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Consumption of apples is associated with a better diet quality and reduced risk of obesity in children: National Health and Nutrition Examination Survey (NHANES) 2003–2010

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Abstract

Background: Most children do not meet the recommendation for fruit consumption. Apples are the second most commonly consumed fruit in the US; however, no studies have examined the association of total apple products, apples, apple sauce, and 100 % apple juice consumption on diet quality and weight/adiposity in children.

Methods: The purpose of this study was to examine the association between various apple consumption forms with diet quality and weight/adiposity in a nationally representative sample of children. Participants were children 2–18 years of age ($N = 13,339$) from the National Health and Nutrition Examination Survey 2003–2010. Intake was determined using a single interview administered 24-h diet recall. Apple product consumption was determined using the cycle-appropriate USDA Food and Nutrient Database for Dietary Studies food codes. Total diet quality and component scores were determined using the Healthy Eating Index-2010 (HEI). Anthropometrics were determined using standard methods. Covariate adjusted linear and logistic regressions were used to compare apple product consumers with non-consumers; sample weights were used. Probability was set at <0.01 .

Results: Approximately 26 % of the population ($n = 3,482$) consumed some form of apple products. Consumers of apple products, whole apples, apple sauce, and 100 % apple juice had higher HEI scores than non-consumers: 50.4 ± 0.4 v 41.9 ± 0.3 , 52.5 ± 0.5 v 42.7 ± 0.3 , 52.1 ± 0.8 v 47.2 ± 0.4 , and 51.4 ± 0.6 v 46.5 ± 0.4 , respectively. Apple products and whole apple consumers had lower BMI z-scores than non-consumers: 0.4 ± 0.04 v 0.5 ± 0.03 and 0.3 ± 0.1 v 0.5 ± 0.02 , respectively. Apple products and whole apple consumers were 25 % (0.59–0.95 99th CI) and 30 % (0.52–0.95 99th CI), respectively, were less likely to be obese than non-consumers.

Conclusions: Consumption of any form of apples contributed to the fruit recommendation of children and improved diet quality. Apples should be included in the diets of children as a component of an overall healthy diet.

Keywords: NHANES, Apple, Apple juice, Apple sauce, Children, Fruit, Weight, Diet quality

Introduction

Fruit, defined by the Dietary Guidelines for Americans (DGA) [1] as a nutrient-dense food, has also been recognized as part of a healthy eating pattern [1]. Eating nutrient-dense foods, such as fruit helps Americans balance nutrient needs within their energy needs. The recommendation for fruit is age, gender, and physical activity

dependent, and for children ranges from 1 cup equivalent for children 2–3 years of age (years) to 2 cup equivalents for males 14–18 years [2]. Fresh, frozen, canned, or dried fruit can be used to meet the fruit recommendation, as can 100 % fruit juice [2, 3]. Approximately 35 % to 50 % of total fruit intake by children 9 to 18 years [4] comes from 100 % fruit juice, which makes a positive contribution to overall diet quality, and has been associated with increased intake of whole fruit [5–7]. However, most children fail to meet the fruit recommendation [8–14].

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Eating a diet rich in fruit, as part of an overall healthy diet may reduce the risk of cardiovascular disease [15–18], type 2 diabetes [18–20], and some types of cancer [18, 21]. According to the DGA [1], eating fruit, which is a relatively low-energy food, in place of higher energy foods may help lower overall energy intake; however, the effect of fruit consumption on weight or weight loss is controversial [18, 22–24]. Fruit provides a wide array of nutrients, including nutrients of public health concern [1], such as dietary fiber and potassium, as well as other short-fall nutrients, like vitamins A and C and folate [25]. Many of the health benefits seen may be due to these nutrients or to the phytochemicals found in fruit [26].

Apples (*Malus domestica*) are the second most commonly consumed fruit in the United States (US) [27], with 65 % of the apple crop consumed as fresh fruit and 35 % as processed apple products (e.g. apple sauce or apple juice) [28]. One medium raw apple (182 g), with skin, provides approximately 95 kcals, 19 g total sugars, 4 g dietary fiber (22 % of the Daily Value [DV]), and 195 mg of potassium (6 % DV). In addition, raw apples contain virtually no total fat, saturated fatty acids, or sodium; and they have no cholesterol. Processed apple products have a slightly different nutrient profile than raw apples. For example apple sauce may or may not have added sugars and ½ cup (122 g) has only 1.3 g dietary fiber and ½ cup of 100 % fruit juice (124 g) has 0.2 g dietary fiber [25]. These processed apple products still count toward the fruit recommendation [2]. Apples are also especially rich in phenolics, especially hydroxycinnamic acid derivatives and flavonoids [27].

No studies have examined the association of apple product consumption and diet quality or weight/adiposity parameters in children. The purpose of this study was to examine the association between apple/apple product consumption with diet quality and weight/adiposity parameters in a nationally representative sample of children using the National Health and Nutrition Examination Survey (NHANES) 2003–2010 data.

Subjects and methods

The NHANES

The NHANES is a continual program designed to collect data that can be used to assess the health and nutritional status of free-living children and adults in the US. One of major objectives of the NHANES is to provide the data for investigators to be able to examine the relationship between diet, nutrition, and health [29]. The survey is unique in that it collects data from interviews, dietary intake, and physical examinations. Details regarding the survey design, content, operations, procedures, and participation rates are available online [29–32].

