Original research paper

Vegans report less stress and anxiety than omnivores

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Objective: Studies investigating mood in vegetarian diets have yielded conflicting results, either demonstrating risk for mental disorders or mood protection. Our objective was to investigate mood, as well as factors that potentially impact mood in vegans (VG), vegetarians (VEG), and omnivores (OMN).
Methods: We surveyed mood, diet, and lifestyle factors in a broad geographic online sample of adult VG ($n = 283$), VEG ($n = 109$), and OMN ($n = 228$) who were recruited via diet-related social networks. Mood was measured with the Depression Anxiety Stress Scale-21 (DASS-21).
Results: The sample was mostly female (78.5%), and age was inversely correlated with all DASS scores ($P < 0.05$). Mean DASS-A (anxiety) and DASS-S (stress) scores differed by group ($F(2616) = 4.73$, $P = 0.009$, $\eta^2 = 0.015$, and $F(2, 615) = 8.23$, $P < 0.001$, $\eta^2 = 0.026$, respectively), with VG scores lower than OMN scores, indicating less mood disturbance. Analyses of covariance were conducted by gender, adjusting for age. Anxiety scores were different in males only ($F(2128) = 5.39$, $P = 0.006$, $\eta^2_p = 0.078$) and lower anxiety in males was related to a vegan diet and daily fruit and vegetable intake. Mean stress scores were different in females only ($F(2476) = 3.82$, $P = 0.023$, $\eta^2_p = 0.016$) and lower stress in females was related to a vegan diet and lower daily intake of sweets.
Discussion: A strict plant-based diet does not appear to negatively impact mood, in fact reduction of animal food intake may have mood benefits. The improved mood domains were not consistent with those found in other studies, which may be due to methodological differences.

Keywords: Vegan mood, Vegan mental health, Vegan diet, Plant-based diet, Vegetarian diet, Stress and diet, DASS-21

Introduction

Recent studies investigating the vegan diet have found that the risk of major chronic diseases such as obesity, heart disease, and type-2 diabetes may be reduced by adopting a completely plant-based diet vs. an omnivore diet.[1,2] A Belgian study that compared nutrient intake and dietary quality of different diet types found that vegans (VG) had the highest diet quality as measured by the Healthy Eating Index-2010, compared to omnivores (OMN), who had the lowest quality.[3] The German Vegan Study found that VG not only exercised more than OMN, but consumed more than five times the daily intakes of fruits and vegetables than the average population.[4] Less than 5% of the American population call themselves vegan, however, the plant-based diet has become increasingly popular, and is no longer perceived as extreme or difficult to follow as it was in previous decades.[5]

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Evidence for recommending a strict vegan diet, however, does not yet exist in the scientific community due to concern over adequacy of certain nutrients and related long-term health effects.[6] For example, the aforementioned Belgian study[3] found that VG had only about 60% of the mean calcium intakes of vegetarians (VEG) and 75% that of OMN, and the German Vegan Study found that over 70% of VG had calcium intakes below current recommendations,[4] raising the risk of bone density loss. More pertinent to our focus of mental health is the concern that the vegan diet is typically low in a number of nutrients, several of which are related to healthy brain function such as vitamin B12, vitamin D, and long-chain omega-3 fatty acids.[7] Studies have not examined vegan mental health *per se*, and results of studies investigating the broader vegetarian diet and mental health have been conflicting. Compared to OMN, persons following a vegetarian diet have reported more depression and anxiety.[8] Conversely, in a survey we administered to Seventh Day Adventists, VEG

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reported better mood than their omnivorous counterparts who reported higher n-3 intakes.[9] In a subsequent pilot trial, OMN randomized to a vegetarian diet for 2 weeks reported better mood than those consuming fish or control diets.[10] Our objective was to investigate mood and lifestyle factors than can impact mood in VG, VEG, and OMN. To our knowledge, this is the first study investigating self-reported mental health domains in a large sample of VG.

