Processed foods in the context of a vegan diet, and changes in body weight and severe hot flashes in postmenopausal women: a secondary analysis of a randomized clinical trial

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Abstract

Objectives: A plant-based diet has been shown to reduce hot flashes, partly by weight loss. Because some plant-based foods are highly processed, this secondary analysis assessed associations between consumption of processed foods, body weight, and severe hot flashes in postmenopausal women.

Methods: Participants (N = 84) were randomly assigned to a low-fat vegan diet supplemented with soybeans (n = 42) or an omnivorous control group (n = 42) for 12 weeks. Three-day diet records were analyzed using the Nutrition Data System for Research software; the NOVA classification was used to assess processed food consumption. A repeated measures ANOVA was used for statistical analyses.

Results: Consumption of unprocessed or minimally processed animal foods decreased in the vegan group, compared with the control group; effect size: −106 g/d (95% CI: −169 to −42); $P = 0.002$. The reduction in consumption of unprocessed or minimally processed animal foods was associated with weight loss ($r = +0.45$; $P < 0.001$) and a reduction in severe hot flashes ($r = +0.31$; $P = 0.01$). Similarly, consumption of ultra-processed animal foods decreased in the vegan group by 60 g/d (95% CI: −105 to −15); $P = 0.004$, with no significant change in the control group; effect size: −65 g/d (95% CI: −115 to −16); $P = 0.01$. The reduction in consumption of ultra-processed animal foods was associated with weight loss ($r = +0.43$; $P < 0.001$). Consumption of ultra-processed plant-based foods changed only minimally and nonsignificantly and was not associated with changes in weight or hot flash frequency.

Conclusions: These findings suggest that, in the context of a soybean-supplemented vegan diet, replacing the consumption of both unprocessed or minimally processed and ultra-processed animal foods with plant foods (regardless of the level of processing), was associated with significant weight loss and a reduction in severe hot flashes.

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The study was conducted in accordance with the Declaration of Helsinki, and the study protocol was approved by the Advarra Institutional Review Board, located in Columbia, MD. The study was registered on ClinicalTrials.gov (NCT03698955). All participants gave informed written consent.

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Plant-based diets have been shown to significantly reduce body weight in clinical trials.[1,2] However, it is not clear whether the consumption of processed foods would impair weight loss. Some researchers have classified foods based on their processing levels using the NOVA classification system,[3] and the consumption of ultra-processed foods has been suggested to contribute to weight gain and increased risk of type 2 diabetes.[4,5] However, a 2023 analysis of the data from three large US cohorts showed that, while the consumption of animal-based ultra-processed foods and sugar-sweetened beverages was associated with an increased risk of type 2 diabetes, consumption of ultra-processed breads and cereals and packaged sweet and savory snacks was associated with reduced risk.[5] Therefore, the relationship between changes in processed food intake and body weight in the context of a vegan diet merits investigation in randomized controlled trials, taking into account the food origin (animal vs. plant-based).

A low-fat vegan diet supplemented with soybeans has been shown to reduce body weight and postmenopausal hot flashes.[6] Since weight loss may contribute to improvements in hot flashes,[7] this secondary analysis of previously published data[6] assessed the association of NOVA categories, divided into animal and plant-based foods, with changes in body weight and severe hot flashes in postmenopausal women. Our hypothesis was that animal and plant-based foods within the NOVA categories would affect body weight differently, which may have significant implications on specific dietary recommendations for postmenopausal women.

METHODS

The methods have been described in detail previously.[6] Briefly, postmenopausal women aged 40-65 years reporting at least 2 moderate-to-severe hot flashes per day were recruited through social media and screened by telephone in two cohorts (fall and spring) for a parallel-design, 12-week study beginning in September 2020 and February 2021 in Washington, DC. Exclusion criteria were any cause of vasomotor symptoms other than natural menopause; current use of a low-fat, vegan diet; soy allergy; use of hormonal medications in the preceding 2 months; smoking; substance abuse including the consumption of more than 1 alcoholic beverage a day; eating disorder history; use of weight-reducing medication during the last 6 months; a current effort at weight loss; and body mass index < 18.5 kg/m^2. The Advarra Institutional Review Board approved the study on September 2, 2020 (Pro00045315). All participants provided written informed consent. This study follows the Consolidated Standards of Reporting Trials (CONSORT, Supplemental Digital Content 1, http://links.lww.com/MENO/B372) reporting guidelines.

Volunteers who met participation criteria were randomly assigned to a vegan group or control group using a computer-generated sequence. The assignment was done simultaneously, so allocation was concealed before randomization. The main outcome was the number and intensity of hot flashes, which were tracked with a mobile application, over 12 weeks. The vegan group was asked to avoid all animal foods and follow a low-fat plant-based diet, consisting of fruits, vegetables, grains, and legumes, including one-half cup (86 g) of cooked soybeans per day. Control participants maintained their usual diets. No instructions regarding processed food consumption were given to either group. Participants in both groups were provided with a vitamin B12 supplement (100 μg) and were asked to keep their medications and physical activity constant. Alcoholic beverages were limited to one per day.