Study population and dietary intake

The study population consisted of children 2–18 years ($N = 13,339$) who participated in the 2003–2004, 2005–2006, 2007–2008, 2009–2010 NHANES. Intake data were obtained from What We Eat in America which were collected during an in-person automated multiple-pass 24-h dietary recall interview and a telephone 24-h dietary recall conducted three to ten days later [33, 34]. For these studies, only the first day of data collection was used. Detailed descriptions of the dietary interview methods are provided in the NHANES Dietary Interviewers Procedure Manuals [35, 36]. Briefly, proxies, usually parents, provided the 24-h dietary recalls of children 2–5 years; children 6–11 years were assisted by a proxy; older children provided their own recalls. Recall data deemed unreliable by the USDA Food Surveys Research Group ($n = 275$), pregnant and lactating females ($n = 83$), and those children consuming breast milk ($n = 10$) were excluded from the analyses. This left a final analytical sample of 13,339. The NHANES has stringent protocols and procedures that ensure confidentiality and protect individual participants from identification using federal laws [37] and additional Institutional Review Board approval for these secondary analyses was not required [38].

Determination of apple product consumption

Apple/apple product consumption was determined from the 24-h dietary recall by using the cycle-appropriate United States Department of Agriculture food codes [39] for: 1) whole apples; 2) apple sauce (which includes cooked apples); 3) 100 % apple juice; and, 4) total apples, which included all food codes from the three groups above.

Healthy Eating Index (HEI-2010)

The HEI-2010 [40, 41] was used to determine diet quality as specified by the 2010 DGA [1]. For the HEI-2010 a total score is determined, as are 12 component scores. Of these, nine: total fruit, whole fruit, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, and fatty acids measure adequacy; and a higher score is better. Three of the component scores: refined grains, sodium, and empty calories, measure moderation; and higher scores indicate lower consumption. The SAS code used to calculate HEI-2010 scores was downloaded from the Center for Nutrition Policy and Promotion website [42].

Anthropometric and physiological measures

Height, weight, and waist circumference were obtained according to NHANES protocols [43]. Body mass index (BMI) was calculated as kg/m^2 [44]. The SAS program of the Centers for Disease Control and Prevention was used to determine BMI z-score and placement of children on the 2000 growth charts [45]. Children with a BMI \geq the

85th and <95th were considered overweight; and children \geq the 95th percentile were considered obese [46]. Children with a BMI \geq 85th percentile were considered overweight or obese.

Statistical analyses

Sampling weights and the primary sampling units and strata information, as provided by NHANES [47], were included in all analyses using SUDAAN v11.0 (Research Triangle Institute; Raleigh, NC). Least-square means (and the standard errors of the least-square means) were calculated using PROC REGRESS of SUDAAN. Linear regression was used to determine differences in total and sub-component HEI-2010 scores between apple, apple sauce, apple juice, and total apple consumers and non-consumers, as well as differences in anthropometric measures among these consumers and non-consumers. Logistic regression was used to determine if apple, apple sauce, apple juice, and total apple consumers had a lower odds ratio (OR) of being overweight, obese, or overweight or obese. For all linear and logistic regressions, covariates were: age (continuous variable), gender (discrete variable), and ethnicity (discrete variable), all of which were determined from the sample person questionnaire [31]; poverty index ratio (<1.25, 1.25–3.24, >3.25), which was obtained from the NHANES family questionnaire [48]; and physical activity level (sedentary, moderate, and vigorous), which was also obtained from the sample person questionnaire [31, 49]. All covariates were self-reported. A *p* value of <0.01 was considered significant to reduce the likelihood of making a type one error.

Results

Apple consumption and demographic characteristics

Approximately 26 % of the population (*n* = 3,482) consumed some form of apple products; 14 % (*n* = 1,891) consumed whole apple; 5 % (*n* = 332) consumed apple sauce, and ~12 % (*n* = 1,714) consumed 100 % apple juice. Some children consumed more than one apple product in one day; therefore, there was some overlap in the study population. Among consumers, mean intake of any apple products was 222.2 ± 3.9 g, whole apple was 143 ± 3.8 g (~1 cup equivalent), apple sauce was 129.8 ± 5.7 g (~1/2 cup equivalent), and apple juice was 9.6 ± 0.24 fluid ounces (272.5 ± 6.7 g; 1.2 cup equivalents). Total apple product consumers, whole apples, apple sauce, or apple juice were more likely to be younger and less likely to be current smokers than non-consumers (Table 1). There were also racial/ethnic differences among consumers of whole apples and apple sauce, with fewer non-Hispanic blacks and more Mexican-Americans consuming whole apples and fewer Mexican-Americans consuming apple sauce. Apple sauce consumers were less likely to be

sedentary and more likely to be moderately physically active than non-consumers (Table 1).

HEI-2010

Although all HEI-2010 scores were relatively low, consumers of any apple product had higher total HEI-2010 scores than non-consumers (Table 2). Total apple product consumers also had higher HEI-2010 component scores: total fruit, whole fruit, whole grains, sodium, and empty calories than non-consumers. It is important to remember that sodium, refined grains, and empty calories are reverse scored so a higher score indicates lower consumption. Whole apple consumers had higher component scores for total and whole fruit, whole grains, and seafood & plant protein, as well as empty calories. Apple sauce consumers also had higher component scores for total and whole fruit, whereas apple juice consumers had higher component scores for total fruit and empty calories.

