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Original Research

The Effect of Daily Avocado Intake on Food and Nutrient Displacement in a Free-Living Population with Abdominal Obesity

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A B S T R A C T

Background: Avocado intake has been associated with improvements in diet quality. Whether this response is because of avocado intake, *per se*, or combined with a food and/or nutrient displacement (D) has yet to be determined.
Objectives: This secondary analysis, conducted using dietary data from the Habitual Diet and Avocado Trial, sought to assess the effect of consuming a large avocado (168 g, 281 kcal) daily in the avocado-supplemented diet (AD) group compared with the habitual diet (HD) group on food and nutrient D.
Methods: Using data from 3 unannounced telephone 24-h dietary recalls conducted during the 6-mo intervention period, food intake data were evaluated for 898 participants, aged 25–87 y, and a BMI range of 20.5–60.3 kg/m^2. The food group distribution, energy, and nutrient intake of the AD group ($n = 436$) were calculated and compared with those of the HD group ($n = 462$).
Results: The AD group had a higher daily intake of energy (159 ± 575 kcal) ($P < 0.001$), potassium (3193 ± 817 mg compared with 2419 ± 843 mg) ($P < 0.005$), fiber (30 ± 8 g compared with 19 ± 9 g) ($P < 0.05$), and a lower daily intake of animal protein (49 ± 33 g compared with 55 ± 24 g) ($P = 0.02$) compared with the HD group. Partial D with an avocado was observed for energy (43%), total fat (23%), and carbohydrate (87%), indicating a lower intake of these nutrients from non-avocado sources in the AD group. Food group analysis revealed a lower consumption of animal-derived protein from red meat, processed meats, poultry, and fish in the AD group, with no significant differences observed in dairy and egg intake between groups.
Conclusions: Incorporating 1 avocado daily led to favorable modifications in the dietary composition of participants, including an increase in potassium and fiber intake, which can improve diet quality.
This trial was registered at https://clinicaltrials.gov as NCT03528031.

Keywords: avocado, diet composition, nutrient displacement, energy, fiber, animal protein

Introduction

Poor diet quality is associated with an increased risk of developing chronic diseases, including heart disease, diabetes, and certain types of cancer [1,2]. Despite persistent public health endeavors, most Americans consume suboptimal diets [3]. Habitual consumption of avocado—a medium-dense fruit that is a rich source of monounsaturated fatty acids, dietary fiber, vitamin E, and potassium—has been associated with improved diet quality [4–7]. Yet, the essential question persists: Does this positive association stem solely from the direct impact of avocados, or does it result from the displacement (D) of other dietary components? This remains an area of ambiguity.

We previously conducted a study where, over a 6-mo period, participants were randomly assigned to 1 of 2 groups: the

Abbreviations: AD, avocado-supplemented diet; avo, avocado; D, displacement; DGAC, Dietary Guidelines Advisory Committee; EI, expected intake; FDA, Food and Drug Adminstration; HD, habitual diet; IRB, Institutional Review Board; MUFA, monounsaturated fat; PUFA, polyunsaturated fat; NDSR, The Nutrition Data System for Research software; %D, percentage displacement; SFA, saturated fat; %E, percent of energy.

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avocado-supplemented diet (AD) group, where they were provided with and asked to consume 1 large avocado daily, or the habitual diet (HD) group, who were asked to limit their avocado consumption [8]. Results showed that the HD group had no significant change in energy intake. In contrast, the AD group's energy intake was higher. However, this increase was less than expected with the inclusion of avocado. Furthermore, no significant differences in body weight were observed between the 2 groups [8]. This observation prompted an inquiry into whether regular avocado consumption alters the overall diet quality by displacing energy and nutrients from alternative food sources [9].

To bridge the existing knowledge gap, we adopted the concept of energy and nutrient D methodology [10–13]. Jaceldo et al. [11] first introduced the concept of D, which is defined as the *inverse measure of how a food supplement alters the content of a specific nutrient in a supplemented diet.* They examined the effect of almond supplementation in a randomized crossover trial where each participant served as their control. Bitok et al. [10] later proposed modifying this method, using a randomized parallel design in which the HD group provided a more accurate comparison for the diet intervention walnut group during the concurrent intervention period. Both studies indicated favorable D of nutrients, with the supplemented group consuming higher intakes of plant-based protein fiber and lower intakes of sodium, saturated fats, and carbohydrates, with negligible weight changes among participants after the intervention period [10,11].

