Avocado Consumption by Adults is Associated with Better Nutrient Intake, Diet Quality, and Some Measures of Adiposity: National Health and Nutrition Examination Survey, 2001-2012

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Abstract

Background

Avocados contain a beneficial lipid profile, including a high level of monounsaturated fatty acids, as well as dietary fiber, essential nutrients, and phytochemicals. However, little epidemiologic data exist on the effect that consumption of avocados has on overall nutrient intake, diet quality, adiposity parameters, and other metabolic disease risk factors.

Objective

The objective of this research was to investigate whether there were any associations between avocado consumption and overall diet quality, energy and nutrient intakes, physiological indicators of health, and risk of metabolic syndrome.

Methods

Avocado consumption and its association with these diet and health parameters were assessed using a nationally representative sample of adults (n=27,684) participating in the 2001-2012 NHANES. Intake was determined from one day 24-hour dietary recalls. Covariate adjusted means, standard errors, and ANOVA for food groups, nutrients, and health biomarkers were determined using appropriate sample weights. Diet quality was measured using the Healthy Eating Index-2010 (HEI-2010). For linear and logistic regression analyses, $p<0.001$ and $p<0.01$, respectively were used.

Results

Average consumption of avocados by consumers (n=667) was 75.6±3.8 g/day. Avocado consumers had higher intakes of dietary fiber, mono- and polyunsaturated fats, vitamins E and C, folate, magnesium, potassium, and fruit and vegetables and lower intakes of sodium sthan non-consumers. Consumers also had a higher total HEI-2010. Consumers had lower mean weight, body mass index, waist circumference, insulin, and homocysteine levels and had a lower percentage of those with an elevated waist circumference and metabolic syndrome. Avocado consumers were 33% less likely to be overweight/obese and 32% less likely to have an elevated waist circumference.

Conclusions

Avocado consumption was associated with better dietary measures and weight parameters than seen in non-consumers; consumption should be encouraged as part of an overall healthy lifestyle.

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Introduction

Avocados (*Persea americana*) are a member of the laurel family, are native to subtropical America, and have been cultivated there for over 7,000 years (Davidson, 1999). There are at least 500 varieties of this fruit; however, the Hass avocado (also known as the California avocado), a Guatemalan/Mexican hybrid, is the leading cultivar in California (Davidson, 1999) and the primary global variety (Dreher & Davenport, 2013). Approximately 90% of the avocados consumed in the US are grown in California (Hoy, Carman, Li, & Sexton, 2009). In the US, most of the remaining avocados come from Florida, and are known as Florida avocados. These two varieties are visually distinct, with the smaller Hass avocados having a green to brown rough skin with the larger Florida avocado having a smooth green skin; but they have a similar nutritional composition (United States Department of Agriculture [USDA] Agricultural Research Service [ARS]. 2016 a). Avocados have a pleasant taste and creamy texture; and they are versatile from a culinary standpoint. Avocados can be consumed as a snack or as part of a meal—either alone or as part of a prepared dish, such as guacamole, salad, or even dessert. Retail per capita availability of avocados has increased markedly from 0.4 pounds in 1970 to 6.1 pounds in 2014 (USDA 2016 e) and consumption has doubled in the past 10 years (USDA 2016 f). Although botanically a fruit, and classified as such by the United States Department of Agriculture's (USDA) Economic Research Service, MyPlate classifies avocados as an "other" vegetable (USDA 2016 b).

Recommendations for fruit and vegetable intake for adults are gender, age, and activity dependent; however, the 2015-2020 Dietary Guidelines for Americans (DGA) recommend that adults consume 1.5- 2 cup equivalents (CE) of fruit and 2-3.5 CE of vegetables because of their nutrient contribution to the diet and the overall health benefits they confer (USDA 2016 d). Fruit and vegetables are an important contributor of nutrients, especially dietary fiber; vitamins A, C and K; magnesium; and potassium, which are considered shortfall nutrients (USDA 2016 d). Moreover, most fruit and vegetables (when not considering food preparation methods or condiments added after cooking) are also low in added sugars and solid fats which have been identified as nutrients to limit in the diet (USDA 2016 d). In the US, 87% of adults do not consume the recommended vegetable servings and 76% do not meet the fruit servings daily (Moore & Thompson, 2013). A recent study using National Health and Nutrition Examination Survey Data (NHANES) (Hoy, Goldman, & Sebastian, 2016) showed, using an epidemiological method that disaggregated foods, that consumption was 1.8 CE and 1.5 CE of vegetables in males and females, respectively.

Avocados have been defined as a nutrient dense food (USDA 2016 d); however, they have similarities and differences in composition from most other vegetables because of their unique nutrient profile. Similar to other vegetables, Hass avocados are very low in sugar with 0.09 gm/30 gm Nutrition Labeling and Education Act of 1990 (NLEA) serving and relatively high in total monounsaturated fatty acids (MUFA) and total polyunsaturated fatty acids (PUFA) with 2.94 gm and 0.55 gm/NLEA serving, respectively (United States Department of Agriculture [USDA] Agricultural Research Service [ARS]. 2016 a). Florida avocados are also very low in sugar (0.73 gm/NLEA serving), but the MUFA and PUFA content of 1.65 gm and 0.50 gm, respectively, is slightly lower than the Hass avocados (United States Department of Agriculture [USDA] Agricultural Research Service [ARS]. 2016 a). The high lipid content in both varieties

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may help increase the bioavailability of carotenoids from salsas and salads they are often consumed with (Fulgoni, Dreher, & Davenport, 2013). Avocados are also rich in vitamins (e.g. B-vitamins, K, E, and C) and potassium along with phytochemicals, including lutein + zeaxanthin, phenolic, antioxidants, and phytosterols (Ameer, 2016); Fulgoni, et al. (2013) in an evaluation of earlier NHANES data showed that avocado consumers had a better nutrient intake than non-consumers. In their review, Dreher and Davenport (2013) provided the nutrient and phytochemical content of Hass avocados. The lipid, antioxidant, and phytochemical composition of avocados have been associated with numerous potential health benefits (Dreher, et al, 2013).