Weight and adiposity measures

Total apple product and apple consumers had lower mean BMI z-scores than non-consumers (Table 3). Total apple product consumers also had a lower prevalence of obesity and overweight or obesity than seen in non-consumers; whereas, whole apple consumers only had a lower prevalence of obesity than non-consumers. No differences in any measure of weight or adiposity were seen between apple sauce and apple juice consumers, when compared with non-consumers. Table 4 shows that children consuming total apple products or whole apples were 25 % and 30 %, respectively, less likely to be obese than non-consumers. No significant differences were seen when comparing the likelihood of overweight or obesity among apple sauce or apple juice consumers and non-consumers.

Discussion

This is the first study, that we are aware of, that has shown that total apple product consumption, whole apples, and apple sauce and apple juice were associated with higher diet qualities than those seen in non-consumers of the same food groups. It is also the first study to show that total apple consumption and whole apple consumption is associated with a lower prevalence of obesity and a lower likelihood of obesity.

Recently, it was shown that more than three-quarters (77.1 %) of all children 2–19 years consumed any fruit on a given day [8]. There is a clear difference in age, with younger children 2–5 years consuming more than older children 12–19 years [8]. Fruit consumption among children 2–18 years appears to have increased during the time of this study (2003 to 2010) [9] from 0.55 in 2003–2004 to 0.62 in 2009–2010 cup equivalents/1,000 kcal (kcal)

Table 1 Demographic characteristics of children 2–18 years (N = 13,339) participating in NHANES 2003–2010 by total apple and apple product consumption

Variable	Total apple products			Whole apples			Apple sauce			Apple juice		
	Consumers (n = 3,482) LSM ± SE	Non-Consumers (n = 9,857) LSM ± SE	P-value	Consumers (n = 1,891) LSM ± SE	Non-Consumers (n = 11,448) LSM ± SE	P - value	Consumers (n = 332) LSM ± SE	Non-Consumers (n = 13,007) LSM ± SE	P-value	Consumers (n = 1,714) LSM ± SE	Non-Consumers (n = 11,625) LSM ± SE	P-value
Gender (%)												
Female	49.9 ± 1.4	49.0 ± 0.8	0.584	50.4 ± 1.8	49.0 ± 0.8	0.466	49.5 ± 3.2	49.2 ± 0.8	0.930	49.9 ± 2.1	49.1 ± 0.8	0.732
Ethnicity (%)												
NHW	58.3 ± 2.0	61.0 ± 2.0	0.334	57.1 ± 2.3	60.8 ± 2.0	0.220	76.7 ± 3.2	59.7 ± 1.9	<0.001	55.6 ± 2.6	60.9 ± 1.9	0.105
NHB	13.0 ± 1.1	14.9 ± 1.1	0.227	10.6 ± 1.1	15.0 ± 1.1	0.004	12.4 ± 2.0	14.5 ± 1.0	0.367	15.4 ± 1.4	14.3 ± 1.0	0.508
MA	15.9 ± 1.3	12.4 ± 1.2	0.039	18.0 ± 1.5	12.5 ± 1.2	0.004	5.2 ± 1.3	13.6 ± 1.2	<0.001	16.1 ± 1.6	12.9 ± 1.1	0.104
Age (Years)	8.3 ± 0.2	10.7 ± 0.1	<0.001	9.1 ± 0.2	10.3 ± 0.1	<0.001	7.2 ± 0.3	10.2 ± 0.1	<0.001	7.2 ± 0.2	10.5 ± 0.1	<0.001
PIR	2.6 ± 0.1	2.5 ± 0.1	0.486	2.6 ± 0.1	2.5 ± 0.1	0.155	2.6 ± 0.2	2.5 ± 0.1	0.504	2.4 ± 0.1	2.5 ± 0.1	0.159
PA (%)												
Sedentary	13.0 ± 1.0	12.7 ± 0.6	0.839	12.4 ± 1.3	12.9 ± 0.5	0.722	8.2 ± 1.7	12.9 ± 0.5	0.009	16.0 ± 1.6	12.3 ± 0.5	0.032
Moderate	20.4 ± 1.1	19.8 ± 0.7	0.676	20.4 ± 0.7	17.6 ± 1.6	0.115	32.7 ± 3.7	19.6 ± 0.7	<0.001	20.8 ± 1.7	19.9 ± 0.7	0.590
Active	66.7 ± 1.3	67.5 ± 0.9	0.621	66.8 ± 0.8	70.0 ± 2.2	0.164	59.1 ± 3.7	67.5 ± 0.8	0.025	63.2 ± 1.9	67.8 ± 0.8	0.025
Current smoker (%)	2.5 ± 0.4	7.5 ± 0.5	<0.001	6.8 ± 0.4	2.3 ± 0.4	<0.001	1.3 ± 0.7	6.3 ± 0.4	<0.001	2.6 ± 0.7	6.7 ± 0.4	<0.001
Alcohol (g)	0.3 ± 0.1	0.6 ± 0.1	0.012	0.5 ± 0.1	0.3 ± 0.1	0.075	0.0 ± 0.0	0.5 ± 0.1	<0.001	0.2 ± 0.1	0.5 ± 0.1	0.016

Data Source: Children 2 to 18 years of age participating in the NHANES 2003–2010

Bolded values are significantly different $p < 0.01$; statistical differences were assessed using z-statistics

Abbreviations: LSM = Least Square Means; SE = Standard Error; NHW = Non-Hispanic White; NHB = Non-Hispanic Black; MA = Mexican American; PIR = poverty index ratio; PA = physical activity

Table 2 Association between consumption of apple products, apples, apple sauce, and apple juice and Healthy Eating Index-2010 total and component scores in children participating in NHANES 2003–2010 (N = 13,339)