Given the similarities in their results with our main study—particularly that an increase in energy intake was not associated with increased weight gain—and the comparable nutrient profile of 1 avocado to 1.5 oz of almonds and walnuts [4], we hypothesized that daily consumption of an avocado would result in favorable changes in the supplemented diet. Like the previous studies, our outcomes included the major macronutrients and the micronutrients of public health concern such as potassium and fiber. However, we also examine the impact of avocado intake on various food groups, which had only been done in 1 previous D study [14].

We therefore aimed to investigate the effects of daily avocado consumption on the D of macronutrients, nutrients, and certain micronutrients of public health concern. We also aimed to evaluate if there were any differences in intake between the 2 dietary groups as it relates to foods from the 12 main food groups defined as fruits, vegetables, animal-derived protein, grains, nuts and seeds, legumes, protein alternatives, dairy, fats, and oils, sweets and sugar, beverages, and miscellaneous foods.

Methods

This was a secondary analysis of data derived from the Habitual Diet and Avocado Intake Trial, which is a randomized parallel design study involving 1008 participants with abdominal obesity [defined as waist circumference ≥35 inches (88.9 cm) for females and ≥40 inches (101.6 cm) for males] [8, 15]. The details of the methodology, the inclusion and exclusion criteria, and the primary outcomes have already been published elsewhere [8,15]

In brief, participants who were ≥25 y of age had an elevated waist circumference—ascertained through measurement of the waist circumference with a self-locking nonstretchable flexible fiberglass tape measure during the screening session—and consumed <2 avocados per month were randomly assigned to 2 groups: the AD group ($n = 505$) and the HD group ($n = 503$). The AD group was provided with and instructed to incorporate 1 large avocado (168 g, 281 kcal) daily into their diet over 6 mo, and the HD group was instructed to limit avocado intake to <2 per month. No additional dietary counseling was provided to either group. Participants were encouraged to maintain their usual dietary and physical activity patterns.

Written informed consent was obtained from all participants, and the study protocols were approved by the Institutional Review Board (IRB) at each study site, with Wake Forest University serving as the central IRB. The study is registered at clinicaltrials.gov under the identification number NCT03528031.

Dietary assessment and compliance measures

The analyses used dietary intake data from 3 unannounced, telephone-administered 24-h dietary recalls conducted during the 6-mo intervention period. The recalls were performed at 3 points during the study, aiming for 2-weekday recalls and 1-weekend recalls (Supplemental Figure 1) [15]. The Nutrition Data System for Research software (NDSR; versions 2017 and 2018) by the Nutrition Coordinating Center at the University of Minnesota was employed for data collection [16,17]. The automated multiple-pass method of NDSR was utilized, including a quick list, forgotten food list, time and occasion, details cycle, and final probe [18]. During the recalls, participants used the NDSR Food Amount Booklet to estimate portion sizes [15].

Given that the overall diet composition of the 1008 participants had already been published and we desired to investigate the "true" effect of consuming 1 avocado per day compared with no avocado intake on food and nutrient D, we opted to use per-protocol analysis to determine our outcome [19]. Therefore, of the 1008 randomly assigned participants, 898 had 2 or more valid recalls (Figure 1). Recalls were considered valid if participants had ≥2 dietary recalls of 500–5000 kcal. Two participants lacking baseline weight data were excluded from the analysis.

Nutrient displacement

The average energy and nutrient intakes between the AD group and the HD group groups were compared [10]. Total energy and nutrient D were calculated using a modified method proposed by Bitok et al. [10], given that both their study and our study were randomized parallel study designs [11]. The percentage displacement (% D) was determined using the equation:

$$\% \text{ D} = \frac{(\text{Energy intake of Habitual diet (HD)} + \text{Energy content of avocado (Avo)})\text{-Energy intake of avocado-supplemented diet (AD)}}{\text{Energy content of avocado (Avo)}} \times 100$$

