·5	10·2	0·8	
Mexican Americans	3453	72·2	1·3	8·3	0·6	9·6	0·8	10·0	0·9	
Others	937·0	72·6	1·9	8·3	1·3	8·2	1·1	10·9	1·1	
BMI (kg/m^2)										
<18·5	2442	72·5	1·4	13·1	1·0	8·2	0·8	6·2	0·9	<0·001
18·5–24·9	4812	73·5	0·9	7·2	0·5	8·9	0·6	10·3	0·6	
25·0–29·9	3450	73·9	0·8	8·2	0·5	8·8	0·5	9·1	0·6	
≥30·0	3267	78·3	1·3	7·5	0·6	7·2	0·8	7·0	0·6	
PIR‡										
<1·30	5025	72·9	0·8	8·4	0·6	9·3	0·5	9·4	0·6	<0·05
1·30–3·49	5185	75·3	1·1	9·0	0·5	7·6	0·7	8·1	0·5	
≥3·50	3761	75·4	1·1	7·7	0·6	8·4	0·7	8·5	0·6	
Beverage consumption										
Other fruit juice (g/d)	13 971	29·3	1·5	32·3	2·9	28·2	3·2	37·3	6·2	0·33
Fruit drinks (g/d)	13 971	65·5	3·2	58·1	4·1	70·4	6·9	69·2	5·8	0·23
Milk (g/d)	13 971	269	2·8	262	3·9	285	4·6	344	6·2	<0·001
Soft drinks (g/d)	13 971	435	15·4	277	24·1	313	16·9	348	16·5	<0·01
Alcohol consumption§										
No	2222	73·9	1·2	9·5	0·8	8·6	0·8	8·0	0·6	<0·05
Yes	5059	76·5	0·8	7·0	0·5	7·9	0·5	8·6	0·6	
Current smoking‖										
No	2104	76·1	1·2	7·3	0·6	9·6	0·8	7·0	0·6	<0·001
Yes	1703	82·8	1·1	4·7	0·7	4·8	0·5	7·8	1·0	
Dietary supplement use¶										
No	8514	76·9	0·9	7·1	0·5	7·4	0·4	8·7	0·4	<0·01
Yes	5444	72·7	0·8	9·6	0·5	9·3	0·5	8·4	0·5	
Exercise level**										
0	2766	78·3	1·2	7·0	0·6	7·3	0·6	7·5	0·9	<0·01
T1	2665	75·5	1·1	8·5	0·8	7·7	0·6	8·4	0·6	
T2	2631	73·5	0·8	6·7	0·7	9·8	0·8	10·0	0·6	
T3	2640	74·1	1·2	6·8	0·8	8·0	0·6	11·1	1·0	

OJ, orange juice; NHANES, National Health and Nutrition Examination Survey; T1, T2 and T3, first, second and third tertiles; PIR, poverty income ratio.
*OJ consumers were defined as those who reported consumption of non-sweetened 100 % orange juice at least once in two non-consecutive 24 h diet recalls in NHANES 2003–2006.
†*P* values were analysed by χ^2 to test the differences in OJ consumption by gender, age subgroups, BMI, PIR, alcohol consumption, smoking, dietary supplement use and exercise level.
‡Ratio of the median family income over the poverty index. PIR < 1·3 is required to be eligible for food assistance programmes.
§Alcohol consumption: yes means having at least 12 alcoholic drinks/year.
‖Current smoking: yes means having smoked cigarettes, cigars or pipes or used chewing tobaccos or snuffs every day or some days.
¶Dietary supplement use means taking any dietary supplements that include any vitamins, minerals or other dietary supplements at the time of interview.
**Exercise levels, expressed as MET (metabolic equivalent of task) scores, were calculated by combining the intensity level of the leisure-time activities reported with their mean duration and frequency.

reviewed, no positive association between OJ consumption and weight has been reported[4].

