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Almond Consumption during Energy Restriction Lowers Truncal Fat and Blood Pressure in Compliant Overweight or Obese Adults[1–3]

Jaapna Dhillon, Sze-Yen Tan, and Richard D Mattes*

Department of Nutrition Science, Purdue University, West Lafayette, IN

Abstract

Background: The inclusion of almonds in an energy-restricted diet has been reported both to enhance or to have no effect on weight loss. Their effects specifically on visceral body fat stores during energy restriction have not been widely examined. In addition, almond consumption has been associated with reduced blood pressure (BP), but whether this is linked to or independent of changes in body composition has to our knowledge not been examined.

Objective: We evaluated the effects of consuming almonds as part of an energy-restricted diet on body composition, specifically visceral adipose tissue (VAT) and BP, compared to a nut-free energy-restricted diet.

Methods: A randomized controlled 12-wk clinical trial of 86 healthy adults [body mass index (in kg/m^2): 25–40] was conducted. Participants were randomly assigned to 1 of 2 energy-restricted (500-kcal deficit/d) diets: an almond-enriched diet (AED) (15% energy from almonds) or a nut-free diet (NFD). A linear mixed-model analysis on primary outcomes such as body weight, body fat, VAT, and BP was performed on all participants [intention-to-treat (ITT) analysis] and compliant participants (complier analysis).

Results: Body weight, truncal and total fat percentage, VAT, and systolic BP decreased after 12 wk of energy restriction in both the ITT and complier analyses ($P < 0.05$). The complier analysis (but not the ITT analysis) indicated a greater mean ± SEM reduction in truncal fat (AED: −1.21% ± 0.26%; NFD: −0.48% ± 0.24%; $P = 0.025$), total fat (AED: −1.79% ± 0.36%; NFD: −0.74% ± 0.33%; $P = 0.035$), and diastolic BP (AED: −2.71 ± 1.2 mm Hg; NFD: 0.815 ± 1.1 mm Hg; $P = 0.029$), and a greater tendency for VAT loss (AED: −8.19 ± 1.8 cm^2; NFD: −3.99 ± 1.7 cm^2; $P = 0.09$) over time in the AED group than the NFD group.

Conclusions: Moderate almond consumption by compliant overweight and obese individuals during energy restriction results in greater proportional reductions of truncal and total body fat as well as diastolic BP and hence may help to reduce metabolic disease risk in obesity. This trial was registered at clinicaltrials.gov as NCT02360787. *J Nutr* 2016;146:2513–9.

Keywords: almonds, blood pressure, body composition, body fat, energy restriction, nuts, obesity, visceral fat, weight loss

Introduction

Despite their high energy content, the inclusion of almonds in an energy-restricted diet does not compromise and may enhance weight loss (1–3). This may occur by several mechanisms, the most important of which is probably through improved dietary compliance. This is likely attributable to greater sensory variety that results in a higher palatability of the diet (4), stronger locus of control (5) that leads to a sense of empowerment, and management of appetitive sensations through their slow and sustained energy release (6). The satiating effects of almonds may prolong intermeal intervals, promote smaller meal sizes, and reduce the desire to eat when not hungry and hence contribute to purposeful weight loss (7).

A goal of weight loss is to maximize the reduction of fat mass while retaining fat-free mass. Traditionally, exercise was viewed as the primary way of achieving this outcome, but evidence shows that dietary factors can also be effective (8). Increasing the proportion of protein in an energy-restricted diet enhances satiety, energy expenditure, and greater relative fat mass loss (9). In addition, different types of dietary fat may influence substrate oxidization. Monounsaturated fats are oxidized preferentially (10, 11), and a diet higher in the unsaturated:saturated fat ratio may reduce subcutaneous adipose tissue (12) and, more importantly, visceral adipose tissue (VAT)[4]

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*To whom correspondence should be addressed. E-mail: mattes@purdue.edu.

[4] Abbreviations used: AED, almond-enriched diet; BP, blood pressure; CVD, cardiovascular disease; ITT, intention to treat; NFD, nut-free diet; SAD, sagittal abdominal diameter; VAT, visceral adipose tissue.

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during weight loss (13). Few studies, to our knowledge, have investigated the effects of dietary FA composition on abdominal fat changes (14). VAT undergoes rapid lipolytic activity that leads to an increased flux of FFA to the liver and systemic circulation. As a consequence, muscle insulin sensitivity is reduced and insulin secretion is stimulated. Elevated peripheral insulinemia will suppress lipolysis and promote lipogenesis, resulting in the accumulation of more abdominal and visceral fat (15). The preferential loss of VAT is believed to mitigate metabolic syndrome and hence improve metabolic fitness. Almonds are good sources of protein and monounsaturated fats, and their effects on visceral body fat loss, in conjunction with energy restriction, have not been directly examined.