Healthy eating index-2010 & Components	Total apple products			Apples			Apple sauce			Apple juice		
	Consumers (n = 3,482) LSM ± SE	Non-Consumers (n = 9,857) LSM ± SE	P-value	Consumers (n = 1,891) LSM ± SE	Non-Consumers (n = 11,448) LSM ± SE	P-value	Consumers (n = 332) LSM ± SE	Non-Consumers (n = 13,007) LSM ± SE	P-value	Consumers (n = 1,714) LSM ± SE	Non-Consumers (n = 11,625) LSM ± SE	P-value
Total Score	50.4 ± 0.4	41.9 ± 0.3	<0.001	52.5 ± 0.5	42.7 ± 0.3	<0.001	52.1 ± 0.8	47.2 ± 0.4	<0.001	51.4 ± 0.6	46.5 ± 0.4	<0.001
Total Vegetables	2.2 ± 0.1	2.1 ± 0.03	0.519	2.3 ± 0.1	2.1 ± 0.03	0.108	1.7 ± 0.1	2.0 ± 0.03	0.055	2.0 ± 0.1	2.0 ± 0.04	0.730
Greens & Beans	0.7 ± 0.1	0.6 ± 0.03	0.052	0.8 ± 0.1	0.6 ± 0.02	0.021	0.4 ± 0.1	0.6 ± 0.03	0.070	0.6 ± 0.1	0.5 ± 0.03	0.162
Total Fruit	4.2 ± 0.04	1.9 ± 0.1	<0.001	4.4 ± 0.1	2.2 ± 0.04	<0.001	4.0 ± 0.1	3.1 ± 0.1	<0.001	4.4 ± 0.1	2.9 ± 0.1	<0.001
Whole Fruit	3.6 ± 0.1	1.5 ± 0.1	<0.001	4.7 ± 0.04	1.6 ± 0.04	<0.001	4.4 ± 0.1	2.5 ± 0.1	<0.001	2.8 ± 0.1	2.5 ± 0.1	0.071
Whole Grains	2.0 ± 0.1	1.7 ± 0.1	<0.001	2.1 ± 0.1	1.8 ± 0.1	0.002	2.5 ± 0.3	2.1 ± 0.1	0.102	2.2 ± 0.1	2.1 ± 0.1	0.457
Dairy	7.1 ± 0.1	6.8 ± 0.1	0.028	7.2 ± 0.1	6.9 ± 0.1	0.043	8.0 ± 0.3	7.7 ± 0.1	0.227	7.8 ± 0.2	7.7 ± 0.1	0.521
Total Protein Foods	3.4 ± 0.04	3.5 ± 0.03	0.032	3.5 ± 0.1	3.5 ± 0.03	0.451	3.3 ± 0.1	3.3 ± 0.03	0.608	3.3 ± 0.1	3.4 ± 0.04	0.362
Seafood & Plant Protein	1.4 ± 0.1	1.3 ± 0.03	0.113	1.6 ± 0.1	1.3 ± 0.03	0.001	1.3 ± 0.2	1.4 ± 0.1	0.699	1.3 ± 0.1	1.4 ± 0.1	0.230
Fatty Acid Ratio	3.8 ± 0.1	3.7 ± 0.1	0.466	3.9 ± 0.1	3.8 ± 0.1	0.377	3.3 ± 0.3	3.4 ± 0.1	0.787	3.5 ± 0.2	3.3 ± 0.1	0.281
Sodium	5.3 ± 0.1	4.9 ± 0.1	<0.001	5.3 ± 0.2	5.0 ± 0.1	0.019	6.1 ± 0.4	5.4 ± 0.1	0.091	5.7 ± 0.2	5.4 ± 0.1	0.072
Refined Grains	5.4 ± 0.1	5.1 ± 0.1	0.022	5.3 ± 0.2	5.2 ± 0.1	0.408	6.2 ± 0.4	5.7 ± 0.1	0.300	6.0 ± 0.2	5.6 ± 0.1	0.064
Empty Calories	11.2 ± 0.2	8.6 ± 0.1	<0.001	11.5 ± 0.3	8.9 ± 0.12	<0.001	11.1 ± 0.4	10.1 ± 0.2	0.025	11.7 ± 0.3	9.8 ± 0.2	<0.001

Data Source: Children 2 to 18 years of age participating in the NHANES 2003–2010

Bolded values are significantly different $p < 0.01$; statistical differences were assessed linear regression

Abbreviations: LSM-Least Square Means; SE-Standard Error

Covariates: Gender, ethnicity, age, Poverty Income Ratio (PIR 0–1.25, 1.25–3.4, ≥3.50), and Physical Activity Level (Sedentary, Moderate, Active)

Table 3 Weight status^a apple products, apples, apple sauce, and apple juice of children participating in NHANES 2003–2010 (N = 13,339)