There are a limited number of studies demonstrating a potential benefit of avocados on cardiovascular health. A recent meta-analysis (Peou, Milliard-Hasting, & Shah, 2016) of 10 studies (n=229) was conducted: five studies evaluated healthy patients, two evaluated diabetic patients with or without dyslipidemia, three studies evaluated patients with dyslipidemia, and two studies evaluated overweight subjects. The studies varied in length of time, the type of avocado assessed, and whether other sources of MUFA were also included. Not surprisingly results varied; overall, however, avocado consumption significantly reduced total cholesterol, low-density lipoprotein cholesterol (LDL-C), and triglycerides; high-density lipoprotein cholesterol (HDL-C) was decreased only in healthy individuals who had avocados added to a free diet. A review article (Dreher, et al., 2013) on the composition of Hass avocados and potential health effects has described most of these articles.

Only a single study (Fulgoni, et al., 2013) that we were able to find has examined the association of avocado consumption and weight and diet quality, using the Healthy Eating Index (HEI) 2005 (USDA 2016 a). The purpose of this study was to update the study of Fulgoni, et al. (2013) using more recent data from the National Health and Nutrition Examination Survey data and to examine nutrient intake, food group intake, diet quality—using the HEI-2010, adiposity, and cardiovascular risk factors (CVRF) in avocado consumers and non-consumers.

Subjects and Methods

Study population and analytic sample

The NHANES is an ongoing initiative conducted by the National Center for Health Statistics of the Centers for Disease Control and Prevention to collect information on the health and nutritional status of a nationally represented cross-sectional sample of the total civilian, noninstitutionalized US population. The NHANES design is a stratified, multistage probability sample and use of appropriate sample weights are necessary to ensure national representation and to account for oversampling of specific age and race/ethnicity groups. For the present analyses, data from adults 19+ y (n=31,093) participating in the NHANES 2001-2012 were combined to increase sample size (Centers for Disease Control and Prevention [CDC] 2016 a). Analyses excluded individuals without reliable dietary records (n=183) and females who were pregnant or lactating (n=1,231). The final analytic sample had 29,684 individuals (51% female). NHANES employs stringent protocols and procedures that ensure confidentiality and protects individual participants from identification (CDC 2016 g).

Demographics and Dietary Information

The methods and study design for NHANES have been previously described. Briefly, demographic information was obtained from the NHANES interviews (CDC 2016 f). Intake data were obtained from Day 1, in-person 24-hour dietary recall interviews administered using an automated multiple-pass method (Moshfegh et al., 2008; Blanton,

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Moshfegh, Baer, & Kretsch, 2006). Beginning in 2003-2004, two days of intake were collected; however, for consistency, only Day 1 dietary recall data were used in this study. Detailed descriptions of the dietary interview methods are provided in the NHANES Dietary Interviewers Procedure Manual (CDC 2016 b).

To identify avocado consumers, the following food code from the USDA Food and Nutrient Database for Dietary Studies (FNDDS) (USDA ARS 2016 b) was used: 63105010; no distinction was made between the type of avocado (Hass or Florida) consumed. Individuals were classified as consumers if avocado was ingested the day of the recall; however, consumers of guacamole were excluded since other foods were included and recipes varied.

Energy, Nutrient, and Food Group Intakes

Energy and nutrient intakes were calculated using the USDA's FNDDS as appropriate for the NHANES releases (USDA ARS 2016 b). The FNDDS was used to process and analyze dietary recall data. The MyPyramid Equivalents Database (USDA ARS c) and the more recently developed Food Pattern Equivalent (USDA ARS d) were used, as appropriate to the NHANES cycle year, to examine ounces and CE consumption of the seven major food groups (avocados were counted as a vegetable) and corresponding subgroups. The number of CE consumed was based on the 24-hr dietary recall data from NHANES 2001-2012 participants.

Healthy Eating Index (HEI-2010)

The HEI-2010 was used to determine diet quality and to evaluate adherence to the 2010 Dietary Guidelines for Americans (Guenther et al., 2014). The SAS code used to calculate HEI-2010 scores and component scores was downloaded from the Center for Nutrition Policy and Promotion website (National Cancer Institute Division of Cancer Control & Population Studies, 2016). Of the component scores, nine: total fruit, whole fruit, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, and fatty acid ratio measures adequacy; a higher score indicates higher consumption. The remaining three component scores: refined grains, sodium, and empty calories, measure moderation; and higher scores indicate lower consumption.