Measurements were performed at baseline and week 12. The frequency and intensity of hot flashes were recorded, using the My Luna mobile application (Blue Trail Software Holding). Body weight was measured using a self-calibrating digital scale (Renpho Model ES-CS20M), accurate to 0.05 kg.

Dietary adherence was assessed weekly. In addition, each participant completed a 3-day dietary record (two weekdays and one weekend day) at baseline and week 12. Dietary intake data were collected and analyzed by a staff member certified in the Nutrition Data System for Research which was developed by the Nutrition Coordinating Center at the University of Minnesota, Minneapolis, MN.[8] All foods were categorized for the degree of processing using the NOVA system,[3] and by their origin (animal, plant-based, or mixed). NOVA category 1 is defined as unprocessed or minimally processed foods; category 2 includes processed ingredients, such as salt, sugar, oil, and butter; category 3 includes processed foods made by adding salt, sugar, preservatives, etc.; and category 4 is composed of ultra-processed foods, greatly modified by industrial techniques and processes. L.C. served as an independent reviewer, blinded to group assignment, to check the accuracy of food categorization. Physical activity was assessed by the International Physical Activity Questionnaire (IPAQ).[9]

The intention-to-treat analysis included all study participants. In addition, an analysis was performed, including only study completers who submitted complete data at baseline and week 12. A repeated measure ANOVA was used by a statistician blinded to dietary interventions, with factors group, subject, and time. Dietary intake in each NOVA category was the dependent variable. For each intake outcome, a linear mixed model was fit with fixed effects for the study arm and time period (baseline and 12 wk) and an interaction between time periods. A random effect was included to take into account the correlation between within-participant measurements; separate covariances were fit for the two treatment groups. Least-square estimates of changes within each treatment arm and of the difference in changes between treatment arms, along with (two-sided 95%) CIs and significance assessments, were then constructed from

TABLE 1. NOVA categories at baseline and 12 weeks

Intake (g/d)	Vegan group			Control group			Effect size	P
	Week 0	Week 12	Change	Week 0	Week 12	Change		
Category 1, animal	73 (42-104)	1 (0-2)	−73 (−104 to −42)[a]	72 (20-123)	105 (33-176)	33 (−24 to 90)	−106 (−169 to −42)	0.0018
Category 1, plant-based	1201 (993-1408)	1632 (1309-1956)	432 (118 to 745)[b]	1185 (936-1434)	1248 (980-1515)	63 (−209 to 334)	369 (−45 to 783)	0.0798
Category 2, animal	1 (0-3)	0 (0-1)	−1 (−2 to 0)	2 (0-4)	1 (0-2)	−1 (−2 to 1)	0 (−2 to 2)	0.8605
Category 2, plant-based	12 (8-16)	32 (4-61)	20 (−9 to 49)	48 (−3-99)	67 (−24-157)	19 (−29 to 67)	2 (−53 to 57)	0.9543
Category 3, animal	9 (3-15)	0 (0-1)	−9 (−15 to −3)[b]	10 (0-20)	2 (0-4)	−8 (−19 to 3)	−1 (−13 to 11)	0.8712
Category 3, plant-based	14 (7-21)	5 (2-7)	−9 (−16 to −1)[c]	21 (13-29)	15 (6-23)	−6 (−14 to 2)	−3 (−14 to 8)	0.5686
Category 4, animal	63 (18-108)	3 (0-8)	−60 (−105 to −15)[c]	37 (17-56)	42 (21-63)	5 (−17 to 27)	−65 (−115 to −16)	0.0110
Category 4, plant-based	385 (285-485)	346 (225-466)	−39 (−150 to 72)	349 (263-434)	461 (223-699)	112 (−141 to 366)	−152 (−426 to 122)	0.2691
Category 4, mixed	117 (87-146)	122 (72-171)	5 (−47 to 57)	114 (80-148)	122 (77-167)	8 (−28 to 44)	−3 (−64 to 59)	0.9301

Data are presented as means with 95% CIs.
[a] $P < 0.001$.
[b] $P < 0.01$.
[c] $P < 0.05$.

these models. All results are presented as means with 95% CIs. In addition, within-group and between-group differences were tested, using paired *t* tests. For food categories exhibiting a significant between-group difference in consumption changes, Spearman correlations (in both groups combined) were used to evaluate the magnitude and significance of associations between food intake changes and changes in hot flashes and body weight. After Bonferroni correction, *P* values <0.01 (0.05/4) were considered significant.