	Consumers LSM ± SE ^b	Non-Consumers LSM ± SE	P-value
Total Apple Products			
BMI z-score	0.4 ± 0.04	0.5 ± 0.03	0.009
Waist Circumference (cm)	68.2 ± 0.3	68.9 ± 0.3	0.066
% Overweight	14.1 ± 1.0	15.5 ± 0.6	0.233
% Obese	13.5 ± 0.9	16.9 ± 0.8	0.004
% Overweight or Obese	27.6 ± 1.5	32.4 ± 1.0	0.007
Whole Apples			
BMI z-score	0.3 ± 0.1	0.5 ± 0.02	0.008
Waist Circumference (cm)	68.1 ± 0.4	68.9 ± 0.3	0.105
% Overweight	14.5 ± 1.6	15.2 ± 0.6	0.695
% Obese	12.6 ± 1.1	16.6 ± 0.7	0.003
% Overweight or Obese	27.1 ± 2.0	31.8 ± 1.0	0.040
Apple Sauce			
BMI z-score	0.4 ± 0.1	0.5 ± 0.02	0.301
Waist Circumference (cm)	67.7 ± 0.6	68.8 ± 0.2	0.101
% Overweight	14.2 ± 2.4	15.1 ± 0.6	0.688
% Obese	11.2 ± 2.0	16.2 ± 0.7	0.018
% Overweight or Obese	25.4 ± 3.2	31.3 ± 1.0	0.078
Apple Juice			
BMI z-score	0.4 ± 0.1	0.5 ± 0.02	0.502
Waist Circumference (cm)	68.5 ± 0.4	68.8 ± 0.2	0.528
% Overweight	15.6 ± 1.6	15.0 ± 0.6	0.722
% Obese	13.8 ± 1.2	16.3 ± 0.7	0.074
% Overweight or Obese	29.4 ± 2.2	31.4 ± 1.0	0.407

^aAdjusted for age, gender, ethnicity, poverty income ratio, physical activity level (sedentary, moderate, vigorous)

Bolded values are significantly different $p < 0.01$; statistical differences were assessed linear regression

^bSE: Standard Error; LSM: Least Squares Mean

because of significant increases in whole fruit intake. Similar results have been shown for children 2–17 years [10]. Fruit juice consumption declined over this period, going from 0.31 to 0.22 cup equivalents/1,000 kcals [9]. Despite these encouraging numbers, fruit is still under-consumed by children [11–14].

Consumption of total apple products and whole apples clearly has a significant impact on overall diet quality, suggesting that fruit intake and in particular apple products, should be encouraged. This complements other studies that have shown that consumption of individual types of whole fruit, including grapefruit [50], mangos [51], pears [52], and avocados [53], and 100 % fruit juice [6, 54] was associated with a higher HEI score than non-consumers. In this study, total apple products, apples, and apple sauce were all associated with intakes of greater

Table 4 Odds ratios of waist circumference and weight status by apple product consumption

	Consumers ^a			P-value
	OR ^{b,c}	LCL	UCL	
Total Apple Products				
Obese	0.75	0.59	0.95	0.002
Overweight	0.89	0.72	1.11	0.173
Overweight or Obese	0.79	0.66	0.94	0.001
Apples				
Obese	0.70	0.52	0.95	0.003
Overweight	0.95	0.68	0.32	0.681
Overweight or Obese	0.79	0.60	1.04	0.027
Apple Sauce				
Obese	0.62	0.32	1.18	0.056
Overweight	0.92	0.54	1.58	0.693
Overweight or Obese	0.73	0.45	1.19	0.098
Apple Juice				
Obese	0.80	0.58	1.10	0.068
Overweight	1.05	0.76	1.45	0.707
Overweight or Obese	0.90	0.69	1.19	0.331

^aNon-consumers are the comparison group

^bAdjusted for age, gender, ethnicity, poverty income ratio, physical activity level

Non-consumers are the comparative group

^{b,c}OR: Odds ratio; LCL: Lower 99th percentile confidence limit; UCL: Upper 99th percentile confidence limit; statistical differences were determined using logistic regression

intakes of total and whole fruit, whereas, consumption of 100 % fruit juice was not. This differs from other studies that have examined the diet quality of 100 % fruit juice consumers [6, 54], perhaps because of the number of 100 % apple juice consumers was relatively small compared with the total number of children consuming 100 % of any type of fruit juice. In addition, the higher diet quality for consumers of all apple products was also driven by higher component scores for whole grains and fewer empty calories consumed.

Determining the effect of fruit consumption on weight is difficult, since most studies have considered fruit and vegetables together [22, 23]; further, most studies have been conducted in adults. Although the association of fruit and vegetables consumption and weight or weight loss is inconsistent [22], the recommendation is to increase fruit and vegetable consumption in the diet to help manage weight [1, 18]. The single study that has examined apple intake and weight loss was a randomized controlled trial of overweight adult females ($n = 411$) who consumed three apples (300 g), three pears (300 g), or oat cookies (60 g) per day for 12 weeks. Groups consuming either apples or pears lost 1.21 kg, compared with the group consuming cookies that lost only 0.88 kg [24].

Ours is the only epidemiologic study that has examined apple products and weight, and the only study in children. This study showed that only total apple products and whole apples were associated with lower BMI z-scores and that consumers were less likely to be obese. Consumption of neither apple sauce nor 100 % apple juice showed any association with weight. The lack of an association between 100 % apple juice with weight is of particular import since although the majority of studies of fruit juice consumption have shown no association with weight [55, 56], one study has shown that apple juice consumption was associated with increased BMI and ponderal index in children [57]. However, that was a small regional study and the data were subsequently disputed [58]. It's not clear why total apple products and whole apples and not apple sauce or 100 % apple juice would be inversely associated with BMI z-score, but it may be related to satiety factors, at least acutely, associated with whole fruit rather than a semi-solid food like apple sauce or a liquid like 100 % apple juice [59, 60].

The strengths of this study were that it included a large sample size with a nationally representative sample of children. The NHANES has carefully controlled protocols and screens 24-h dietary recalls confirming they are valid and complete; the NHANES also uses the multiple pass method to obtain dietary intake, which is the best dietary assessment method available for large scale epidemiologic studies. Twenty-four hour dietary recalls, used in this study do have several inherent limitations: they are memory dependent, and under- and over-reporting may occur. In proxy-assisted recalls of children, parents may know what their children consume at home [61, 62], but they may not know what their children consume outside the home, for example in school or day care [63]. Finally, cause-and-effect relationships cannot be determined from a cross-sectional study.