Anthropometric and Physiologic Measures

Height, weight, and waist circumference (WC) were obtained according to NHANES protocols (CDC 2016 c). Body mass index (BMI) was calculated as body weight (kilograms) divided by height (meters) squared (National Institutes of Health National Heart, Lung, and Blood Institute [NIH NHLBI] 1999). For the odds ratio (OR) assessments, described below, overweight/obesity and high WC were determined using the National Heart Lung and Blood Institute Clinical Guidelines (National Institutes of Health National Heart, Lung, and Blood Institute [NIH NHLBI] 1999). Overweight was defined as having a BMI between 25.0 and 29.9; obesity was defined as having a BMI of 30.0 or higher; and overweight/obesity was defined as having a BMI 25.0 or higher. An elevated WC was defined as >102 cm in males and >88 cm in females.

Systolic and diastolic blood pressures were determined using the standard NHANES protocol (CDC 2016 d). Procedures for laboratory values are as described by NHANES (CDC 2016 e); while low density lipoprotein-cholesterol, triglycerides, blood glucose, and insulin were determined on only fasted subjects, whereas other lab values may not have been. Thus, not all individuals may have values for all tests. Metabolic syndrome was defined using the National Heart Lung and Blood Institute Adult Treatment Panel III criteria (National Cholesterol Education Program, 2002); that is having three or more of the following risk factors: abdominal obesity, WC>102 cm (males), >88 cm

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(females); hypertension, SBP ≥130 mmHg or DBP ≥85 mmHg or taking anti-hypertensive medications; HDL-cholesterol, <40 mg/dL (males), <50 mg/dL (females); high triglycerides, ≥150 mg/dL or taking anti-hyperlipidemic medications; high fasting glucose, ≥110 mg/dL or taking insulin or other hypoglycemic agents.

Statistical Analyses

Sampling weights and the primary sampling units and strata information, as provided by NHANES (CDC 2016 a), were included in all analyses using SAS v9.2 (SAS Institute; Cary, NC) and SUDAAN v10.0 (Research Triangle Institute; Raleigh, NC). Linear regression was used to determine differences in avocado consumers and non-consumers for HEI-2010 and anthropometric measures. Logistic regression was used to determine if avocado consumers had a lower OR of being overweight or obese or having an elevated WC. Most covariates were obtained from the NHANES interviews (CDC 2016 f): age, race/ethnicity, poverty index ratio, and physical activity level, and smoking status; alcohol consumption was obtained from the 24-hour dietary recall data (USDA ARS 2016 b), as was energy intake which was included as a covariate for the nutrient comparisons. For the linear regression analyses, consistent with a previous study USDA study involving NHANES data (Sebastian et al., 2010), in lieu of a Bonferroni correction, a p value of <0.001 was used to reduce the risk of a type I statistical error. For the logistic regression, the more conservative level of p<0.01 was used, rather than the more common value of p<0.05.

Results:

Demographics

Mexican-Americans (p<0.0001) were the only ethnic group that had a higher percentage of avocado consumers than non-consumers. Non-Hispanic blacks (p<0.0001) had a lower percentage reporting avocado consumption. Compared to non-consumers, the percentage of avocado consumers that reported smoking (p<0.0001) was significantly lower than seen in non-consumers. On average, avocado consumers consumed nearly 76 grams (g) of avocado per day (Table 1).

Mean Intake of Adjusted Nutrient Intake

Avocado consumers had a significantly higher intake of dietary fiber (p<0.001), total fat (p<0.0001), MUFA (p<0.0001) and PUFA (p=0.0001) compared to non-consumers. Compared to non-consumers, intakes of total carbohydrate was significantly lower (p=0.0001). Avocado consumers had significantly higher intakes of vitamins E (p<0.0001) and C (p<0.0001), and total folate (p= 0.0001) compared to non-consumers. Compared to non-consumers, consumers of avocados had significantly higher intakes of magnesium (p<0.0001), copper (p<0.0001), and potassium (p<0.0001) and lower intakes of sodium (p=0.0001) (Table 2).

Mean Food Group Consumption (cup equivalents)

Avocado consumers had significantly higher intakes of fruit (p=0.0002), vegetables (p=0.0001) (Table 3). Intakes of added sugars (p=0.0001) and solid fats were significantly lower and discretionary oils were significantly higher (p=0.0001) among avocado consumers compared to non-consumers (Figure 1).

Healthy Eating Index-2010

Although all HEI-2010 scores were relatively low, avocado consumers had higher total HEI-2010 scores than non-consumers (p<0.0001) (Table 4). Overall, consumers had higher HEI-2010 component scores for total vegetables (p<0.0001), greens and beans (p=0.0005, total fruit (p<0.0001), whole fruit (p<0.0001), seafood & plant protein (p=0.0002), the fatty acid ratio (p<0.0001), sodium (p=0.0006), and empty calories (p<0.0001). It is important to remember that sodium and empty calories are reverse scored

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so that a higher score indicates lower consumption.

Physiologic Measures

Overall, consumers of avocados were on average 3.4 kg lighter (p=0.0002), had a mean BMI 1 unit less (p<0.0001), and a mean WC of 3 cm less (p=0.0001) than non-consumers. Insulin and homocysteine levels were lower, p=0.0003 and p<0.0001, in avocado consumers than in non-consumers.

A lower percentage of avocado consumers also had an elevated WC (p=0.0005) and metabolic syndrome (p<0.0001) than non-consumers. Avocado consumers had a 33% lower likelihood of being overweight or obese and a 32% lower likelihood of having an elevated WC than non-consumers (Table 6).