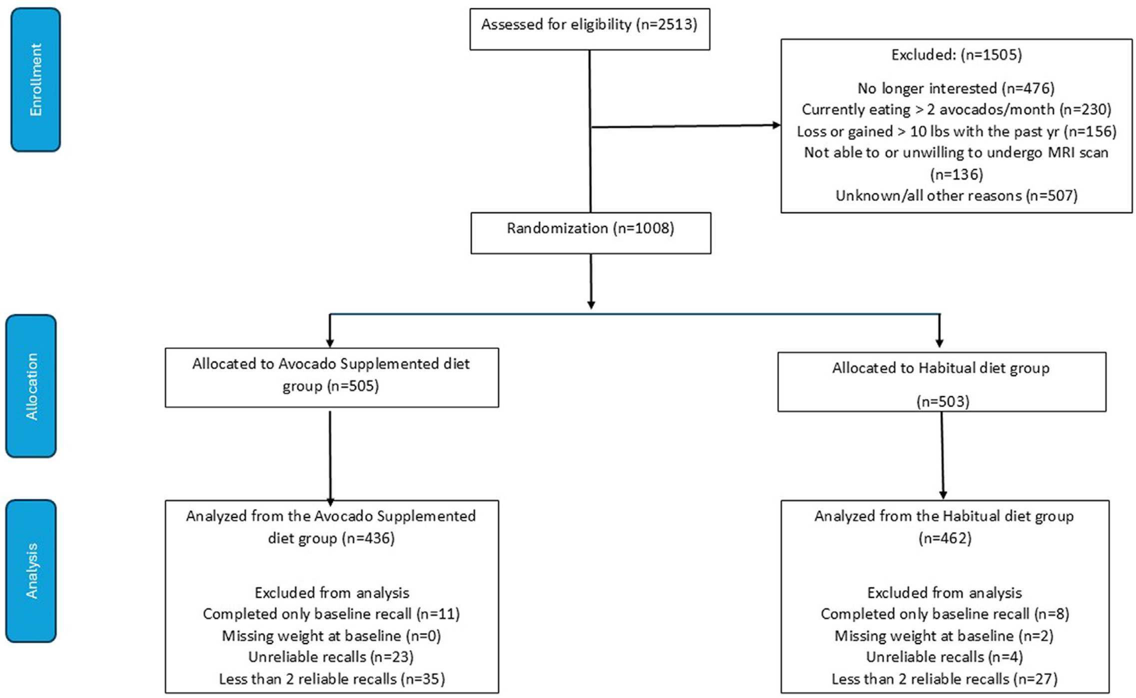

FIGURE 1. This is a CONSORT flow diagram showing the participants recruited and those included in the final analysis. CONSORT, Consolidated Standards of Reporting Trials.

%D reflects the amount of nutrient (s) in the avocado that displaced the same nutrient(s) from non-avocado food sources in the AD compared with that of the HD. A value of 0% indicates no D (Figure 2 [10]), which means there is no reduction in the intake of the nutrient(s) from the non-avocado food source, and with the avocado, and the overall intake of the nutrient(s) in the AD group is greater than that of the HD group. A value between 1% and 99% indicates partial D. This means that although there is an overall increase in intake of the nutrient(s) in the AD compared with the HD, there is a reduction in intake of that nutrient from the non-avocado food sources. A value of 100% suggests that the nutrient(s) in the avocado totally displaces the nutrient(s) from the non-avocado food sources, and the amount of the nutrient in the AD is equivalent to that of the HD. A value of >100% D indicates that even with the avocado, the AD group consumed less of the nutrient(s) than the HD group [10].

Selected micronutrients

In addition to the macronutrients, including fiber, the micronutrients analyzed were based on the 2020 Dietary Guidelines Advisory Committee (DGAC) designation of micronutrients of public health concern, which include sodium, calcium, and potassium [20,21]. Although the DGAC has identified vitamin D as a nutrient of concern, it was excluded from the analysis as avocado is not a significant source of vitamin D [22].

Food group analysis

Foods were categorized into 12 majors and subgroups on the basis of NDSR output (Supplemental Table 1), considering associations with obesity and other cardiometabolic risk factors health outcomes [16,23–25]. Servings were based on Food and Drug Adminstration standard food size serving [17].