Being overweight increases the risk of hypertension by 46–75% (16). There is evidence implicating visceral adiposity as the primary cause of obesity-related hypertension (17). Losing weight may reduce blood pressure (BP), and this may be augmented by incorporating almonds into the diet. In addition, food-derived peptides such as arginine reduce the risk of cardiovascular disease (CVD) (18). Arginine is the physiologic precursor of NO, a vasodilator (19). NO inactivation increases BP (20). Certain nuts and seeds are good plant-based sources of arginine, and studies with peanuts (2.8 g arginine/100 g peanuts, as indicated in the USDA National Nutrient Database) reveals their ingestion for 12 wk leads to notable reductions in diastolic BP (21). Almonds also contain a high concentration of arginine (2.4 g arginine/100 g almonds), but their effect on BP is not well characterized.

The purpose of this study (NCT02360787) was to evaluate the effects of almond consumption as part of an energy-restricted diet on weight, body composition, VAT, and BP compared to a nut-free diet (NFD) matched on the level of energy restriction. We hypothesized that including almonds in an energy-restricted diet would augment the rate of weight loss, lead to greater fat loss (especially in the visceral depot), and reduce BP compared to a control diet matched on energy restriction.

Methods

Participants

Eighty-six healthy adults (21 men and 65 women) aged 18–60 y who were overweight and obese [BMI (in kg/m^2): 25–40] were recruited. Eligibility criteria included the following: no nut allergies, willingness to consume almonds, not taking medications known to influence metabolism and appetite, nonsmoker for >1 y, consistent diet and activity patterns, and weight-stable (<3-kg change over the last 3 mo). All procedures involving human subjects were approved by the Purdue University Institutional Review Board. Participants were recruited via public advertisements. Participants were excluded from the trial if they had diabetes or prediabetes, uncontrolled hypertension, CVD, or dyslipidemia requiring drug therapy. Informed consent was obtained from participants who met eligibility criteria before the commencement of study visits.

Study protocol

The study was a 12-wk randomized, controlled, parallel-arm clinical trial. Participants were randomly assigned to 1 of 2 energy-restricted study arms: an almond-enriched diet (AED) or NFD. Both groups received dietary counseling with the use of the MyPlate food guidance system (21) to reduce energy intake to achieve a 500-kcal deficit/d to support weight loss. Their estimated energy requirement was calculated with the use of the Schofield equations (22) with a physical activity level factor of 1.3. Participants met with a dietitian on a weekly basis for the first 5 wk (including baseline) to establish their dietary prescription and every 2 wk until the 10th week of the study to monitor dietary adherence. Weekly energy and nutrient analyses were conducted with the use of 24-h food recalls to determine participants' compliance to dietary recommendations. Compliance to consistent physical activity was tracked every 4 wk on 2 d (1 weekday and 1 weekend day) with the use of a previously validated triaxial accelerometer (RT3; Stayhealthy) (23).

Forty-three participants were randomly assigned to both the AED and NFD groups. They were asked to consume almonds providing 15% energy in their individualized energy-restricted diet. The almonds were dry-roasted at 129.4°C for ~50 min and were lightly salted (199 mg Na/100 g almonds) to enhance palatability. The energy from almonds was accounted for during dietary modeling so that a 500-kcal deficit/d was achieved. Participants in the AED group were asked to avoid consuming other nuts and seeds. Participants in the NFD group were asked to avoid all nuts, seeds, and nut products during the intervention period.

Study outcomes

The primary outcomes for this study were weight, body composition, VAT, and resting BP. Other outcomes were waist circumference, sagittal abdominal diameter (SAD), serum lipids, insulin, glucose, 24-h ambulatory BP, and 24-h free-living appetite. All outcomes were assessed at baseline and 12 wk after the intervention.

Anthropometric outcomes. Body weight was measured with the use of a calibrated scale (model ABC; Tanita) with participants wearing minimal light-weight clothing. Height was measured with the use of a wall-mounted stadiometer. Body composition was assessed with the use of DXA (Lunar iDXA; GE Healthcare). SAD was measured with the use of a portable sliding caliper (Holtain-Kahn Abdominal Caliper; Holtain Limited) placed at the level of the iliac crest while participants were in a supine position. Waist circumference was measured with the use of a measuring tape placed at the narrowest part of the torso.

VAT was predicted with the use of 2 multivariate anthropometric models. The first model was based on waist circumference (centimeters), proximal thigh circumference (centimeters), age (years), and/or BMI (24) [i.e., women: VAT = 2.15 (waist circumference) – 3.63 (proximal thigh circumference) + 1.46 (age) + 6.22 (BMI) – 92.713; men: VAT = 6 (waist circumference) – 4.41 (proximal thigh circumference) + 1.19 (age) – 213.65 (model 1) (24)]. Proximal thigh height was measured with the use of a measuring tape placed around the thigh just distal to the gluteal crease. The second model was based on SAD (centimeters), age (years), waist circumference (centimeters), and truncal fat (percentage) [i.e., VAT = −208.2 + 4.62 (SAD) + 0.75 (age) + 1.73 (waist circumference) + 0.78 (truncal fat) (model 2) (25)]. Although this model has only been validated for women, we applied it to men as well and examined the correlations between the 2 models with regard to sex.