In conclusion, the consumption of total apple products, whole apples, apple sauce, and 100 % apple juice contributed to the fruit recommendations of children and was associated with better diet quality, and in the case of total apple products and whole apples with a decreased risk of obesity in children. Apple products should be encouraged as part of a healthy diet [64] to help children meet the recommendations for fruit.

Abbreviations

BMI: Body Mass Index; DGA: Dietary Guidelines for Americans; HEI-2010: Healthy Eating Index-2010; NHANES: National Health and Nutrition Examination Survey.

Competing interests

This work is a publication of the USDA/ARS Children's Nutrition Research Center, Department of Pediatrics, Baylor College of Medicine, Houston, Texas. The contents of this publication do not necessarily reflect the views or policies of the USDA, nor does mention of trade names, commercial products, or organizations imply endorsement from the U.S. government. Partial support was received from the United States Department of

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Authors' contributions

All authors contributed equally to this manuscript. TAN, CO'N, and VLF planned the study; VLF conducted the statistical analyses; TAN, CO'N, and VL interpreted the data; CO'N wrote the original draft of the manuscript; TAN and VLF edited this manuscript. All authors read and approved the final manuscript.

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References

- United States Department of Agriculture. Center for nutrition policy and promotion, dietary guidelines for Americans. 2010 [http://www.cnpp.usda.gov/sites/default/files/dietary_guidelines_for_americans/PolicyDoc.pdf]
- United States Department of Agriculture. Choose my Plate. [<http://www.choosemyplate.gov>]
- US Food and Drug Administration. 4. Name of Food. Guidance for Industry: A Food Labeling Guide. [<http://www.fda.gov/Food/GuidanceComplianceRegulatoryInformation/GuidanceDocuments/FoodLabelingNutrition/FoodLabelingGuide/ucm064872.htm>]
- National Cancer Institute. Usual Dietary Intakes: Food Intakes, US Population, 2007–10, 2014. [<http://appliedresearch.cancer.gov/diet/usualintakes/pop/2007-10/#results>]
- Nicklas TA, O'Neil CE, Kleinman R. Association between 100 % juice consumption and nutrient intake and weight of children aged 2 to 11 years. *Arch Pediatr Adolesc Med.* 2008;162:557–65.
- O'Neil C, Nicklas T, Zhanovec M, Fulgoni III V. Diet quality is positively associated with 100 % fruit juice consumption in children and adults in the United States: NHANES 2003–2006. *Nutr J.* 2011;10:1–10.
- O'Neil CE, Nicklas TA, Zhanovec M, Kleinman RE, Fulgoni III VL. Fruit juice consumption is associated with improved nutrient adequacy in children and adolescents: the National Health and Nutrition Examination Survey (NHANES) 2003–2006. *Public Health Nutr.* 2012;15:1871–8.
- Nielsen SJ, Rossen LM, Harris DM, Odgen CL. Fruit and vegetable consumption of U.S. Youth, 2009–2010. *NCHS Data Brief.* 2014;156:1–8.
- Kim SA, Moore LV, Galuska D, Wright AP, Harris D, Grummer-Strawn LM, et al. Vital signs: fruit and vegetable intake among children - United States, 2003–2010. *MMWR Morb Mortal Wkly Rep.* 2014;63:671–6.
- Hazel ABH, Guenther PM, Rihane CI. Diet quality of children age 2–17 years as measured by the healthy eating index-2010. Alexandria, VA: US Department of Agriculture; Center for Nutrition Policy and Promotion. Insight 52; 2013 [http://www.cnpp.usda.gov/sites/default/files/nutrition_insights_uploads/Insight52.pdf]
- Timperio A, Ball K, Roberts R, Campbell K, Andrianopoulos N, Crawford D. Children's fruit and vegetable intake: associations with the neighbourhood food environment. *Prev Med.* 2008;46:331–5.
- Krebs-Smith SM, Guenther PM, Subar AF, Kirkpatrick S, Dodd KW. Americans do not meet federal dietary recommendations. *J Nutr.* 2010;140:1832–8.
- Guenther PM, Dodd KW, Reedy J, Krebs-Smith SM. Most Americans eat much less than recommended amounts of fruits and vegetables. *J Am Diet Assoc.* 2006;106:1371–9.
- Upton D, Upton P, Taylor C. Fruit and vegetable intake of primary school children: a study of school meals. *J Hum Nutr Diet.* 2012;25:557–62.