Discussion:

This is the second report to investigate avocado consumption among U.S adults (Fulgoni et al., 2013), and explore the relationship of energy and nutrient intake and intake of food groups. In this study, avocado consumption was associated with significantly higher intakes of dietary fiber, total fat, MUFA, and PUFA compared to non-consumers. Intakes were also higher for vitamins E and C; total folate; magnesium; copper; and potassium and lower for intakes of sodium. In addition, diet quality, consumption of fruit and vegetables, and weight, BMI, waist WC, and percentage of the population with metabolic syndrome were also more desirable in consumers compared with non-consumers. The favorable dietary intake and physiologic parameters are consistent with the avocado nutrient composition (USDA ARS a), as well as results from a prior epidemiologic study (Fulgoni et al., 2013), prior clinical studies linking avocado consumption to cardiovascular risk factors (Ameer, 2016; Peou, et al., 2016; Wien, Haddad, Oda, & Sabaté, 2013; Wang, Bordi, Fleming, Hill, & Kris-Etherton (2015); Li, et al., 2013; López Ledesma, et al., 1996; Pieterse, et al., 2005; Carrazana-Madrigal, et al., 1997), and in vitro studies using avocado extracts (Rodríguez-Sánchez, et al., 2013; Rodríguez-Sánchez, et al., 2015).

The demographic data suggested that there were clear racial/ethnic divides among consumers of avocados. This was unsurprising since cultural food patterns affecting food purchase and consumption are common (Keller, Fleury, & Rivera, 2007; Pignotti, et al., 2015; Sharma, Sheehy, & Kolonel, 2014). Although ethnic diversity of avocados is not well studied, Mexican Americans have been shown previously to consume more avocados than non-Hispanic whites (Sharma, et al., 2014; Bartholomew, Young, Martin, & Hazuda, 1990). These findings warrant further exploration; but in the current study, the effect of racial/ethnic differences was minimalized by using race/ethnicity status as a covariate.

Avocado consumers had higher intakes of dietary fiber, MUFA, PUFA, vitamins E and C, folate, magnesium, and potassium, and lower intakes of sodium than non-avocado consumers. These nutrients have been associated with reduced risk of cardiovascular disease risk factor (Hammad, Pu, & Jones, 2016; Mathur, Ding, Saldeen, & Mehta, 2015; Grooms, Ommerborn, Pham, Djoussé, & Clark, 2013). Food group assessment and assessment of sub-components of the HEI-2010 also showed that avocado consumption was associated with higher consumption of fruit and vegetables. This is noteworthy, since consumption of fruit and vegetables is important for primary prevention of cardiovascular disease (Hartley, et al., 2013; Buil-Cosiales, et al., 2016; 51 DGAC Report). These findings suggest a role for avocados in improving nutrient intakes and may be a strategy for getting Americans closer to meeting the fruit and vegetable recommendations.

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The evidence-based 2015 Dietary Guidelines Advisory Committee (DGAC) (USDA 2016 c) stated that the evidence from randomized control trials showing that replacing saturated fatty acids with unsaturated fatty acids, especially PUFA was strong and consistent for significantly reducing total and low-density-lipoprotein cholesterol. However, the evidence is conflicting as to whether MUFA, such as that found in avocados, as well as olive oil and nuts, reduces the risk of cardiovascular disease events and coronary mortality (Hammad, et al., 2016; Jakobsen, et al., 2009; Joris & Mensink, 2016). Epidemiologic studies showed the health benefits of MUFAs, including improving cardiovascular disease risk, anti-hypertensive effects and improvement of insulin sensitivity (Root & Dawson, 2013; Miura, et al., 2013; Yubero-Serrano, et al., 2015).

In this study, lower adiposity measures were the only cardiovascular risk factors associated with avocado consumption. The mean BMI of consumers was only one unit lower than non-consumers; although modest, a recent cross-sectional study in Ireland (Kearns, Dee, Fitzgerald, Doherty, & Perry, 2014) showed that a projected one unit decrease in BMI would result in 28 fewer cases of chronic disease per 1,000 individuals, respectively. This suggests that even a small difference in BMI is beneficial to health. The reason for lower mean BMI and WC measurements seen in avocado consumers when compared to and non-consumers, which confirms the findings of Fulgoni et al. (2013) is not clear since there were no differences in energy intake or in physical activity levels between the consumption groups. One potential reason may be the energy density of avocados. Avocados have a moderate energy density of 1.7 kcal/g (Dreher & Davenport, 2013) and coupled with a viscose water, dietary fiber, and fruit oil matrix may that enhance satiety, at least in overweight adults (Wien, et al., 2013). Another reason may be the overall dietary pattern, since avocado consumers had higher consumption levels of dietary fiber, fruit, and vegetables than non-consumers. Although studies are inconsistent (Ledoux, Hingle, & Baranowski, 2011; Tohill, Seymour, Serdula, Kettel-Khan, & Rolls, 2004), fruit and vegetable consumption has been associated with lower measures of adiposity in adults (Azagba & Sharaf, 2012; Cavallo, Horino, & McCarthy, 2016; Pomerleau, Lock, Knai, & McKee, 2005). Finally, physical properties of avocados may account for the lower measures of adiposity seen in consumers. Avocados and tree nuts have similar dry weight compositions for MUFA and dietary fiber (Dreher & Davenport, 2013), and tree nut consumption has repeatedly been shown to have an inverse relationship with measures of adiposity (Tan, Dhillon, & Mattes, 2014), which may be the result of several factors including the satiety factor of nuts and their inefficient absorption. It is unknown if avocados have the same effect; however, these studies provide support not to restrict intake of healthy fats for reducing cardiovascular disease risk or for maintenance of body weight. Therefore, dietary guidance should provide specific recommendations to optimize the types and amounts of dietary fat consumed and not reducing total fat (Harcombe, Baker, DiNicolantonio, Grace, & Davies, 2016; Harcombe, et al., 2015).