Resting BP was assessed with the use of an automated digital BP monitor (model 6013; American Diagnostic Corporation). The participants rested for 5 min before BP measurement. Three readings were taken, and the mean was used to determine resting BP. Twenty-four–hour ambulatory BP in a free-living environment was assessed with the use of an automated ambulatory BP machine (ABPM50; Contec) that was programmed to measure BP every hour from 0800 to 2400 and then every 4 h until 0800 the next day. This device was worn on the arm for 24 h, and the cuff was periodically inflated and deflated to measure BP.

Serum lipids, insulin, and glucose. Fasting blood samples (8 mL) obtained from participants were analyzed for serum insulin with the use of an ELECSYS 2010 analyzer (Roche Diagnostics) (CV: 2.5–2.8%), and glucose (CV: 1.1–1.4%) and lipids [total cholesterol (CV: 1.4–1.9%), LDL cholesterol (CV: 1.8–1.9%), HDL cholesterol (CV: 0.7–1%), and TGs (CV: 1.9%)] were analyzed with the use of a COBAS INTEGRA 400 Plus analyzer (Roche Diagnostics).

Free-living appetite ratings. Hunger, fullness, desire to eat, and prospective consumption ratings were measured on visual analog scales on palm pilots with end anchors of "not at all" to "extremely." These ratings were assessed hourly during waking hours over a 24-h period. The mean of the respective appetite ratings were considered for analysis.

Almond acceptance and palatability ratings

Participants randomly assigned to the AED group rated the acceptability of almonds with the use of a food action rating scale (26) and the palatability of almonds with the use of a hedonic general labeled magnitude scale (27, 28) 1 wk after the start of the intervention and at the end of the intervention.

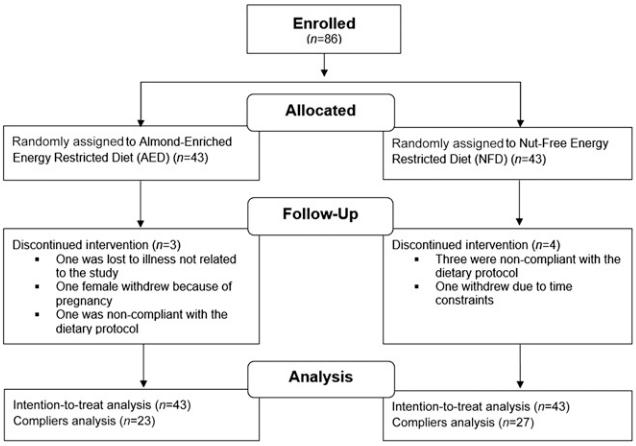

FIGURE 1 Participant flow throughout the almond weight-loss study.

Compliance assessment

Participants' compliance with energy restriction (regardless of group) was assessed via self-reported intake (24-h food recalls) and weight loss. The 24-h recalls were collected by a registered dietitian every week for the first 5 wk (including at baseline) and then every 2 wk until the 10th week of the study. Participants' compliance to their respective intervention groups (i.e., almond consumption or no nut consumption) was monitored via self-reported intake (24-h food recalls) as well as by analyzing their erythrocyte membranes for lipids and flavonoids at baseline and 12 wk after the intervention.

The lipid extracts from participants' erythrocytes were prepared with the use of a procedure by Rose and Oklander (29) and were analyzed by a shotgun lipidomics approach (J Dhillon, CR Ferreira, TJP Sobreira, RD Mattes, unpublished data, 2016). The most informative lipids identified through the lipidomic scans and nut flavonoids reported in the literature were combined into 2 MS methods, single-ion monitoring and multiple-reaction monitoring, with the use of a triple-quadrupole mass spectrometer. Data obtained from the targeted single-ion and multiple-reaction monitoring methods were analyzed via univariate (volcano plots) and multivariate statistics with the use of MetaboAnalyst version 3.0 (30). The performance of the different *m/z* values and their combinations and ratios was evaluated by receiver-operating characteristic analyses.

Statistical analysis

We conducted 2 analyses: an ITT analysis followed by an analysis of participants compliant to their respective intervention groups. Both analyses used a linear mixed model with time, intervention group, and a time-by-intervention-group interaction as factors for all absolute values of outcomes. An additional linear mixed-model analysis on the change in outcomes as opposed to absolute values was also performed. In each analysis, when significant interactions were observed, pairwise comparisons with Bonferroni correction were carried out. Age range, sex, and BMI range were also considered as between-subject factors for all the tests, but there were no effects of the aforementioned factors on any of the outcomes.