Statistical methods

The arithmetic means or median daily intake of energy and selected nutrients were obtained from participants with 2 or more eligible recalls. The percentage energy of macronutrients was calculated, and differences between diet groups were assessed using independent *t* tests or Wilcoxon tests. Participants' characteristics were presented as mean ± standard deviation or as frequencies and percentages. Sensitivity analyses were conducted by sex and BMI for the nutrient profile. Statistical analyses were conducted using SAS version 9.4 (SAS Institute).

Results

The participant characteristics of the AD group and HD group were comparable (Table 1). Compared with the HD group, we observed that the AD group had a significantly higher daily intake of energy, dietary fiber, and MUFA but a lower daily intake of protein, especially from animal sources (Table 2). It should be noted that plant protein intake was slightly higher among the consumers from the AD group. No significant differences were identified between the 2 groups regarding saturated fat and total carbohydrate intake. We also observed that the AD group had a higher potassium intake compared with the HD group. However, the sodium intake was similar in both groups.

Similar findings were observed between females and males (Supplemental Table 2) and participants in most BMI categories (Supplemental Table 3). There were no significant differences between the 2 dietary groups regarding total daily protein intake for participants with a BMI of >40 kg/m^2 (Supplemental Table 3).

The percent of energy (% E) from animal protein and carbohydrates were lower whereas energy intake from fat was higher in the AD group compared with the HD group (Table 2).

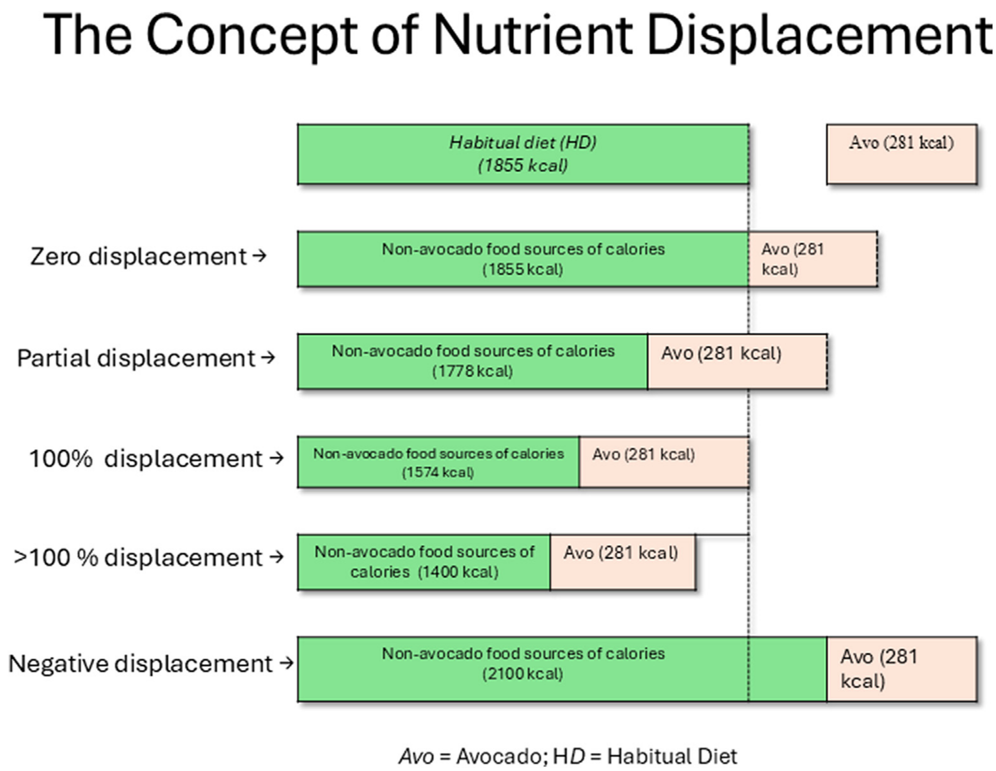

FIGURE 2. This is an illustration of the theoretical concept of "displacement" using the hypothetical example of energy displacement by the avocado in the diet (adapted from Bitok et al. [10]).

Among the AD group, incorporating 1 avocado daily resulted in partial D of energy (43%), dietary fat [including saturated fat (75%)], carbohydrates, and potassium, with no D observed for fiber. A D of >100% was observed for protein, calcium, and sodium (Table 3).