Methods

Participants and recruitment

An online survey targeting VG was delivered via Surveymonkey in spring of 2013. The survey notice with link was posted on vegan and vegetarian pages on social networking and Meetup sites, emailed to vegan and vegetarian groups, distributed at health food stores and vegan and vegetarian restaurants, and provided to onsite volunteers at a large event frequented by VG and VEG. Prospective participants were notified that if they were 25–60 years of age and healthy (without a debilitating chronic disease) they were eligible to complete an anonymous survey investigating food choices, health, and wellness. Participants were informed generally about the study when they entered the survey link and that completion of the survey indicated their informed consent, but were not informed about the study hypotheses. No incentive was provided to participants for survey completion. This targeted sampling from social media websites allowed us to reach a considerable number of VG who are often underrepresented in comparative studies. We did not exclude non-VG in order to conduct comparative analyses.

Survey measures

Participants first completed a series of demographic questions related to geographic location, ethnicity, marital status, and education. They were then asked to estimate their height and weight to calculate body mass (BMI; kg/m^2), and about their weekly physical activity levels with questions from the Godin Leisure-Time Exercise Questionnaire.[11] Participants also completed a number of lifestyle questions related to alcohol intake, dieting, smoking, work hours, hours spent outdoors, sleep hours, and regular use of medications and supplements. Finally, social support was assessed with three representative questions pertaining to family, friend, and significant other support taken from the Multidimensional Scale of Perceived Social Support Assessment.[12]

Next, embedded in the survey was the Depression Anxiety Stress Scales-21 (DASS-21) which measures symptoms consistent with depression, anxiety, and stress.[13] Responses to seven statement characteristics of each of the three conditions range from 0 (did not apply to me at all) to 3 (applied to me very much). Normal scores for DASS-depression (DASS-D) are 0–9, for DASS-anxiety (DASS-A) are 0–7, and for DASS-stress (DASS-S) are 0–14. The intensity of any of the three conditions is defined by the sum of scores of each seven-item subscale. The DASS-21 is widely used and demonstrates good psychometric properties.[13] Coefficient alpha values obtained for our sample were 0.90 for DASS-D, 0.60 for DASS-A, 0.79 for DASS-S, and 0.89 for the total scale, in line with previous findings for non-clinical populations,[13,14] although our estimate for DASS-A was a little lower.

For the purpose of diet classification, participants were then asked the question, 'Which of the following foods do you include in your diet (at least monthly)? Reponses were any of the following: meat (beef, pork, lamb), chicken/turkey, fish/shellfish, eggs, and dairy foods. Other diet questions related to intake of food groups with potential mood impact were adapted from the EPIC Oxford study questions such as daily intakes of fruits, vegetables (excluding potatoes and corn), and sweets, as well as monthly intakes of high omega-3 plant foods (canola oil+flaxseed oil+flaxseeds+chia seeds+walnuts) and certain vitamin D foods (milk+other fortified milk substitutes+button mushrooms).

Statistical analyses

Descriptive statistics were reported for all outcome measures and data reported as mean ± SD. Data were not normal, however, parametric analyses were conducted due to the large sample size. Relationships between mood, demographic and lifestyle variables were investigated using Chi square tests, Pearson's correlations, one-way analysis of variance (ANOVA), and univariate analysis of covariance (ANCOVA), where appropriate. Data were analyzed using the IBM SPSS software (version 21.0), and P values < 0.05 were considered significant.

Results

Survey completion rate was 88% and yielded 792 completed surveys. Those who did not complete the diet classification question or the DASS-21 were removed prior to analysis, as were extreme DASS-21 subscale scores (>3 SD from mean). The remaining 620 participants were classified into three diet groups based on inclusion of animal foods at least monthly: OMN consumed meat, poultry, or fish ($n = 228$, 37.5%); VEG consumed only eggs or dairy ($n = 109$, 17.8%); and VG consumed no animal foods ($n = 283$, 44.7%). Most of the population was North American (USA 78%, Canada 6%), with only 16% of participants reporting their residence outside of North America. The largest regional representation from the USA