The sample size calculations for this study were based on the detection of a 7% difference in visceral fat between groups with 80% power and a 2-tailed α of 0.05. Complete data were required from 40 participants/group.

Between-group differences were assessed at baseline by using independent-sample *t* tests. Categorical outcomes were assessed with the use of chi-square tests. The α level was set at 0.05. SPSS version 22 (IBM) was used for all statistical analyses. Data are reported as means ± SEMs unless otherwise stated.

Results

Participants. Eighty-six participants enrolled in the study, but 7 withdrew during the intervention (**Figure 1**). The attrition rates

TABLE 1 Baseline characteristics of overweight and obese participants in the AED and NFD groups[1]

	ITT analysis		Complier analysis	
Characteristics	AED (*n* = 43)	NFD (*n* = 43)	AED (*n* = 23)	NFD (*n* = 27)
Sex, *n* (%)				
Men	11 (25.6)	10 (23.3)	8 (34.8)	7 (25.9)
Women	32 (74.4)	33 (76.7)	15 (65.2)	20 (74.1)
Age, y	31.1 ± 12.9	31 ± 13.2	33.6 ± 12.9	34.9 ± 13.1
BMI, kg/m^2	29.9 ± 3.2	40 ± 4.5	30.3 ± 3.2	30.6 ± 3.9
BMI category, *n* (%)				
Overweight	23 (53.5)	21 (48.8)	10 (43.5)	13 (48.2)
Obese	20 (46.5)	22 (51.2)	13 (56.5)	14 (51.8)
Body weight, kg	82.8 ± 12.9	84.7 ± 14.1	83.5 ± 12.9	82.2 ± 14.6
Waist circumference, cm	88.1 ± 8.7	90.2 ± 9.8	90.1 ± 8.7	90.2 ± 9.4
SAD, cm	21.9 ± 2.7	22.2 ± 3.2	22.6 ± 2.8	22.4 ± 3
Resting BP, mm Hg				
Systolic	123 ± 11.4	121 ± 8.6	125 ± 9.3	121 ± 8.2
Diastolic	75.2 ± 8.8	73.9 ± 7.2	74.5 ± 6.5	76.3 ± 9.6
Total fat mass, kg	31.7 ± 7.5	33.1 ± 8.9	31.6 ± 8.6	32.1 ± 8.7
Truncal fat mass, kg	16.1 ± 4.5	17 ± 5.4	16.6 ± 4.8	16.7 ± 5.2
Total fat-free mass, kg	50.1 ± 9.6	50.6 ± 8.8	50.8 ± 9.8	49.3 ± 9.6
Truncal fat-free mass, kg	22.5 ± 4.4	22.8 ± 3.7	22.8 ± 4.6	22.3 ± 3.9
VAT,[2] cm^2				
Model 1	92.4 ± 44	107 ± 51	105 ± 45	115 ± 43
Model 2	101 ± 32	107 ± 40	110 ± 33	111 ± 39
Almond palatability ratings, gLMS	68.3 ± 1.9	—	72.5 ± 2.2	—
Almond acceptance ratings, FACT scale	6.9 ± 0.17	—	7.1 ± 0.19	—

[1] Values are means ± SDs unless otherwise indicated. There were no statistically significant differences between the 2 intervention groups at baseline assessed with the use of independent sample *t* tests. AED, almond-enriched diet; BP, blood pressure; FACT, food action rating scale; gLMS, general labeled magnitude scale; ITT, intention to treat; NFD, nut-free diet; SAD, sagittal abdominal; VAT, visceral adipose tissue.

[2] ITT analysis: AED, *n* = 36; NFD, *n* = 37. Complier analysis: AED, *n* = 20; NFD, *n* = 23.

were 7% for the AED group and 9.3% for the NFD group at 12 wk. There were no significant differences in attrition between the AED and NFD intervention groups at 12 wk. The baseline characteristics of all participants are described in **Table 1**. There were no significant differences in the baseline characteristics of participants between groups.

Compliance to energy restriction. The energy-restriction compliance rates were 65.1% for the AED group and 67.4% for the NFD group at 12 wk. There were no significant differences in compliance to energy restriction as assessed by the dietary intake data and weight loss between the AED and NFD intervention groups at 12 wk.

Compliance to intervention groups. Data from 24-h recalls indicated that total energy, carbohydrates, fat, protein, and sodium intake decreased over time ($P < 0.05$). The percentage of energy from fat and total MUFAs, oleic acid, the MUFA:SFA ratio, linoleic acid, total α-tocopherol, magnesium, copper, and phytic acid intake (almonds are rich in these nutrients) was greater and the percentage of energy from carbohydrates lower in the AED group than the NFD group at the end of the intervention ($P < 0.05$) (**Table 2**).