We observed that participants in the AD group consumed fewer servings of animal-derived protein than the HD group ($P = 0.001$). This lower intake was primarily from red meat, processed meats, poultry, and fish, but not from dairy or eggs (Table 4). No significant differences were noted in the number of

TABLE 1
Characteristics of participants.

Characteristics	All, n (%)	Habitual diet group (n = 462)	Avocado-supplemented diet group (n = 436)
Sex			
Female	654 (73)	341 (74)	313 (72)
Male	244 (27)	121 (26)	123 (28)
Race			
African American	131 (15)	72 (16)	59 (13)
Asian	54 (6)	30 (7)	24 (6)
Caucasian	628 (70)	311 (67)	317 (73)
Other	85 (9)	49 (11)	36 (8)
BMI categories			
≤29.9 kg/m^2	293 (33)	146 (31)	147 (34)
≥30 kg/m^2 and ≤34.9 kg/m^2	342 (38)	174 (38)	168 (38)
≥35 and ≤39.9 kg/m^2	173 (19)	91 (20)	82 (19)
≥40 kg/m^2	90 (10)	51 (11)	39 (9)
	Mean ± SD	Mean ± SD	Mean ± SD
Age (y)	51 ± 14	51 ±14	50 ±14
Waist circumference (cm)	109 ± 13	110 ±13	109 ± 13
Energy (kcal/d)	1857 ± 726	1847 ± 712	1868 ± 742

Abbreviations: BMI, body mass index; SD, standard deviation.
[1]Chi-square test.
[2]Independent t test.

TABLE 2
Comparison of intakes of selected nutrients between dietary groups during intervention period.

Nutrients	Avocado-supplemented diet group[1]	Habitual diet group[1]	Difference	P value
	Mean ± SD	Mean ± SD	AD-HD	
Energy (kcal)	2036 ± 570	1878 ± 579	159	<0.001
Percent of energy from total fat (% E)	44±7	38±6	6	<0.001
Total fat (g)	101±30	81±29	20	<0.001
SFA (% E)	13±3	12±3	1	0.020
SFA (g)	28±10	27±11	1	0.090
MUFA (% E)	19±3	13±3	6	<0.001
MUFA (g)	43±11	29±11	14	<0.001
PUFA (% E)	9±2	8±3	1	0.400
PUFA (g)	20±8	18±8	2	<0.001
Total cholesterol (mg)	293±170	317±174	–24	0.030
Percent of energy from total Carbohydrates (% E)	39±8	43±9	–4	<0.001
Total Carbohydrates (g)	209±73	206±80	3	0.600
Dietary-fiber (g)	30±8	19±9	11	<0.001
Added sugars (g)	45±33	49±37	–4	0.070
Percent of energy from total protein (% E)	15±4	18±5	–3	<0.001
Total protein (g)	77±25	81±27	–4	0.020
Animal protein (g)	49 ± 33	55 ± 24	–6	0.0001
Plant protein (g)	28 ± 11	26 ± 12	2	0.006
Potassium (mg)	3193 ± 817	2491 ± 843	704	<0.001
Calcium (mg)	821 ± 327	833 ± 382	–14	0.600
Sodium (mg)	3098 ± 1232	3145 ± 1222	–43	0.600

Abbreviations: AD, avocado-supplemented diet group; HD, habitual diet group; SFA, saturated fat; MUFA, monounsaturated fat; PUFA, polyunsaturated fats; % E, percent of energy.
[1] Absolute mean differences between the 2 groups.

servings of fruits, vegetables, legumes, nuts, grains, meat alternatives, or beverages (excluding water) between the 2 groups.

Discussion

Although this is the first study, to the best of our knowledge, to investigate the effect of consuming 1 large avocado on food and nutrient D, our findings align with other D studies where habitual consumption of a nutrient dense food was associated with favorable dietary changes [10–12,14] These favorable dietary improvements were mainly attributed to a decreased intake of animal-based protein from red and processed meats and an increased intake of fiber and potassium among avocado consumers. The reduction in animal protein intake, particularly from red and processed meat, is noteworthy, given the established associations of these foods with higher risks of type 2 diabetes, coronary artery disease, and colorectal cancer [16,24,26].