15. Hung HC, Joshipura KJ, Jiang R, Hu FB, Hunter D, Smith-Warner SA, et al. Fruit and vegetable intake and risk of major chronic disease. *J Natl Cancer Inst.* 2004;96:1577–84.
16. He FJ, Nowson CA, Lucas M, MacGregor GA. Increased consumption of fruit and vegetables is related to a reduced risk of coronary heart disease: meta-analysis of cohort studies. *J Hum Hypertens.* 2007;21:717–28.
17. Dauchet L, Amouyel P, Hercberg S, Dallongeville J. Fruit and vegetable consumption and risk of coronary heart disease: a meta-analysis of cohort studies. *J Nutr.* 2006;136:2588–93.
18. WHO. Global strategy on diet, physical activity and health: diet, nutrition and the prevention of chronic diseases. In: Report of the joint WHO/FAO expert consultation, WHO technical report series, No. 916 (TRS 916). 2003 [http://www.who.int/dietphysicalactivity/en]
19. Muraki I, Imamura F, Manson JE, Hu FB, Willett WC, van Dam RM, et al. Fruit consumption and risk of type 2 diabetes: results from three prospective longitudinal cohort studies. *Br Med J.* 2013;347:f5001.
20. Carter P, Gray LJ, Troughton J, Khunti K, Davies MJ. Fruit and vegetable intake and incidence of type 2 diabetes mellitus: systematic review and meta-analysis. *Br Med J.* 2010;341:c4229.
21. Wang Q, Wang X, Gong G, Li G, Li C. Consumption of fruit, but not vegetables, may reduce risk of gastric cancer: results from a meta-analysis of cohort studies. *Eur J Cancer.* 2014;50:1498–509.
22. Kaiser KA, Brown AW, Bohan Brown MM, Shikany JM, Mattes RD, Allison DB. Increased fruit and vegetable intake has no discernible effect on weight loss: a systematic review and meta-analysis. *Am J Clin Nutr.* 2014;100:567–76.
23. Mytton OT, Nnoaham K, Eyles H, Scarborough P, Ni Mhurchu C. Systematic review and meta-analysis of the effect of increased vegetable and fruit consumption on body weight and energy intake. *BMC Public Health.* 2014;14:886.
24. Conceição de Oliveira M, Sichieri R, Moura A. Weight loss associated with a daily intake of three apples or three pears among overweight women. *Nutrition.* 2003;19:253–6.
25. United States Department of Agriculture. Agricultural Research Service. National Nutrient Database for Standard Reference Release 27. [http://www.ars.usda.gov/Services/docs.htm?docid=8964]
26. Hyson DA. A comprehensive review of apples and apple components and their relationship to human health. *Adv Nutr.* 2011;2:408–20.
27. United States Department of Agriculture. Economic Research Service. Food Availability (Per Capita) Data System. 2014 [http://www.ers.usda.gov/data-products/food-availability-%28per-capita%29-data-system/.aspx#U_tVLM08oE]
28. Mark's Fruit Crops. Apple-Malus domestica. [http://www.fruit-crops.com/apple-malus-domestica]
29. Centers for Disease Control and Prevention. National Health and Nutrition Examination Survey. NHANES 2007–2008 Public Data General Release File Documentation, 2009. [http://www.cdc.gov/nchs/nhanes/nhanes2007–2008/generaldoc_e.htm]
30. United States Department of Health and Human Services. Centers for Disease Control and Prevention. National Center for Health Statistics. National Health and Nutrition Examination Survey, 2013–2014. [http://www.cdc.gov/nchs/data/nhanes/nhanes_13_14/2013–14_overview_brochure.pdf]
31. Centers for Disease Control and Prevention. National Center for Health Statistics. National Health and Nutrition Examination Survey. Questionnaires, Datasets, and Related Documentation. [http://www.cdc.gov/nchs/nhanes/nhanes_questionnaires.htm]
32. United States Department of Health and Human Services. Centers for Disease Control and Prevention. National Center for Health Statistics. National Health and Nutrition Examination Survey, NHANES Response Rates and Population Totals. [http://www.cdc.gov/nchs/nhanes/response_rates_cps.htm]
33. Moshfegh AJ, Rhodes DG, Baer DJ, Murayi T, Clemens JC, Rumpler WV, et al. The US Department of Agriculture Automated Multiple-Pass Method reduces bias in the collection of energy intakes. *Am J Clin Nutr.* 2008;88:324–32.
34. Blanton CA, Moshfegh AJ, Baer DJ, Kretsch MJ. The USDA Automated Multiple-Pass Method accurately estimates group total energy and nutrient intake. *J Nutr.* 2006;136:2594–9.
35. National Center for Health Statistics: The NHANES 2002 MEC In-Person Dietary Interviewers Procedures Manual. [http://www.cdc.gov/nchs/data/nhanes/nhanes_01_02/dietary_year_3.pdf]
36. National Center for Health Statistics: Phone Follow-up Dietary Interviewer Procedures Manual. [http://www.cdc.gov/nchs/data/nhanes/nhanes_03_04/DIETARY_PFU.pdf]
37. NHANES: Is my survey information confidential? [http://www.cdc.gov/nhanes/pQuestions.htm#]
38. US Department of Health & Human Services. Office of Extramural Research. [http://grants.nih.gov/grants/policy/hs/hs_policies.htm]
39. U.S. Department of Agriculture, Agricultural Research Service. USDA Food and Nutrient Database for Dietary Studies, Versions 1.0–4.1 Documentation and User Guide, 2004, 2006, and 2008. [http://www.ars.usda.gov/Services/docs.htm?docid=12089]
40. Guenther PM, Casavale KO, Reedy J, Kirkpatrick SI, Hiza HA, Kuczynski KJ, et al. Update of the Healthy Eating Index: HEI-2010. *J Acad Nutr Diet.* 2013;113:569–80.
41. Guenther PM, Kirkpatrick SI, Reedy J, Krebs-Smith SM, Buckman DW, Dodd KW, et al. The Healthy Eating Index-2010 is a valid and reliable measure of diet quality according to the 2010 Dietary Guidelines for Americans. *J Nutr.* 2014;144:399–407.
42. United States Department of Agriculture. Center for Nutrition Policy and Promotion. Healthy Eating Index Support Files 07 08. [http://www.cnpp.usda.gov/healthy-eating-index-support-files-07–08]
43. National Center for Health Statistics. The NHANES Anthropometry Procedures Manual. Revised 2004. [http://www.cdc.gov/nchs/data/nhanes/nhanes_03_04/BM.pdf]
44. National Institutes of Health. National Heart, Lung, and Blood Institute. Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults. [http://www.nhlbi.nih.gov/guidelines/obesity/ob_gdlns.pdf]
45. Centers for Disease Control and Prevention. A SAS Program for the 2000 CDC Growth Charts (ages 0 to <20 years). [http://www.cdc.gov/nccdphp/dnpao/growthcharts/resources/sas.htm]
46. Centers for Disease Control and Prevention. Healthy Weight—it's not a diet, it's a lifestyle. [http://www.cdc.gov/healthyweight/assessing/bmi/childrens_bmi/about_childrens_bmi.html]
47. National Center for Health Statistics. Analytic and Reporting Guidelines: The National Health and Nutrition Examination Survey (NHANES). 2006 [http://www.cdc.gov/nchs/data/nhanes/nhanes_03_04/nhanes_analytic_guidelines_dec_2005.pdf]
48. United States Department of Health and Human Services. Centers for Disease Control and Prevention. National Center for Health Statistics. National Health and Nutrition Examination Survey, 2009–2010 Data Documentation, Codebook, and Frequencies: Income. [http://www.cdc.gov/nchs/nhanes/nhanes2009–2010/INQ_F.htm]
49. United States Department of Health and Human Services. Centers for Disease Control and Prevention. National Center for Health Statistics. National Health and Nutrition Examination Survey, 2009–2010 Data Documentation, Codebook, and Frequencies: Physical Activity. [http://www.cdc.gov/nchs/nhanes/nhanes2009–2010/PAQ_D.htm]
50. Murphy MM, Barraj LM, Rampersaud GC. Consumption of grapefruit is associated with higher nutrient intakes and diet quality among adults, and more favorable anthropometrics in women, NHANES 2003–2008. *Food Nutr Res.* 2014;8:58. doi:10.3402/fnr.v58.22179. eCollection 2014.
51. O'Neil CE, Nicklas TA, Fulgoni III VL. Mango Consumption is Associated with Improved Nutrient Intake and Better Diet Quality in Children and Adults, and Better Levels of Some Cardiovascular Risk Factors in Adults: National Health and Nutrition Examination Survey, 2001–2008. *J Nutr Food Sci.* 2013;3:185.
52. O'Neil CE, Nicklas TA, Fulgoni III VL. Fresh pear consumption is associated with a better nutrient intake profile, better diet quality, and lower risk of obesity in adults (19 + y): NHANES (NHANES) 2001–2010. *FASEB J.* 2014;25:4810.16.
53. Fulgoni 3rd VL, Dreher M, Davenport AJ. Avocado consumption is associated with better diet quality and nutrient intake, and lower metabolic syndrome risk in US adults: results from the National Health and Nutrition Examination Survey (NHANES) 2001–2008. *Nutr J.* 2013;12:1.
54. O'Neil CE, Nicklas TA, Rampersaud GC, Fulgoni 3rd VL. One hundred percent orange juice consumption is associated with better diet quality, improved nutrient adequacy, and no increased risk for overweight/obesity in children. *Nutr Res.* 2011;31:673–82.
55. O'Neil CE, Nicklas TA. Childhood obesity and the consumption of 100% fruit juice: where are the evidence-based findings? In: Rippe JM, editor. *Fructose, high fructose corn syrup, sucrose and health.* New York NY: Springer; 2014. p. 247–76.
56. O'Neil C, Nicklas T. A review of the relationship between 100 % fruit juice consumption and weight in children and adolescents. *Am J Lifestyle Med.* 2008;2:315–54.