The shotgun metabolomics analysis conducted on 61 participants whose erythrocytes were collected indicated that specific ratios and combinations of mainly membrane lipids such as phosphatidylcholine and sphingomyelin were discriminatory of almond consumption from the nut-free diet at the end of the 12-wk intervention in the AED group (J Dhillon, CR Ferreira, TJP Sobreira, RD Mattes, unpublished data, 2016). However, 8 participants in the AED group and 3 from the NFD group were misclassified into the opposite group, indicating possible noncompliance to their respective interventions that was supported by dietary intake data. These participants, as well as those who did not comply with the energy restriction, were excluded from the secondary complier analysis. There were no significant differences in overall compliance based on weight loss and the metabolomics analysis to the AED and NFD intervention groups at 12 wk. The baseline characteristics of the compliers are shown in Table 1.

Anthropometric outcomes. Weight loss was similar in both the AED and NFD groups in the ITT and complier analyses (**Table 3**). However, the complier analysis indicated a significantly greater decrease in truncal fat mass and percentage and total fat percentage and a significantly greater increase in the truncal and total fat-free mass percentage in the AED group than the NFD group ($P < 0.05$) (**Figure 2**). In general, truncal and total fat mass and percentage fat significantly decreased after the intervention ($P < 0.05$) in both analyses, whereas truncal and total fat-free mass significantly decreased only in the complier analysis. Truncal and total fat-free mass percentage significantly increased after the intervention in both analyses ($P < 0.05$) (Figure 2).

SAD and waist circumference measurements were similar in the AED and NFD groups after the intervention in both analyses (Table 3). However, SAD and waist circumference significantly decreased after the intervention in both analyses ($P < 0.05$) (Table 3).

VAT, predicted with the use of both models, significantly decreased after the intervention ($P < 0.05$) in both analyses (Table 3). Although there was a tendency for greater VAT loss in the AED group than the NFD group (model 1: $P = 0.09$) in the complier analysis, this difference was not statistically significant (Table 3). Although VAT model 2 was validated only for women, it strongly correlated with VAT model 1 for both men ($r = 0.94$; $P < 0.001$) and women ($r = 0.92$; $P < 0.001$) (baseline correlations shown).

TABLE 2 Mean change in nutrient intakes over 10 wk for all overweight and obese participants in the AED and NFD groups[1]

Nutrients	Intervention groups: AED (n = 43)	Intervention groups: NFD (n =43)	P value
Energy,[2] kcal/d	−233 ± 102	−292 ± 105	0.69
Carbohydrates,[2] g/d	−39.4 ± 15.9	−23.1 ± 16.4	0.48
Carbohydrates, % energy	−3.46 ± 2.24	3.46 ± 2.3	0.034
Fat,[2] g/d	−3.81 ± 5.41	−19 ± 5.6	0.05
Fat, % energy	3.67 ± 1.88	−5.02 ± 1.93[2]	0.002
Protein,[2] g/d	−11.2 ± 5.5	−9.02 ± 5.64	0.76
Protein, % energy	−1.2 ± 1.22	1.04 ± 1.26	0.2
Dietary fiber, g/d	1.4 ± 1.55	0.59 ± 1.6	0.55
Total MUFAs, g/d	2.87 ± 2.05	−8.16 ± 2.1[2]	<0.001
MUFAs,[2] % energy	4.06 ± 0.82	−2.52 ± 0.84	<0.001
Total PUFAs, g/d	0.47 ± 1.8	−4.29 ± 1.81	0.06
Total SFAs,[2] g/d	−6.39 ± 2.27	−5.40 ± 2.33	0.76
MUFA:SFA ratio[2]	0.77 ± 0.12	−0.03 ± 0.13	<0.001
PUFA:SFA ratio[2]	0.31 ± 0.13	0.11 ± 0.14	0.28
Oleic acid, g/d	3.26 ± 1.95	−7.63 ± 2[2]	<0.001
Linoleic acid,[2] g/d	0.79 ± 1.6	−4.01 ± 1.65	0.041
Total α-tocopherol,[2] mg/d	6.36 ± 1.09	−1.72 ± 1.12	<0.001
Magnesium, mg/d	51.6 ± 20.1[1]	−14.9 ± 20.7	0.024
Copper, mg/d	0.13 ± 0.1	−0.24 ± 0.1[2]	0.01
Phytic acid, mg/d	203 ± 92.5[2]	−75 ± 95	0.039
Sodium, mg/d	−400 ± 270	−417 ± 277	0.97

[1] Values are means ± SEMs obtained from a linear mixed-effects model with time as within-subject factor and intervention group as a between-subject factor. AED, almond-enriched diet; NFD, nut-free diet.
[2] Significant change over 10 wk, $P < 0.05$.