The higher fiber and potassium intake observed in the AD group are also significant, given the association between both nutrients and health [27,28].

Our colleagues previously reported no changes in saturated fat intake between the 2 groups [6]. Although our findings were the same, we observed a 75% D of saturated fat among consumers in the AD group. Because a large avocado contains ~4 g

TABLE 3
Displacement of selected nutrients between diet groups during intervention period.

Nutrients	Avocado-supplemented diet group	Habitual diet group	Avocado	Expected intake	Displacement	% Displacement
	AD	HD	Avo	EI = HD + Avo	D = EI−AD	% D = D/Avo*100
Energy (kcal)	2036	1877	281	2158	122	43
Total fat (g)	101	81	26	107	6	23
SFA (g)	28	27	4	31	3	75
MUFA (g)	43	29	17	46	3	12
PUFA (g)	20	18	3	21	1	33
Total cholesterol (mg)	293	370	0	370	1	.
Total Carbohydrates (g)	208	206	15	221	13	87
Added sugars (g)	45	49	0	49	4	.
Dietary fiber (g)	30	19	11	30	0	0
Total protein (g)	77	81	3	84	7	233
Animal protein (g)	49	55	0	55	6	.
Plant protein (g)	28	26	3	29	1	33
Calcium (mg)	821	833	22	857	36	164
Sodium (mg)	3098	3145	13	3154	56	431
Potassium (mg)	3193	2491	852	3341	202	24

Abbreviations: % D, percent displacement; AD, avocado-supplemented diet group; Avo, avocado; D, displacement; EI, expected intake; HD, habitual diet group; SFA, satuturated fat; MUFA, monounsaturated fat; PUFA-Polyunsatured fats

TABLE 4
Distribution of food groups by servings between the habitual diet and the avocado-supplemented diet during intervention period.

Food group	Avocado-supplemented diet		Habitual diet		*P* value[1]
	Mean ± SD	Median (IQR)	Mean ± SD	Median (IQR)	
Fruits (excluding avocado)	1.3 ± 1.4	0.9 (1.5)	1.4 ± 1.4	0.93 (1.6)	0.400
Total vegetables	3.3 ± 2.0	3.0 (2.3)	3.3 ± 2.1	3.0 (2.3)	0.800
Nonstarchy vegetables	2.8 ± 1.9	2.3 (2.1)	2.7 ± 2.0	2.4 (2.0)	0.600
Starchy vegetables	0.5 ± 0.7	0.3 (0.8)	0.6 ± 0.7	0.4 (0.9)	0.004
Total Animal-derived protein (excluding dairy)	7.2 ± 3.6	4.6 (3.2)	8.0 ± 4.0	5.2 (3.8)	0.001
Red and processed meats	3.6 ± 2.3	3.0 (3.0)	3.9 ± 2.4	3.4 (3.1)	0.030
Poultry and fish	2.9 ± 2.4	2.7 (2.7)	3.4 ± 2.5	3.0 (3.4)	0.010
Eggs	0.7 ± 0.7	0.5 (1.0)	0.7 ± 0.7	0.5 (1.0)	0.500
Grains	5.5 ± 2.7	5.3 (3.5)	5.6 ± 2.8	5.6 (3.5)	0.300
Whole grains	1.3 ± 1.2	1.0 (1.4)	1.3 ± 1.3	1.0 (1.5)	0.800
Refined grains	3.6 ± 2.3	3.3 (3.0)	3.8 ± 2.5	3.46 (3.4)	0.300
Nuts and seeds	0.8 ± 1.27	0 (1.1)	0.8 ± 1.4	0.31(1.1)	0.200
Legumes	0.2 ± 0.4	0 (0.3)	0.2 ± 0.5	0 (0.3)	0.090
Protein alternatives	0.2 ± 0.6	0 (0.1)	0.3 ± 0.8	0 (0.2)	0.500
Meat alternatives	0.1 ± 0.5	0 (0)	0.2 ± 0.8	0 (0)	0.900
Dairy alternatives	0.1 ± 0.3	0 (0)	0.1 ± 0.3	0 (0)	0.210
Dairy	1.3 ± 0.9	1.1 (1.1)	1.4 ± 1.1	1.2 (1.3)	0.30
Fats and oils	4.3 ± 2.8	3.9 (2.8)	4.7 ± 2.7	4.2 (3.5)	0.010
Animal fats	1.8 ± 2.0	1.3 (1.8)	1.9 ± 1.8	1.4 (2.1)	0.050
Plant fats	2.5 ± 1.9	2.05(2.3)	2.8 ± 2.1	2.3 (2.9)	0.020
Sweets and sugar	1.5 ± 2.03	0.84 (1.8)	1.7 ± 2.1	0.97 (1.9)	0.300
Beverages, including water	8.5 ± 3.8	7.8 (5.12)	8.3 ± 3.5	7.8 (4.3)	0.400
Sweetened beverages	0.6 ± 1.0	0 (0.8)	0.5 ± 0.9	0.12 (0.7)	0.500
Unsweetened beverages, including water	7.7 ± 3.9	7.0 (4.7)	7.4 ± 3.5	7.0 (4.4)	0.400
Alcoholic beverages	0.4 ± 0.8	0 (0.4)	0.3 ± 0.3	0 (0.4)	0.600
Mis (condiments, sauces, etc.)	1.5 ± 1.6	1.0 (1.8)	1.6 ± 1.9	1.03(1.7)	0.400