Table 1 Participant characteristics by diet group

	OMN (n = 228)	VEG (n = 109)	VG (n = 283)	Test statistics	P value
Age (years, mean)	34.6 ± 10.8[a]	32.7 ± 9.5[b]	37.2 ± 10.3[ab]	F = 9.51	<0.001
Gender (% female)	82.4%	79.6%	74.8%	y^2 = 4.33	0.115
Education (years after high school)	5.4 ± 1.9[a]	5.0 ± 2.1	4.5 ± 2.6[a]	F = 9.27	<0.001
Marital status (% married)	41.2%[a]	17.1%[ab]	41.7%[b]	X^2 = 16.35	0.038
BMI (kg/m^2, mean)	25.2 ± 7.2	24.1 ± 5.2	24.1 ± 5.0	F = 2.24	0.107
Moderate exercise X/week	3.8 ± 3.7[a]	4.1 ± 2.6	4.9 ± 4.3[a]	F = 4.31	0.014
Yoga/stress practice (count)	72[a]	42[ab]	120[b]	X^2 = 6.67	0.036
Dieted in last year (yes)	72[a]	22[ab]	67[b]	X^2 = 6.47	0.039
Cigarette smoker (yes)	10	6	25	X^2 = 4.22	0.121
Hours at work/week	38.9 ± 18.3[a]	36.6 ± 16.4	34.6 ± 30.6[a]	F = 1.93	0.145
Hours outdoors/week	8.6 ± 8.8[a]	8.2 ± 7.6[b]	11.2 ± 10.9[ab]	F = 6.43	0.002
Sleep, hours/night	7.2 ± 0.9	7.4 ± 1.1[b]	7.1 ± 1.0[b]	F = 4.57	0.011
Social support (mean score)	17.0 ± 4.5[a]	16.3 ± 3.7	15.4 ± 4.7[a]	F = 8.00	<0.001
Psychotropic meds (yes)	23	9	13	X^2 = 5.86	0.053
Multivitamin mineral user (yes)	15	16	73	X^2 = 33.82	<0.001
Alcohol servings/week	3.4 ± 4.4[ab]	1.7 ± 2.5[b]	2.5 ± 4.2[a]	F = 7.43	0.001
Fruit intake/day	2.2 ± 1.3[a]	2.2 ± 1.4[b]	3.0 ± 2.2[ab]	F = 14.79	<0.001
Vegetable intake/day	2.5 ± 1.5[a]	2.9 ± 1.7[b]	3.4 ± 1.9[ab]	F = 19.09	<0.001
Sweets/day	1.0 ± 0.9[a]	1.0 ± 0.9[b]	0.7 ± 0.9[ab]	F = 9.12	<0.001
Selected vitamin D foods/month	9.7 ± 3.0[a]	10.3 ± 3.2[b]	11.2 ± 3.2[ab]	F = 15.12	<0.001
High plant n-3 foods intakes/month	10.2 ± 7.7[a]	11.0 ± 7.3	12.9 ± 7.4[a]	F = 8.52	<0.001
DASS-depression (mean)	5.38 ± 6.70	5.38 ± 5.86	5.38 ± 6.49	F = 0.000	1.000
DASS-anxiety	4.67 ± 5.30[a]	3.89 ± 4.54	3.39 ± 4.20[a]	F = 4.73	0.010
DASS-stress	10.02 ± 8.16[a]	9.27 ± 7.52	7.46 ± 6.26[a]	F = 8.23	<0.001
Total DASS	19.53 ± 16.63[a]	0.94 ± 14.29	15.85 ± 13.67[a]	F = 3.80	0.023

Significant differences are indicated by same letter.

was 39% Midwest, followed by 23% Northeast, 15% West, 10% Southeast, and 5% Southwest. This was an educated sample with almost 82% of the total population and 72% of VG reporting at least 4-year college degrees (Table 1).

Age was inversely correlated with all DASS scores ($P < 0.05$), indicating that as age increased, negative emotion declined. A vegan diet was inversely correlated with DASS-A and DASS-S scores ($P < 0.001$), indicating that being vegan was associated with lower reporting of anxiety and stress symptoms (see Table 2 for correlation coefficients).