To our knowledge, the present study is the first one that documents a negative association between OJ consumption and BMI along with other measures of body composition in adults. Prevalence of overweight and obesity was lower in OJ consumers than non-consumers in the general US population in this analysis. Of entire OJ consumers in the

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Table 2 Macronutrient intakes by OJ consumption in the US population aged 4–18 years, NHANES 2003–2006*,†

	OJ non-consumers (*n* 4040)		OJ consumers, T1 (*n* 605)		OJ consumers, T2 (*n* 606)		OJ consumers, T3 (*n* 605)		
Nutrient	Mean	SE	Mean	SE	Mean	SE	Mean	SE	*P* trend‡
OJ consumption range									
ml/d	0·0		<121		121–216		≥216		
fl oz/d	0·0		<4·1		4·1–7·3		≥7·3		
Mean OJ consumption									
ml/d	0·0		83	0·0	160	0·0	370	5·9	
fl oz/d	0·0		2·8	0·0	5·4	0·0	12·5	0·2	
Energy									
kJ/d	8556	63	8251	151	8920	201	10 209	285	<0·001
kcal/d	2045	15	1972	36	2132	48	2440	68	<0·001
t Test§	–		0·09		0·08		<0·017		
Energy excluding OJ									
kJ/d	8556	63	8109	151	8632	201	9552	280	<0·05
kcal/d	2045	15	1938	36	2063	48	2283	67	<0·05
Protein (g/d)	72·1	0·6	71·4	1·5	74·1	1·9	87·9	2·7	0·67
t Test	–		0·66		0·28		<0·017		
Protein excluding OJ (g/d)	72·1	0·6	70·9	1·5	73·1	1·9	85·7	2·7	0·18
Carbohydrate (g/d)	272	2·2	262	5·2	286	6·6	333	8·5	<0·001
t Test	–		0·13		0·03		<0·017		
Carbohydrates excluding OJ (g/d)	272	2·2	254	5·2	270	6·6	296	8·1	<0·001
Total sugar (g/d)	136	1·7	129	2·8	144	3·8	171	4·6	<0·001
t Test	–		0·08		0·03		<0·017		
Total sugar excluding OJ (g/d)	120	1·2	105	2·1	115	2·5	129	2·6	<0·001
Added sugar (g/d)	78	1·5	73	3·4	80	3·7	80	3·3	0·31
Total fat (g/d)	76·6	0·7	73·4	1·8	79·0	2·3	86·4	3·0	<0·001
t Test	–		0·09		0·34		<0·017		
Total fat excluding OJ (g/d)	81·0	0·8	74·8	1·2	77·0	1·4	89·3	1·7	<0·001
Fatty acids									
SFA (g/d)	27·0	0·3	25·9	0·7	27·7	0·8	30·6	1·1	<0·01
MUFA (g/d)	28·3	0·3	27·0	0·7	29·0	0·8	31·6	1·1	<0·001
PUFA (g/d)	15·1	15·1	14·4	0·4	15·8	0·7	16·6	0·7	<0·01
Cholesterol (mg/d)	225	2·8	245	8·0	231	5·8	290	11·9	0·44
%E from protein/d	14·1	0·1	14·5	0·2	13·8	0·2	14·3	0·2	0·75
%E from carbohydrate/d	52·9	0·2	52·8	0·5	53·8	0·4	54·6	0·4	<0·001
%E from added sugar/d	16·9	0·3	16·1	0·6	16·4	0·8	14·9	0·8	0·21
%E from fat/d	33·1	0·2	32·8	0·4	32·4	0·4	31·1	0·4	<0·001

OJ, orange juice; NHANES, National Health and Nutrition Examination Survey; T1, T2 and T3, first, second and third tertiles; %E, percentage of energy.
*Estimation of nutrient intake was based on two non-consecutive 24 h diet recalls in NHANES 2003–2006.
†OJ consumers were defined as those who reported consumption of non-sweetened 100 % orange juice at least once in two non-consecutive 24 h diet recalls in NHANES 2003–2006.
‡*P* trend values were adjusted for age, gender, ethnicity and energy intake; *P* value for energy intake was adjusted for age, gender and ethnicity. *P* value was calculated across the mean of intake of OJ in each tertile using multivariate regression models.
§Student's *t* tests were performed between OJ non-consumers and consumers in each tertile of OJ consumption with Bonferroni correction, where statistical significance was defined as $P<0·017$.

present study, 26 % were overweight and 20 % were obese; while during the same period 2003–2006, 33 % of adults over 20 years in the USA were overweight and 33 % were obese[23]. In addition, 32 % of children and adolescents aged 2–19 years were overweight (BMI-for-age > 85th percentile) and 17 % were obese (BMI-for-age > 95th percentile) during 2007–2008[24].