[1] Wilcoxon test was used to determine the difference.

saturated fat and avocado consumers eat less red and processed meats, which are high sources of saturated fat, we concluded that the saturated fat from red and processed meat was displaced by the saturated fat in the avocado, resulting in no difference in total saturated fat intake between the 2 groups. This conclusion aligns with the food group analysis, which showed no significant differences in the dietary groups' intake of added animal fats (such as butter). The relationship between the type, source, and amount of saturated fat and cardiovascular disease risk is an important consideration [29–31].

Although it was not within the scope of this article to assess the effect of food and nutrient D by an avocado on cardiometabolic outcomes, it is noteworthy that previous publications indicated that there were no significant differences between the 2 groups in most cardiometabolic risk factors, including visceral adiposity, blood pressure, triglycerides, and total cholesterol [8]. Those authors noted that the study duration (6 mo) might have been too short to observe any significant changes. However, it is important to note that their analysis included 1008 participants, with 76%–78% compliance rates in the AD group and 92%–94% in the HD group [8]. Future studies could explore potential differences in the cardiometabolic outcomes among the 898 participants who adhered to the treatment plan.

The lack of significant findings regarding differences in intake for other nutrients, especially micronutrients of concern, such as calcium, or other food groups, such as sugar-sweetened beverages, which could impact overall health, underscores the importance of dietary guidance on food and dietary habits [32]. Our participants had no dietary counseling, and therefore, the substitutions observed can be considered arbitrary.

Our study's strengths include using multiple 24-h dietary recalls for dietary assessment and capturing seasonal variations [33] for 6 mo for each participant and our large sample size of 898 participants. Utilizing the HD group as a concurrent control helped balance potential temporal biases. However, self-reported dietary data pose limitations, potentially leading to under or overreporting [34]. Yet, the automated multiple-pass method used in data collection demonstrated accuracy, and the large sample size allowed for a more accurate assessment of population-level intake [35,36]. Another limitation was that physical activity was not measured during the intervention [15]. However, subjects were advised not to make any lifestyle changes (including physical activity) during the study.

Our findings suggest that incorporating a large avocado daily into the diet provides several potential health benefits stemming from decreased animal protein from red and processed meats, as well as increased fiber and potassium intake. Guidance is needed to educate individuals on effective strategies for integrating avocados into their diets while achieving optimal food and nutrient intakes.

Author contributions

The authors' responsibilities were as follows – JS, AEC: spearheaded the development of the research plan; GS-S: contributed to the research execution; KO: played a key role in the data analysis; AEC, JS: took the lead in drafting the manuscript; SR; KSLB, GS-S, AHL, DMR, MP: contributed to the editing process; and all authors: thoroughly reviewed and read and approved the final manuscript.

Conflict of interest

Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors.

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Data availability

The data described in the manuscript, along with the codebook and analytic code, will be made available upon reasonable request, pending application.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cdnut.2024.104451.

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