In regard to the main outcome measures of mood as assessed by the DASS-21, an ANOVA showed a main effect of diet type on DASS-A scores ($F(2616) = 4.73$, $P = 0.009$, $\eta^2 = 0.015$). *Post-hoc* analyses indicated that anxiety scores were lower for the VG than the OMN group. A main effect of diet type was also observed for DASS-S scores ($F(2, 615) = 8.23$, $P < 0.001$, $\eta^2 = 0.026$) with stress scores again lower for the VG than the OMN group (Fig. 1).

Since gender was related to DASS-S scores ($P < 0.001$), we stratified these results and controlled for age utilizing univariate ANCOVA. There was a significant effect of diet type on DASS-A scores, however, the effect was observed in males only ($F(2128) = 5.39$, $P = 0.006$, $\eta_p^2 = 0.078$). Planned contrasts revealed that VEG males ($P = 0.022$, 95% CI (−0.401, −5.140)) and VG males ($P = 0.002$, 95% CI (−1.03, −4.56)) reported significantly lower anxiety scores than OMN males (VEG: 3.02 ± 0.97 and VG: 3.00 ± 0.54 vs. OMN: 5.79 ± 0.71). The covariate age was significantly related to anxiety scores ($F(2, 128) = 6.51$, $P = 0.012$, $\eta_p^2 = 0.048$). In males, anxiety was correlated with an omnivorous diet ($r = 0.230$, $P = 0.008$), lower daily intakes of fruits and vegetables ($r = -0.216$, $P = 0.013$), BMI

Table 2 Pearson correlation coefficients with DASS-21 scores

	DASS-D	DASS-A	DASS-S	DASS-total
Age	−0.104*	−0.234**	−0.177**	−0.197**
Gender (male/female)	−0.005	0.015	0.140**	0.064
Education	−0.052	−0.006	0.025	−0.006
Married (no/yes)	−0.083*	−0.076	−0.005	−0.056
BMI	0.113**	0.075	−0.008	0.072
Mod exercise X/week	−0.043	−0.013	−0.017	−0.020
Yoga practice (no/yes)	−0.114**	−0.049	−0.015	−0.068
Dieted in last year (no/yes)	−0.065	0.111**	0.107**	0.105*
Cigarette smoker (no/yes)	0.126**	0.115**	0.044	0.121**
Work hours/week	−0.083*	−0.011	0.015	−0.027
Hours outdoors	−0.058	−0.083*	−0.101*	−0.101*
Sleep, hours/night	−0.003	−0.066	−0.042	−0.050
Social support	−0.280**	−0.091*	−0.086*	−0.163**
Vegan diet (no/yes)	0.000	−0.109**	−0.158**	−0.105**
Alcohol/week	0.114**	0.109**	0.097*	0.132**
Fruits and vegetables/day	−0.131**	−0.088*	−0.073	−0.116**
Sweets/day	0.085*	0.106**	0.087*	0.111**
Vitamin D plant foods/month	−0.047	0.081*	−0.002	−0.003
Plant n-3 foods/month	−0.073	−0.043	−0.065	−0.064

*P value < 0.05; ** P value < 0.01.