Resting diastolic BP significantly decreased in the AED group after the intervention ($P < 0.05$) but not in the NFD group for compliant participants (Table 3). However, resting systolic BP significantly decreased after the intervention ($P < 0.05$) in both analyses (Table 3). Twenty-four–hour ambulatory systolic and diastolic BP remained unchanged at the end of the intervention in both analyses. In general, ambulatory BP readings were significantly higher during waking hours (systolic: 124 ± 0.6 mm Hg; diastolic: 73.9 ± 0.46 mm Hg) than sleeping hours (systolic: 114 ± 1.04 mm Hg; diastolic: 64.1 ± 0.94 mm Hg) ($P < 0.05$).

Serum lipids, insulin, and glucose. Fasting serum insulin, TGs, total cholesterol, and HDL and LDL cholesterol remained unchanged after the intervention, whereas fasting glucose increased significantly after the intervention regardless of the intervention group ($P < 0.05$) (Table 3). In the complier analysis, fasting glucose remained unchanged after the intervention in both groups (Table 3).

Free-living appetite ratings. Twenty-four–hour hunger, desire-to-eat, and prospective consumption ratings significantly decreased at the end of the intervention ($P < 0.05$), with no differences between the AED and NFD groups (Table 3). Fullness ratings remained unchanged at the end of the intervention (Table 3). In the complier analysis, hunger, desire-to-eat, and fullness ratings followed the same trend as in the ITT analysis, but prospective consumption ratings remained unchanged at the end of the intervention (Table 3).

Almond palatability and acceptance. The almond palatability ratings significantly decreased after the intervention (−4.81 ± 2.2 food action rating scale units; $P < 0.05$), whereas the almond acceptance

TABLE 3 Mean change in outcomes of overweight and obese participants in the AED and NFD groups over the 12-wk intervention[1]

	ITT analysis			Complier analysis		
Characteristics	AED (n = 43)	NFD (n = 43)	P value	AED (n = 43)	NFD (n = 43)	P value
Body weight,[2] kg	−2.22 ± 0.46	−1.09 ± 0.46	0.21	−3.55 ± 0.47	−2.46 ± 0.44	0.1
VAT,[2,3] cm^2						
Model 1	−4.31 ± 1.48	−1.4 ± 1.49	0.75	−8.19 ± 1.81	−3.99 ± 1.68	0.1
Model 2	−9.04 ± 1.31	−1.4 ± 1.33	0.21	−12.8 ± 1.6	−9.23 ± 1.48	0.11
Waist circumference,[2] cm	−4.36 ± 1.78	−2.57 ± 1.77	0.33	−3.24 ± 0.44	−2.54 ± 0.41	0.25
SAD,[2] cm	−0.8 ± 0.15	−0.59 ± 0.15	0.35	−1.15 ± 0.18	−0.88 ± 0.16	0.26
Resting BP, mm Hg						
Systolic[2]	−3.11 ± 1.35	−1.56 ± 1.35	0.56	−3.23 ± 1.85	−2.2 ± 1.7	0.66
Diastolic	−1.07 ± 0.92	0.07 ± 0.92	0.24	−2.71 ± 1.15[2]	0.82 ± 1.1	0.029
Fasting serum blood profile, mg/dL						
Insulin	−1.17 ± 2.32	−2.79 ± 2.33	0.55	−3.54 ± 3.81	−3.22 ± 3.52	0.95
Glucose[4]	3.20 ± 1.8	2.57 ± 1.81	0.75	2.61 ± 2.63	4.41 ± 2.43	0.62
TGs	−18.1 ± 11.4	−7.57 ± 11.5	0.55	−17.7 ± 18.7	−15.1 ± 17.3	0.92
Total cholesterol	−2.43 ± 3.54	2.57 ± 3.56	0.35	−1.61 ± 4.5	2.26 ± 4.15	0.53
HDL cholesterol	2.65 ± 1.4	0.57 ± 1.4	0.28	1.99 ± 2.03	1.69 ± 1.87	0.92
LDL cholesterol	−0.79 ± 3	1.6 ± 3	0.55	0.212 ± 4.14	1.22 ± 3.82	0.86
Appetite ratings, mm						
Hunger[2]	−3.15 ± 2.61	−6.07 ± 3.81	0.2	−3.42 ± 3.54	−6.71 ± 4.12	0.48
Fullness	0.09 ± 2.9	1.88 ± 4.19	0.27	0.25 ± 4	1.89 ± 4.6	0.71
Desire to eat[2]	−5.23 ± 2.69	−5.63 ± 3.93	0.06	−6.76 ± 3.59	−4.87 ± 4.19	0.4
Prospective consumption[4]	−3.45 ± 2.47	−7.02 ± 3.57	0.07	−3.29 ± 3.41	−6.92 ± 3.94	0.18

[1] Values are means ± SEMs obtained from a linear mixed-effects model with time as a within-subject factor and intervention group as a between-subject factor. AED, almond-enriched diet; BP, blood pressure; ITT, intention to treat; NFD, nut-free diet; SAD, sagittal abdominal; VAT, visceral adipose tissue.
[2] Significant change over the 12-wk intervention for both analyses, $P < 0.05$.
[3] ITT analysis: AED, n = 36; NFD, n = 37. Complier analysis: AED, n = 20; NFD, n = 23.
[4] Significant change over the 12-wk intervention for the ITT analysis only, $P < 0.05$.

ratings remained unchanged (−0.29 ± 0.28 general labeled magnitude scale units) for participants in the AED group in the ITT analysis. The complier analysis indicated no change in almond palatability ratings after the intervention (−3.8 ± 2.8), and the almond acceptance ratings remained unchanged as well (−0.16 ± 0.33).