More studies are needed to confirm these epidemiologic data and the potential associations between increased intake of avocados and other dietary components and health outcomes. However, with the clear nutrient and health benefits associated with consumption, nutrition educators, including registered dietitians, should consider helping all consumers to include avocados as part of a healthy diet.

Strengths and Limitations of the Study

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The strengths of this study were that it included a large sample size with a nationally representative sample of adults. The NHANES has carefully controlled protocols and screens 24-hour dietary recalls confirming that they are valid and complete; the NHANES also uses the multiple pass method to obtain dietary intake (Ahluwalia, Dwyer, Terry A, Moshfegh, & Johnson, 2016), which is the most commonly used dietary assessment method available for large scale epidemiologic studies. The NHANES also uses measured anthropometrics and does not rely on self-reported physiological data.

However, self-reported dietary intakes, including 24-hour dietary recalls have several inherent limitations. Participants relied on memory to self-report dietary intakes; therefore, data were subject to non-sampling errors, especially underreporting of energy (Moshfegh, et al., 2008) and some macro- and micronutrients (Briefel, Sempos, McDowell, Chien, & Alaimo, 1997). Underreporting is related to total energy intake and is higher in overweight and obese individuals, as well as women (Moshfegh, et al., 2008); however, the degree of underreporting is lower than in other dietary intake instruments. The one-day intake used in this study may not represent usual intake of individuals over time, and it is possible that individuals were mis-categorized. Further, since causal inferences cannot be drawn from NHANES analyses, and due to multi-collinearity of diet, foods other than avocados may have contributed to differences in nutrient intake of the participants. Additionally, there were a relatively small number of avocado consumers in this study; also we could not assess season of the year or geographic area of subjects as these data are not available in the publicly released data. Finally, while we used numerous covariates in our regression models, it is possible that residual confounding exists (e.g., other foods concomitantly consumed with avocados may, in part, be responsible for some of our results), thus, associations should be interpreted with caution.

Conclusions

This study confirms the findings of a previous study (Fulgoni, et al., 2013) showing an association between avocado consumption and improved nutrient intake, food group consumption, diet quality, weight, and metabolic syndrome which can be generalized to the US adult population. Avocados can be included in the diet of most adults as part of an overall healthful diet that focuses on increased fruit and vegetable intake.

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Authorship

VLF, CO'N, and TAN conceived the overall design of the study. VLF was responsible for the analysis; VLF, CO'N, and TAN all reviewed the analysis and the data. CO'N drafted the initial manuscript, which

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was edited and critically reviewed by VLF and TAN. All authors contributed equally to this manuscript.

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Conflict of Interest

Aside from the above funding sources, the authors declare no conflicts of interest

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Table 1. Demographics of adults 19+ years (n = 27, 684) participating in NHANES 2001-2012 by avocado consumption category

Variable	**Avocado Consumption Category**		
	Consumer (n=667)	**Non-Consumer (n=29,017)**	
	LSM±SE	**LSM±SE**	**P[1]**
Gender = Female (%)	54.4±3.0	50.7±0.3	0.223
Ethnicity			
NHW (%)	61.2±3.4	70.7±1.4	0.009
NHB (%)	**2.6±0.6**	**11.6±0.8**	**<0.001**
MA (%)	**19.9±2.3**	**7.6±0.6**	**<0.001**
OH (%)	12.0±2.3	4.5±0.5	0.001
O (%)	4.3±1.1	5.6±0.3	0.252
Age (mean—yrs)	46.2±1.4	46.6±0.3	0.822
Poverty Index Ratio			
Mean	3.1±0.1	3.0±0.03	0.223
< 1.35 (%)	19.8±2.7	23.0±0.7	0.262
Physical Activity			
Sedentary (%)	21.8±2.6	27.7±0.6	0.029
Moderate (%)	34.9±2.9	35.0±0.4	0.967
Vigorous (%)	43.3±3.2	37.3±0.7	0.065
Smoking Current (%)	**14.2±2.1**	**23.9±0.5**	**<0.001**
Alcohol Intake (g)	12.1±1.3	11.2±0.3	0.506
Avocado Consumption (g)	75.8±3.8	0±0	**<0.001**

[1]Differences assessed using z-scores

Abbreviations: LSM = least square means; SE = standard error; NHW = non-Hispanic white; NHB = non-Hispanic Black; MA = Mexican-American; OH = other Hispanics; O = other

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Table 2. Nutrient intake of adults 19+ years participating in NHANES 2001-2012 by avocado consumption category