For OJ consumers ingesting <216 ml/d (<7·3 fl oz/d), there was no association with energy intake in children. In the adult group, OJ consumers in the lowest tertile group ingesting <121 ml/d (<4·1 fl oz), OJ consumption was inversely associated with energy intake. However, we found that energy intake was higher only in the group in the highest tertile of OJ consumption for both children and adults ($P<0·017$). This has been observed in previous studies[8,10] and warrants further investigation to determine the source and effect of the additional energy. However, it is premature to suggest that OJ solely contributes to this increase in energy, since the observed linear trends of increased energy intake remained after OJ was removed from the food list of items consumed. To determine the effect of this lower energy intake on weight status would require a sufficiently powered longitudinal study[8]. In addition, further investigation is warranted to understand potential mechanisms of OJ and weight control, since preliminary studies have documented the potential effectiveness of OJ consumption in weight control[25,26]. For example, in an animal model, Titta *et al.* reported that blood orange juice inhibited fat accumulation in mice despite increased energy intake from sugar[25].

In the present study, OJ consumption was positively correlated with milk consumption and negatively associated with carbonated soft drinks consumption, indicating that drinking OJ facilitates achieving nutrient adequacy and

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Table 3 Macronutrient intakes by OJ consumption in the US population aged ≥19 years, NHANES 2003–2006*,†

	OJ non-consumers (*n* 5921)		OJ consumers, T1 (*n* 754)		OJ consumers, T2 (*n* 712)		OJ consumers, T3 (*n* 728)		
Nutrient	Mean	SE	Mean	SE	Mean	SE	Mean	SE	*P* trend‡
OJ consumption range									
ml/d	0·0		<121		121–222		≥222		
fl oz/d	0·0		<4·1		4·1–7·5		≥7·5		
Mean OJ consumption									
ml/d	0·0		89	0·0	169	0·0	363	6	
fl oz/d	0·0		3·0	0·0	5·7	0·0	12·3	0·2	
Energy									
kJ/d	8941	71	8150	142	8862	176	10 577	201	<0·001
kcal/d	2137	17	1948	34	2118	42	2528	48	<0·001
t Test§	–		<0·017		0·68		<0·017		
Energy excluding OJ									
kJ/d	8941	71	7991	142	8556	176	9920	201	<0·01
kcal/d	2137	17	1910	34	2045	42	2371	48	<0·01
Protein (g/d)	83·5	0·8	76·3	1·6	80·3	1·3	95·6	2·0	0·13
t Test	–		<0·017		0·05		<0·017		
Protein excluding OJ (g/d)	83·5	0·8	75·7	1·6	79·3	1·3	93·4	2·0	<0·01
Carbohydrate (g/d)	255	2·0	237	5·0	269	5·7	320	5·7	<0·001
t Test	–		<0·017		0·02		<0·017		
Carbohydrates excluding OJ (g/d)	255	2·0	228	5·1	252	5·6	283	5·7	<0·001
Total sugar (g/d)	115	1·4	106	3·4	127	3·3	159	3·1	<0·001
t Test	–		0·02		<0·017		<0·017		
Total sugar excluding OJ (g/d)	115	1·4	98	3·5	112	3·3	126	3·1	<0·01
Added sugar (g/d)	77	1·0	79	2·6	77	3·1	79	3·7	0·75
Total fat (g/d)	82·2	0·9	74·9	1·5	77·5	1·9	90·9	2·0	<0·001
t Test	–		<0·017		0·02		<0·017		
Total fat excluding OJ (g/d)	82·2	0·9	74·8	1·5	77·3	1·9	90·5	2·0	<0·001
Fatty acids									
SFA (g/d)	27·4	0·3	24·6	0·5	25·3	0·7	29·6	0·7	<0·001
MUFA (g/d)	30·5	0·4	27·8	0·6	28·6	0·8	33·7	0·7	<0·001
PUFA (g/d)	17·3	0·2	16·0	0·4	16·9	0·5	19·6	0·5	<0·05
Cholesterol (mg/d)	289	3·6	285	10·5	267	5·9	336	9·2	0·08
%E from protein/d	16·3	0·1	16·0	0·2	15·5	0·2	15·6	0·2	<0·01
%E from carbohydrate/d	48·8	0·2	49·7	0·5	51·9	0·3	52·1	0·3	<0·001
%E from added sugar/d	17·6	0·3	18·7	0·7	17·0	0·7	14·6	0·7	0·91
%E from fat/d	34·9	0·2	34·3	0·4	32·6	0·3	32·4	0·3	<0·001