Activity energy expenditure. Mean activity energy expenditure was significantly higher on weekdays (0.7 ± 0.04 kcal/min) than weekend days (0.59 ± 0.05 kcal/min; $P < 0.05$) but remained unchanged over the intervention in both AED and NFD groups.

Discussion

This study presents several important findings, particularly for individuals who might comply with this type of dietary change. Despite similar weight loss with the 2 diets, almond consumption was associated with considerably greater proportional improvements in overall body composition and greater fat loss in the truncal area in compliant participants. Estimates of truncal fat (DXA) are typically strongly correlated with abdominal visceral fat (r = 0.86–0.89) (31); hence, a reduction in truncal fat could reduce metabolic disease risk. One possible explanation for the greater fat loss with almond consumption stems from their high unsaturated fat content. Unsaturated fats have high-fat oxidation rates that can preferentially reduce visceral fat (7). However, these beneficial effects may only be observed in individuals who fully complied with the protocol (i.e., with energy restriction and almond consumption) because no such effects were found in the ITT group.

Although there was no statistically significant difference in VAT loss between the 2 diets, there was a tendency (P = 0.09) for a greater reduction in VAT with almond consumption when assessed with the use of models that took into account DXA estimates of truncal fat and other measures of central obesity such as SAD and waist circumference. Two nut-based intervention trials examined VAT directly and found conflicting results (32, 33); whereas walnut consumption led to substantial reductions of fat in both visceral and subcutaneous depots in overweight diabetic individuals in one trial (33), pistachio consumption for 24 wk did not lead to a reduction in VAT or subcutaneous adipose tissue (assessed by MRI) in individuals with metabolic syndrome in the other trial (32). Although the walnut trial was conducted in the context of weight maintenance, participants still lost weight. Hence, nut consumption in the context of weight loss might have greater effects on VAT loss. Nut-specific effects are also possible, but in most clinical outcomes there are generally more similarities between nut types than there are differences.

Our intervention demonstrated a decrease in resting systolic BP in both groups, but only the AED was associated with a reduction in resting diastolic BP (−3.6%) in compliant participants (but not in the ITT analysis). Our findings differ from the preponderance of clinical evidence that suggests no effect of tree nuts on resting BP in individuals without existing CVD (34). Similar reductions in diastolic BP have been observed with peanut consumption, but only in individuals with elevated BP at baseline (21). Moreover, in the Primary Prevention of Cardiovascular Disease with a Mediterranean Diet trial, the consumption of a nut-based Mediterranean diet for 1 y led to a