Macro-nutrients[1]	Consumers LSM± SE	Non-Consumers LSM± SE	p-value
Energy (kcals)[2]	2265 ± 40	2182.5 ± 8	0.0384
Protein (g)	82.1 ± 1.7	83.3 ± 0.3	0.4933
Carbohydrate (g)	**251.4 ± 3.5**	**265.3 ± 0.7**	**0.0001**
Dietary Fiber (g)	**23.4 ± 0.5**	**16.3 ± 0.1**	**<0.0001**
Total Fat (g)	**90.6 ± 1.3**	**82.3 ± 0.2**	**<0.0001**
Saturated Fatty Acids (g)	27.5 ± 0.7	27.0 ± 0.1	0.5466
Monounsaturated Fatty Acids (g)	**36.2 ± 0.7**	**30.1 ± 0.1**	**<0.0001**
Polyunsaturated Fatty Acids (g)	**19.4 ± 0.4**	**17.8 ± 0.1**	**0.0001**
Cholesterol (mg)	272.8 ± 10.7	287.3 ± 1.8	0.1749
Vitamins[1,3]			
Vitamin A (RAE) (mcg)	683.3 ± 33.0	631.9 ± 8.8	0.1069
Vitamin E (mg)[4]	**10.2 ± 0.3**	**7.7 ± 0.1**	**<0.0001**
Thiamin (mg)	1.7 ± 0.1	1.7 ± 0.0	0.4291
Riboflavin (mg)	2.3 ± 0.1	2.2 ± 0.0	0.2175
Niacin (mg)	25.0 ± 0.6	25.2 ± 0.1	0.8303
Vitamin B_6 (mg)	2.1 ± 0.0	2.0 ± 0.0	0.0034
Total Folate (DFE) (mcg)	**620.8 ± 18.0**	**547.6 ± 3.5**	**0.0001**
Vitamin B_{12} (mcg)	4.9 ± 0.2	5.4 ± 0.1	0.0052
Vitamin C (mg)	**114.8 ± 4.8**	**86.9 ± 1.2**	**<0.0001**
Minerals[1,3]			
Calcium (mg)	1006.4 ± 36.6	944.2 ± 5.1	0.0990
Phosphorus (mg)	1412.2 ± 29.8	1371.6 ± 4.2	0.1904
Magnesium (mg)	**346.3 ± 5.7**	**296.6 ± 1.4**	**<0.0001**
Iron (mg)	15.5 ± 0.4	15.6 ± 0.1	0.6666
Zinc (mg)	11.7 ± 0.2	12.1 ± 0.1	0.0810
Copper (mg)	**1.6 ± 0.0**	**1.3 ± 0.0**	**<0.0001**
Sodium (mg)	**3393.4 ± 57.7**	**3637.8 ± 9.6**	**0.0001**
Potassium (mg)	**3243.0 ± 79.7**	**2732.3 ± 10.7**	**<0.0001**

[1]Adjusted for Gender, Race/Ethnicity, Age, Energy Intake, Poverty Index Ratio, Physical Activity Level, Smoking Status, Alcohol Consumption
[2]Adjusted for Gender, Race/Ethnicity, Age, Poverty Index Ratio, Physical Activity Level, Smoking Status, Alcohol Consumption
[3]Excludes Supplement Use
[4]Vitamin E as α-tocopherol
Abbreviations: LSM= Least Square Means; SE = Standard Error; kcals = kilocalories; RAE = Retinol Activity Equivalents; DFE = Dietary Folate Equivalent

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Table 3. Food group intake of adults 19+ years participating in NHANES 2001-2012 by avocado consumption category

	Adults 19+ Years		
Food Group (equivalents)[1]	**Consumers LSM ± SE**	**Non-Consumers LSM ± SE**	**p-value**
Total Grains (oz)	6.5 ± 0.2	6.7 ± 0.0	0.3280
Whole Grain (oz)	5.6 ± 0.2	5.9 ± 0.0	0.1300
Non Whole Grains (oz)	0.9 ± 0.1	0.8 ± 0.0	0.0729
Total Fruits (cup)	**1.4 ± 0.1**	**1.0 ± 0.0**	**0.0002**
Total Vegetables (cup)	**2.3 ± 0.1**	**1.6 ± 0.0**	**<0.0001**
Meat, Poultry and Fish (oz)	4.2 ± 0.2	4.9 ± 0.0	0.0031
Eggs (oz)	0.5 ± 0.0	0.5 ± 0.0	0.5701
Legumes (cup)	0.1 ± 0.0	0.1 ± 0.0	0.2074
Nuts and Seeds (oz)	1.0 ± 0.1	0.7 ± 0.0	0.0135

[1]Adjusted for Gender, Race/Ethnicity, Age, Energy Intake, Poverty Index Ratio, Physical Activity Level, Smoking Status, Alcohol Consumption