RESULTS

Of 1,662 volunteers, 361 were screened by telephone, and 84 participants were randomly assigned to the 2 study groups, with 71 participants completing the whole study (Supplemental Fig. 1, Supplemental Digital Content 2, http://links.lww.com/MENO/B373). The baseline demographics are listed in Supplemental Table 1, Supplemental Digital Content 3, http://links.lww.com/MENO/B374. There were no significant between-group differences in any variables, including race, ethnicity, marital status, education, use of medication, body weight, years since menopause, dietary intake, and alcohol consumption, except for the vegan group being slightly younger. The groups were comparable in terms of the number and severity of hot flashes at baseline. The average number of total hot flashes was 5.8 (±3.5) in the vegan and 5.2 (±3.8) in the control group (between-group $P = 0.40$), and most of the reported hot flashes were moderate-to-severe: 4.8 (±3.5) in the intervention and 4.1 (±3.2) in the control group (between-group $P = 0.34$).

Hot flashes and body weight

Severe hot flashes were reduced by 92% (from 1.3/d to 0.1/d) in the vegan group ($P < 0.001$) and did not change significantly in the control group (from 0.7/d to 0.4/d; $P = 0.13$; between-group $P = 0.02$). Moderate-to-severe hot flashes decreased by 88% (from 5.0/d to 0.6/d) in the vegan group ($P < 0.001$) and by 34% (from 4.4/d to 2.9/d) in the control group ($P < 0.001$; between-group $P < 0.001$). Mean body weight decreased by 3.6 kg in the vegan group and 0.2 kg in the control group [effect size: −3.4 kg (95% CI: −4.5 to −2.3); $P < 0.001$]. As reported earlier,[6] the improvements were comparable in the fall and spring cohorts.

NOVA categories

As reported previously,[6] there was no significant between-group difference in energy intake. Changes in animal and plant-based foods in all NOVA categories in study completers with complete data at baseline and week 12 are listed in Table 1. The results from the intention-to-treat analysis that included all study participants were very similar and are shown in Supplemental Table 2, Supplemental Digital Content 4, http://links.lww.com/MENO/B375. Spearman correlations between changes in the consumption of the NOVA food categories with a significant between-group difference and changes in body weight and hot flashes are listed in Table 2. The con-

TABLE 2. Spearman correlations between changes in the NOVA categories and changes in body weight and severe hot flashes with a significant between-group difference

	Δ body weight	Δ severe hot flashes
Category 1, animal	$r = +0.45$; $P < 0.001$	$r = +0.31$; $P = 0.01$
Category 4, animal	$r = +0.43$; $P < 0.001$	$r = +0.24$; $P = 0.07$

After Bonferroni correction, P values < 0.01 (0.05/4) are considered significant.

sumption of unprocessed or minimally processed animal foods decreased in the vegan group, compared with the control group; effect size: −106 g/d (95% CI: −169 to −42); $P = 0.002$. This reduction was associated with weight loss ($r = +0.45$; $P < 0.001$) and a reduction in severe hot flashes ($r = +0.31$; $P = 0.01$). Concomitantly, the intake of unprocessed or minimally processed plant-based foods increased in the vegan group by 432 g/d (95% CI: 118-745); $P = 0.009$, but the between-group difference was not statistically significant ($P = 0.08$). Consumption of animal-based processed culinary ingredients and processed foods was minimal at baseline in both groups. No significant changes in the consumption of animal or plant-based processed culinary ingredients were observed in either group. The processed animal-food consumption decreased in the vegan group by 9 g/d (95% CI: −15 to −3); $P = 0.004$, as did the intake of processed plant-based foods by 9 g/d (95% CI: −16 to −1); $P = 0.02$, but the difference between the groups was not statistically significant for either category. The consumption of ultra-processed animal foods decreased in the vegan group by 60 g/d (95% CI: −105 to −15); $P = 0.004$, with no significant change in the control group; effect size: −65 g/d (95% CI: −115 to −16); $P = 0.01$. The reduction in consumption of ultra-processed animal foods was associated with weight loss ($r = +0.43$; $P < 0.001$) and a reduction in severe hot flashes ($r = +0.31$; $P = 0.01$). There was no significant change in the consumption of ultra-processed plant-based foods or mixed foods in either group.