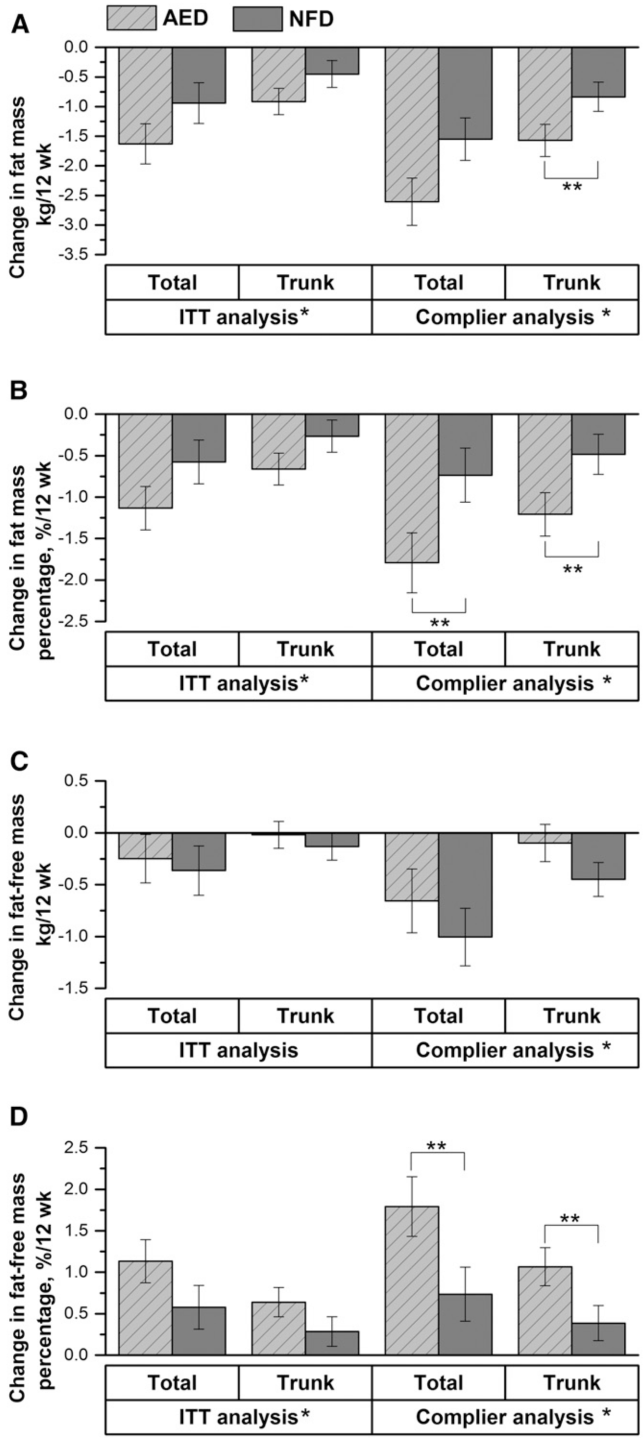

FIGURE 2 Mean change in total and truncal fat mass (A), fat mass percentage (B), fat-free mass (C), and fat-free mass percentage (D) of overweight and obese participants in the AED and NFD groups over the 12-wk weight-loss intervention. Values are means ± SEMs obtained from a linear mixed-effects model with time as a within-subject factor and intervention group as a between-subject factor. *Significant change during the 12-wk intervention, $P < 0.05$. **Different from NFD, $P < 0.05$. ITT analysis: AED, n = 43; NFD, n = 43. Complier analysis: AED, n = 23; NFD, n = 27. AED, almond-enriched diet; ITT, intention to treat; NFD, nut-free diet.

decrease in 24-h ambulatory systolic and diastolic BP, but only in individuals with a high risk of CVD (35). It is possible our findings reflect the use of almonds under energy-restricted weight-loss conditions that could augment the reductions of diastolic BP (36).

In this study, serum insulin and glucose remained unchanged with almond consumption for 12 wk. Although nut consumption has positive effects on glycemic control (37), the long-term effects are typically more favorable in prediabetic (38) and diabetic individuals (39) or those with metabolic syndrome (40). In addition, there were no changes in serum TGs or total, HDL, and LDL cholesterol with almond consumption. The participants in our study were healthy adults who were overweight and obese with no other CVD risk factors, and the preponderance of nut-based evidence shows the greatest improvements in blood cholesterol in individuals with high LDL cholesterol and those with a low BMI and improvements in TGs in individuals with hypertriglyceridemia (41). Moreover, these improvements were observed with a mean daily nut consumption of 67 g, whereas the participants in our study had a mean daily nut consumption of 38 g.

The satiating effects of almond consumption in acute feeding trials are well documented (7). These properties have important implications for weight management because they can translate into strong dietary compensatory responses. Whether these satiating effects can be sustained chronically has yet to be established to our knowledge. In this 12-wk clinical weight-loss trial, almond consumption reduced 24-h–hunger and desire-to-eat ratings to a similar degree as the nut-free diet. However, it is important to note that both intervention groups underwent structured dietary counseling to make healthier and satiating food choices.

Another consideration in long-term feeding studies is the monotony that results from the repeated daily consumption of specific foods (42). This is important because it might undermine compliance to a dietary recommendation to increase the consumption of a given food. Long-term (12-wk) consumption of 30 g nuts/d does not seem to induce the effects of monotony over time (43, 44), but as indicated by the decreased acceptance of nuts with the repeated consumption of 60 g nuts/d, these effects might be dose-dependent (43). In our study, almond palatability ratings decreased considerably over time but remained within an acceptable range (i.e., from over strongly palatable at baseline to over moderately palatable at the end of the intervention). However, individuals who complied with the intervention demonstrated no decline in almond palatability ratings (rated consistently over strongly palatable). Although this finding suggests that these individuals may have been more resistant to the effects of monotony and hence more compliant, it needs to be investigated further.

In conclusion, incorporating modest quantities of almonds in a 12-wk weight-loss regimen led to improvements in body composition and BP in healthy overweight and obese adults who complied with the protocol. The findings from the ITT analysis reflect the practical implications of almond consumption during energy restriction, whereas the complier analysis reflects more closely the efficacy of the almond intervention when individuals are compliant with almond consumption during energy restriction. Nevertheless, the clinical benefits of moderate almond consumption among individuals with or at a high risk for metabolic syndrome and/or CVD have been repeatedly confirmed, and our findings indicate positive health effects among compliant overweight but otherwise healthy adults as well.

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JD, S-YT, and RDM designed and conducted the study, analyzed the data, and shared equal responsibility in writing the manuscript. All authors read and approved the final manuscript.

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