57. Dennison BA, Rockwell HL, Nichols MJ, Jenkins P. Children's growth parameters vary by type of fruit juice consumed. *J Am Coll Nutr.* 1999;18:346–52.
58. Skinner JD, Carruth BR, Moran 3rd J, Houck K, Coletta F. Fruit juice intake is not related to children's growth. *Pediatrics.* 1999;103:58–64.
59. Houchins JA, Tan SY, Campbell WW, Mattes RD. Effects of fruit and vegetable, consumed in solid vs beverage forms, on acute and chronic appetitive responses in lean and obese adults. *Int J Obes (Lond).* 2013;37:1109–15.
60. Houchins JA, Burgess JR, Campbell WW, Daniel JR, Ferruzzi MG, McCabe GP, et al. Beverage vs. solid fruits and vegetables: effects on energy intake and body weight. *Obesity (Silver Spring).* 2012;20:1844–50.
61. Klesges RC, Klesges LM, Brown G, Frank GC. Validation of the 24-h dietary recall in preschool children. *J Am Diet Assoc.* 1987;87:1383–5.
62. Baranowski T, Sprague D, Baranowski JH, Harrison JA. Accuracy of maternal dietary recall for preschool children: socioeconomic status and daycare factors. *J Am Diet Assoc.* 1991;91:669–74.
63. Fisher JO, Butte NF, Mendoza PM, Wilson TA, Hodges EA, Reidy KC, et al. Overestimation of infant and toddler energy intake by 24-h recall compared with weighed food records. *Am J Clin Nutr.* 2008;88:407–15.
64. Freeland-Graves J, Nitzke S. Position of the academy of nutrition and dietetics: total diet approach to healthy eating. *J Acad Nutr Diet.* 2013;113:307–17.

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