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Table 4. Mean total Healthy Eating Index-2010 (HEI) and component scores ± SE in adults 19+ years participating in NHANES 2001-2012 by avocado consumption category				
HEI-2010 Variable	**Avocado Consumers (n=612)**	**Avocado Non-Consumers (26,686)**	**Beta**	**P**
	LSM±SE	**LSM±SE**		
Sub-Component Scores				
1 Total Vegetables	**3.9±0.1**	**3.0±0.02**	**0.9**	**<0.0001**
2 Greens and Beans	**1.7±0.1**	**1.2±0.02**	**0.5**	**0.0005**
3 Total Fruit	**2.8±0.1**	**2.1±0.02**	**0.6**	**<0.0001**
4 Whole Fruit	**2.9±0.1**	**2.0±0.02**	**0.9**	**<0.0001**
5 Whole Grains	2.5±0.2	2.3±0.04	0.2	0.2364
6 Dairy	5.2±0.3	5.0±0.04	0.2	0.4222
7 Total Protein Foods	4.1±0.1	4.2±0.01	-0.1	0.5614
8 Seafood and Plant Protein	**2.5±0.1**	**2.0±0.02**	**0.5**	**0.0002**
9 Fatty Acid Ratio	**6.2±0.3**	**4.9±0.04**	**1.2**	**<0.0001**
10 Sodium	**5.0±0.2**	**4.2+0.03**	**0.8**	**0.0006**
11 Refined Grains	6.7±0.2	6.1±0.04	0.7	0.0069
12 Empty Calories	**14.0±0.4**	**11.2±0.1**	**2.9**	**<0.0001**
Total Score	**57.5±0.8**	**48.2±0.2**	**9.3**	**<0.0001**

Data Source: Participants 19 years of age and older participating in the NHANES 2001 to 2012
Covariates: Age, Gender, Ethnicity, Poverty Index Ratio, Physical Activity Level, Smoking Status, Alcohol Consumption. The smoking status covariates are 0/1 variables for smoking current and smoking past.

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Table 5. Physiologic Measures Least Square Means ± SE in adults 19+ years participating in NHANES 2001-2012 by avocado consumption category

Variable[1]	Consumer		Non-Consumer		Beta	P
	n	LSM±SE	n	LSM±SE		
Weight (kg)	**599**	**78.29±0.88**	**26,313**	**81.71±0.22**	**-3.42**	**0.0002**
Body Mass Index (kg/m^2)	**597**	**27.27±0.30**	**26,183**	**28.48±0.08**	**-1.21**	**0.0001**
Waist Circumference (cm)[2]	**588**	**94.58±0.77**	**25,675**	**97.61±0.18**	**-3.03**	**0.0001**
BP Diastolic (mean rdg mm hg)[3]	579	70.14±0.81	25,223	71.40±0.20	-1.26	0.0918
BP Systolic (mean rdg mm hg)[3]	580	120.74±0.85	25,350	122.39±0.20	-1.65	0.0649
Total cholesterol (mg/dL)	593	200.35±2.82	25,293	198.31±0.43	2.04	0.4690
HDL-cholesterol (mg/dL)	579	55.65±0.94	24,867	52.72±0.16	2.93	0.0022
LDL-cholesterol (mg/dL)[4]	298	120.77±3.00	11,736	116.47±0.46	4.30	0.1541
Triglyceride (mg/dL)	304	135.53±18.68	12,145	138.01±1.53	-2.49	0.8946
C-reactive protein (mg/dL)	471	0.39±0.03	20,906	0.40±0.01	-0.01	0.7392
Glucose, plasma (mg/dL)[4]	305	103.42±2.62	12,254	103.26±0.32	0.16	0.9527
Glycohemoglobin (%)	584	5.58±0.07	25,129	5.54±0.01	0.04	0.5659
Insulin (uU/mL)[4]	**308**	**9.93±0.55**	**12,228**	**12.05±0.15**	**-2.11**	**0.0003**
Homocysteine (umol/L)[3]	**223**	**8.13±0.16**	**11,384**	**8.87±0.06**	**-0.74**	**<0.0001**
Percentage of Population with Risk Factors…						
Overweight[5]	597	32±3	26,183	33±1	-2	0.5465
Obese[5]	597	27±3	26,183	34±1	-7	0.0130
Overweight or Obese	597	59±3	26,183	67±1	-9	0.0051
Triglycerides Elevated	349	28±4	14,754[3]	39±1	-10	0.0060
Waist Circumference Elevated	**588**	**44±2**	**25,675**	**53±1**	**-9**	**0.0005**
Metabolic Syndrome[6]	**432**	**32±3**	**18,669**	**44±1**	**-12**	**<0.0001**

Data source: Adults 19+ years of age participating in NHANES 2001-2008

[1]Covariates: Age, Gender, Ethnicity, Poverty Index Ratio, Physical Activity Level, Smoker Status, Alcohol Consumption was used for all linear and logistic regressions. BMI was used in biophysical linear regressions except when the dependent variable was BMI or waist circumference.

[2]In males, an elevated waist circumference was defined as >102 cm and in females as >88 cm

[3]Mean readings were used for blood pressure measurements

[4]Numbers are substantially lower since these measurements must be taken from fasting blood

[5]Overweight was defined as: a BMI between 25.0 and 29.9; Obesity was defined as: a BMI of 30.0 and above and Overweight or Obese was defined as a BMI 25.0 and higher.

[6]Metabolic syndrome was defined using the National Heart Lung and Blood Institute Adult Treatment Panel III criteria [33]; that is having 3 or more of the following risk factors: abdominal obesity, WC>102 cm (males), >88 cm (females); hypertension, SBP ≥130 mmHg or DBP ≥85 mmHg or taking anti-hypertensive medications; HDL-cholesterol, <40 mg/dL (males), <50 mg/dL (females); high

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triglycerides, ≥150 mg/dL or taking anti-hyperlipidemic medications; high fasting glucose, ≥110 mg/dL or taking insulin or other hypoglycemic agents.