OJ, orange juice; NHANES, National Health and Nutrition Examination Survey; T1, T2 and T3, first, second and third tertiles; %E, percentage of energy.
*Estimation of nutrient intake was based on two non-consecutive 24 h diet recalls in NHANES 2003–2006.
†OJ consumers were defined as those who reported consumption of non-sweetened 100 % orange juice at least once in two non-consecutive 24 h diet recalls in NHANES 2003–2006.
‡*P* trend values were adjusted for age, gender, ethnicity and energy intake; *P* value for energy intake was adjusted for age, gender and ethnicity. *P* value was calculated across the mean of intake of OJ in each tertile using multivariate regression models.
§Student's *t* tests were performed between OJ non-consumers and consumers in each tertile of OJ consumption with Bonferroni correction, where statistical significance was defined as $P<0·017$.

does not replace milk consumption. This finding is in good accordance with previous evidence suggesting that milk and fruit juice consumption was positively associated with the likelihood of achieving recommended intakes of vitamin A, vitamin B_{12}, folate, Ca, K and Mg[27,28]. Harnack and colleagues[28], in analysing data from the Continuing Survey of Food Intakes by Individuals (1994–1996), found that children who consumed more soda consumed less milk and fruit juice, and had lower mean intakes of nutrients related to milk and fruit juice. This inverse association between consumptions of fruit juice and soft drinks may be a potential pathway explaining why OJ consumption was not associated with risk of overweight or obesity among children and inversely associated in the adult group in our study. Future studies are needed to validate this hypothesis in different age groups. Also, future research should examine the extent to which OJ consumption contributes to replacing soft drinks consumption and ameliorating or reducing risk of obesity although OJ consumption itself increases energy intake.

Our findings are interpreted based on several assumptions: first, the USDA food composition databases were constructed based on US representative food samples including varying cultivars, geographic origin, growing seasons, agricultural practices and analytical methods. Second, dietary intake data were based on two non-consecutive 24 h DR which might be a limitation of the current study since there is no scientific agreement on the minimum period of dietary data collection needed to obtain an approximation of usual intake or habitual dietary behaviours. However, the 24 h DR can produce adequate estimates of mean intake of a group that can be useful for contrasting the dietary status of the group with different levels of disease risks or health outcomes[29].

Table 4 Body composition by OJ consumption in the US population aged 4–18 years, NHANES 2003–2006*

	OJ non-consumers		OJ consumers, T1		OJ consumers, T2		OJ consumers, T3		
Body measurement	Mean	SE	Mean	SE	Mean	SE	Mean	SE	*P* trend†
Weight-for-age *Z*-score‡	0·56 (*n* 4015)	0·04	0·47 (*n* 649)	0·06	0·62 (*n* 557)	0·08	0·63 (*n* 603)	0·08	0·23
BMI (kg/m²)	20·6 (*n* 4015)	0·1	20·7 (*n* 649)	0·2	18·8 (*n* 557)	0·2	20·6 (*n* 603)	0·3	0·28
WC (cm)	72·1 (*n* 3966)	0·6	65·4 (*n* 647)	0·6	71·0 (*n* 552)	0·7	75·6 (*n* 599)	0·9	0·51
Triceps skinfold thickness (mm)	14·7 (*n* 3834)	0·2	13·2 (*n* 633)	0·3	14·0 (*n* 537)	0·4	14·7 (*n* 580)	0·4	1·00
Body fat %§	30·0 (*n* 1566)	0·4	30·7 (*n* 212)	0·8	30·1 (*n* 212)	1·0	28·3 (*n* 287)	0·7	0·59
	OR	95 % CI	OR	95 % CI	OR	95 % CI	OR	95 % CI	
BMI-for-age percentile ≥ 85th	1·00 (*n* 4009)	Ref.	0·86 (*n* 649)	0·69, 1·08	1·06 (*n* 557)	0·78, 1·45	1·09 (*n* 603)	0·84, 1·43	0·24
BMI-for-age percentile ≥ 95th	1·00 (*n* 4009)	Ref.	0·80 (*n* 649)	0·58, 1·10	1·06 (*n* 557)	0·77, 1·45	1·02 (*n* 603)	0·70, 1·49	0·53