DISCUSSION

The current randomized trial demonstrated that, in the context of a vegan diet, replacing the consumption of both unprocessed or minimally processed and ultra-processed animal foods with plant foods (regardless of the level of processing), was associated with weight loss and a reduction in severe hot flashes in postmenopausal women. Conversely, the level of processing of plant foods was not associated with changes in body weight or hot flashes, suggesting that the benefits of increasing plant foods are independent of processing level. While consumption of animal-derived ultra-processed foods is associated with an increased risk of type 2 diabetes in observational studies, the reverse is true for most plant-based foods. Even many highly processed plant-based foods are associated with a lower diabetes risk.[5]

Nutrition interventions that are low in fat and rich in whole grains, fruits, and vegetables may help reduce the frequency and intensity of hot flashes. For instance, in The Women's Health Initiative study, this diet increased the likelihood of women being relieved of hot flashes at 1 year by 14% after adjustments for changes in body weight, and by 23% in women who lost at least 10% of body weight.[10]

The findings raise the question of the potential mechanisms that may explain the observed clinical improvements. The positive effects of nutrition modifications on postmenopausal hot flashes may, in part, be mediated by changes in dietary advanced glycation end-products (AGEs), a group of endocrine disruptors affecting the secretion of insulin, reproductive hormones, as well as secretion of adipose tissue hormones such as leptin and adiponectin.[11] A low-fat vegan diet that included daily consumption of soybeans led to a 92% reduction in severe hot flashes and a 73% reduction in dietary AGEs. The reduction in the dietary AGEs, related mainly to the reduction in animal-derived products and increased consumption of plant-based foods regardless of their degree of processing, was associated with the reduction in hot flashes, independent of changes in energy intake and changes in body mass index.[12]

The strengths of the current trial include a randomized, parallel design, which accounted for seasonal effects. The study also has limitations. The food consumption was based on self-reported diet records. The participants were volunteers and may not represent the general population.

CONCLUSIONS

In conclusion, these findings suggest that, in the context of a soybean-supplemented vegan diet, replacing the consumption of both unprocessed or minimally processed and ultra-processed animal foods with plant foods (regardless of the level of processing), was associated with significant weight loss and a reduction in severe hot flashes.

REFERENCES

1. Turner-McGrievy GM, Barnard ND, Scialli AR. A two-year randomized weight loss trial comparing a vegan diet to a more moderate low-fat diet. *Obesity (Silver Spring)*. 2007;15:2276-2281. doi:10.1038/oby.2007.270
2. Barnard ND, Levin SM, Yokoyama Y. A systematic review and meta-analysis of changes in body weight in clinical trials of vegetarian diets. *J Acad Nutr Diet*. 2015;115:954-969. doi:10.1016/j.jand.2014.11.016
3. Khandpur N, Rossato S, Drouin-Chartier J-P, et al. Categorising ultra-processed foods in large-scale cohort studies: evidence from the Nurses' Health Studies, the Health Professionals Follow-up Study, and the Growing Up Today Study. *J Nutr Sci*. 2021;10:e77. doi:10.1017/jns.2021.72eCollection 2021
4. Hall KD, Ayuketah A, Brychta R, et al. Ultra-processed diets cause excess calorie intake and weight gain: an inpatient randomized controlled trial of ad libitum food intake. *Cell Metab*. 2019;30:67-77.e3. doi:10.1016/j.cmet.2019.05.008
5. Chen Z, Khandpur N, Desjardins C, et al. Ultra-processed food consumption and risk of type 2 diabetes: three large prospective U.S. cohort studies. *Diabetes Care*. 2023;46:1335-1344. doi:10.2337/dc22-1993
6. Barnard ND, Kahleova H, Holtz DN, et al. A dietary intervention for vasomotor symptoms of menopause: a randomized, controlled trial. *Menopause*. 2023;30:80-87. doi:10.1097/GME.0000000000002080
7. Kroenke CH, Caan BJ, Stefanick ML, et al. Effects of a dietary

intervention and weight change on vasomotor symptoms in the Women's Health Initiative. *Menopause*. 2012;19:980-988. doi:10.1097/gme.0b013e31824f606e
8. Schakel SF, Sievert YA, Buzzard IM. Sources of data for developing and maintaining a nutrient database. *J Am Diet Assoc*. 1988;88:1268-1271. PMID: 317102.
9. Hagströmer M, Oja P, Sjöström M. The International Physical Activity Questionnaire (IPAQ): a study of concurrent and construct validity. *Public Health Nutr*. 2006;9:755-762. doi:10.1079/phn2005898
10. Indyk D, Bronowicka-Szydełko A, Gamian A, Kuzan A. Advanced glycation end products and their receptors in serum of patients with type 2 diabetes. *Sci Rep*. 2021;11:13264. doi:10.1038/s41598-021-92630-0
11. Ravichandran G, Lakshmanan DK, Raju K, et al. Food advanced glycation end products as potential endocrine disruptors: an emerging threat to contemporary and future generation. *Environ Int*. 2019;123:486-500. doi:10.1016/j.envint.2018.12.032
12. Kahleova H, Znayenko-Miller T, Uribarri J, et al. Dietary advanced glycation end-products and postmenopausal hot flashes: a post-hoc analysis of a 12-week randomized clinical trial. *Maturitas*. 2023;172:32-38. doi:10.1016/j.maturitas.2023.03.008