Abbreviations: LSM = least square mean, SE = standard error; BP = blood pressure; HDL-C = high density lipoprotein-cholesterol; LDL-C = low density lipoprotein-cholesterol.

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Table 6. Likelihood of Overweight and Obesity in Adults among Adults Consumers and Non-Consumers of Avocados: NHANES 2001-2012

Risk Variable	OR	LCL99	UCL99	P
Overweight	0.92	0.62	1.34	0.5473
Obese	0.72	0.51	1.03	0.0202
Overweight or Obese	**0.67**	**0.48**	**0.95**	**0.0032**
WC Elevated	**0.68**	**0.51**	**0.90**	**0.0006**

Covariates: Age, Gender, Ethnicity, PIR, Physical Activity Level, Smoker Status, Alcohol Consumption was used for all logistic regressions. Probability level was <0.01. Non-Consumers are the comparison group

Overweight was defined as: a BMI between 25.0 and 29.9; Obesity was defined as: a BMI of 30.0 and above and Overweight or Obese was defined as a BMI 25.0 and higher.

In males, an elevated waist circumference was defined as >102 cm and in females as >88 cm

Abbreviations: NHANES = National Health and Nutrition Examination Survey; OR = Odds Ratio; LCL = Lower Confidence Limit; UCL = Upper Confidence Level; P = Probability; WC = Waist Circumference.

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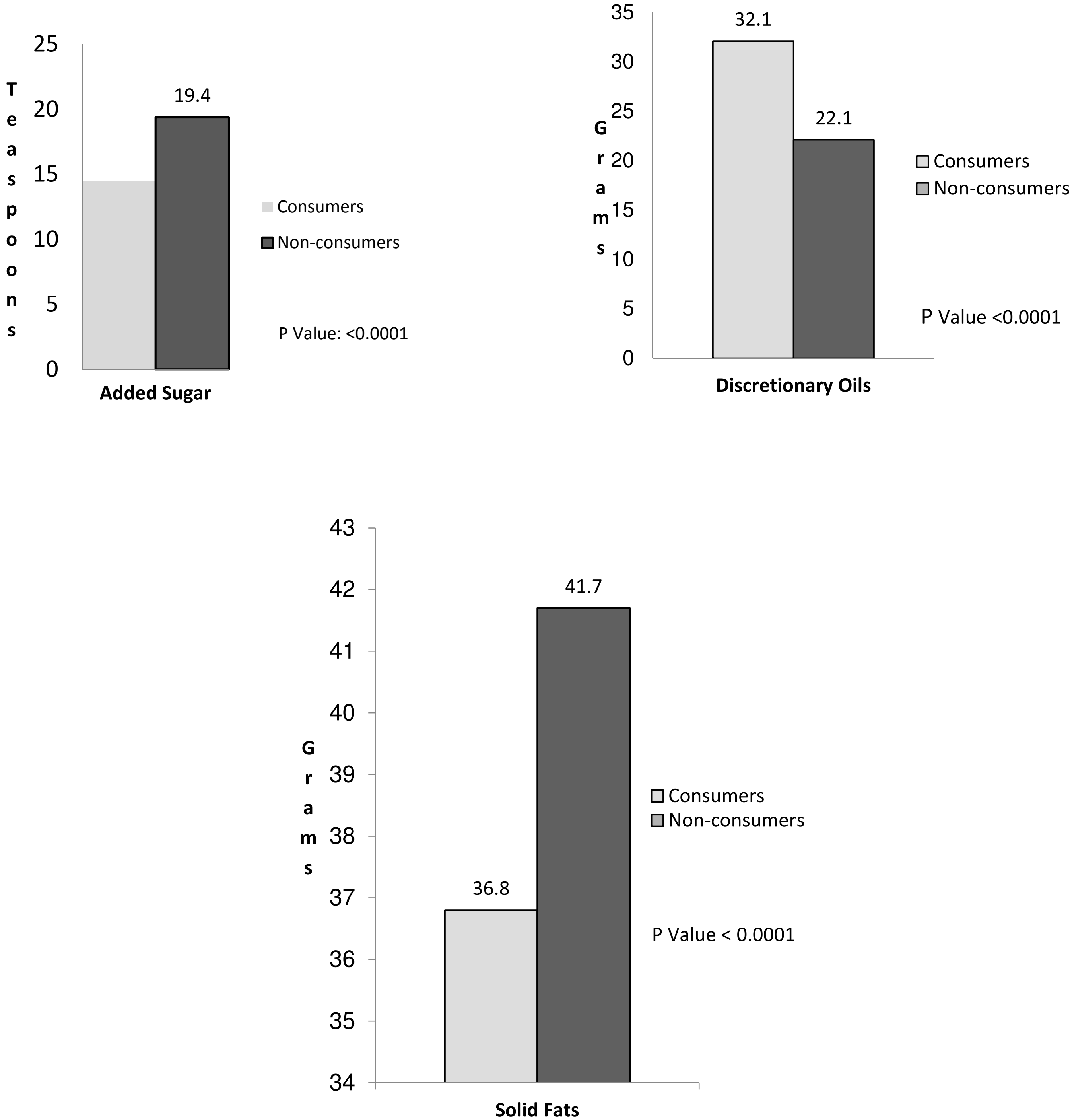

Figure 1. Intake of Added Sugars, Discretionary Oils and Solid Fats for Avocado Consumers vs. Non-Consumers

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