OJ, orange juice; NHANES, National Health and Nutrition Examination Survey; T1, T2 and T3, first, second and third tertiles; WC, waist circumference; body fat %, percentage of body fat; Ref., referent category.
*OJ consumers were defined as those who reported consumption of non-sweetened 100 % orange juice at least once in two non-consecutive 24 h diet recalls in NHANES 2003–2006.
†Adjusted for age, gender, ethnicity and energy intake.
‡Weight-for-age *Z*-score was calculated using 2000 Centers for Disease Control and Prevention growth chart[20].
§Body fat % data are based on NHANES 2003–2004 (aged ≥8 years) and calculated by dividing fat mass by total mass.

Table 5 Body composition by OJ consumption in the US population aged ≥19 years, NHANES 2003–2006*

	OJ non-consumers		OJ consumers, T1		OJ consumers, T2		OJ consumers, T3		
Body measurement	Mean	SE	Mean	SE	Mean	SE	Mean	SE	*P* trend†
Weight (kg)	82·3 (*n* 5845)	0·5	78·4 (*n* 744)	0·8	78·6 (*n* 696)	0·9	81·7 (*n* 719)	0·9	<0·01
BMI (kg/m²)	28·7 (*n* 5845)	0·2	28·1 (*n* 744)	0·2	27·6 (*n* 696)	0·3	27·4 (*n* 719)	0·3	<0·001
WC (cm)	98·1 (*n* 5718)	0·4	96·8 (*n* 717)	0·7	95·4 (*n* 671)	0·7	96·1 (*n* 701)	0·8	<0·001
Triceps skinfold thickness (mm)	19·7 (*n* 5172)	0·2	20·7 (*n* 660)	0·4	19·0 (*n* 617)	0·4	17·5 (*n* 650)	0·4	0·05
Body fat %‡	34·7 (*n* 2925)	0·3	36·0 (*n* 409)	0·4	34·1 (*n* 366)	0·6	32·0 (*n* 362)	0·5	<0·001
	OR	95 % CI	OR	95 % CI	OR	95 % CI	OR	95 % CI	
BMI ≥ 25·0 kg/m²	1·00 (*n* 2925)	Ref.	1·02 (*n* 409)	0·86, 1·22	0·84 (*n* 366)	0·65, 1·08	0·69 (*n* 362)	0·56, 0·84	<0·001
BMI ≥ 30·0 kg/m²	1·00 (*n* 2925)	Ref.	0·88 (*n* 409)	0·72, 1·08	0·73 (*n* 366)	0·56, 0·96	0·68 (*n* 362)	0·53, 0·87	<0·01

OJ, orange juice; NHANES, National Health and Nutrition Examination Survey; T1, T2 and T3, first, second and third tertiles; WC, waist circumference; body fat %, percentage of body fat; Ref., referent category.
*OJ consumers were defined as those who reported consumption of non-sweetened 100 % orange juice at least once in two non-consecutive 24 h diet recalls in NHANES 2003–2006.
†Adjusted for age, gender, ethnicity and energy intake.
‡Body fat % data are based on NHANES 2003–2004 (aged ≥8 years) and calculated by dividing fat mass by total mass.

Last, the present study was based on cross-sectional data and we cannot draw any cause-and-effect conclusion on the impact of OJ consumption on weight status.

Conclusions

OJ consumption was associated with healthier body composition (lower BMI, WC and body fat %) in adults, and there were no significant associations between OJ consumption and body composition in children and adolescents. OJ consumption had no association with BMI, WC, body fat % or odds ratio for overweight and obesity. When we took a further look at age subgroups, children aged 4–8 years did show increased odds ratio for obesity in the third tertile, but other age subgroups had consistent results with the whole group of 4–18 years. The encouraging results from our study, however, suggest that larger, longitudinal studies are warranted.

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