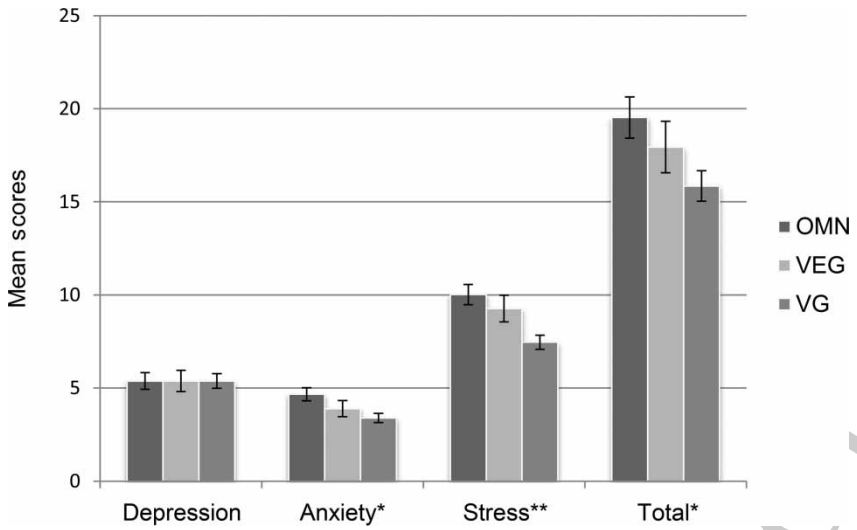

Figure 1 DASS-21 scores by diet group. *Indicates a significant difference at $P < 0.05$; **indicates a significant difference at $P < 0.01$. All significant differences are between OMN and VG groups.

($r = 0.200$, $P = 0.026$), fewer hours outdoors ($r = -0.221$, $P = 0.011$), and younger age ($r = -0.227$, $P = 0.009$). There was also a significant effect of diet type on DASS-S scores, but in females only ($F(2, 476) = 3.82$, $P = 0.023$, $\eta_p^2 = 0.016$). Planned contrasts revealed that VG females ($P = 0.007$, 95% CI (-0.56, -3.51)) reported significantly lower stress than OMN females (VG: 8.19 ± 0.52 vs. OMN: 10.22 ± 0.54). The covariate age was also significantly related to stress scores ($F(2476) = 13.31$, $P < 0.001$, $\eta_p^2 = 0.027$). In females, stress was correlated with an omnivorous diet ($r = 0.145$, $P = 0.001$), daily intake of sweets ($r = 0.102$, $P = 0.025$), dieting ($r = 0.137$, $P = 0.003$), reduced social support ($r = 0.127$, $P = 0.006$), and younger age ($r = 0.181$, $P < 0.001$) (Fig. 1). When we excluded the vegetarian group and compared only the VG and OMN groups, results were similar with only slightly higher effect sizes. No effect of diet type was observed on DASS-D scores.

Previous to this study, we obtained similar data from an onsite pilot survey of 342 adults recruited at a vegan festival (VG, $n = 144$; VEG, $n = 65$; OMN, $n = 133$). Despite the methodological difference of paper vs. online survey delivery, these participants answered the same diet-classifying question about monthly animal food inclusion and also completed the DASS-21. We combined the age, gender, diet type, and DASS data from this pilot survey with the study data in order to conduct a separate additional analysis of the larger data set with respect to comparing mean DASS scores in the three main diet types. Similar results were found, with significant differences in anxiety and stress scores, and VG ($n = 427$) reporting lower scores than OMN ($n = 361$) (DASS-A: 3.24 vs. 4.59, $P < 0.001$; DASS-S: 7.36 vs. 9.60, $P < 0.001$). Since 76% of the combined sample was female and age was inversely correlated with all DASS subscales, we also analyzed results by gender controlling for age. We found a significant difference in mean anxiety scores in both genders, with VG reporting less anxiety than OMN ($P < 0.001$), and a significant difference in mean stress scores only in females, with VG reporting less stress than OMN ($P = 0.001$). This combined analysis confirms our main study results, although anxiety results did not differ by sex.

With regard to diet factors, VG reported consuming more servings of fruit and vegetables per day and major plant sources of vitamin D per month than either VEG or OMN, as well as fewer servings of sweets per day (P values < 0.01). VG also reported consuming more foods high in plant omega-3 than OMN ($P < 0.001$). With regard to demographic and lifestyle factors, VG were older ($P < 0.001$) and spent more time outdoors ($P < 0.01$) than either VEG or OMN. VG also had less education ($P < 0.001$), exercised more ($P < 0.05$), had less social support ($P < 0.001$), and drank less alcohol than OMN ($P < 0.001$).

The percentage of VG using vitamin B12 supplements in our population was about 60%, a higher percentage than the 20–30% that was reported in previous vegan studies;[4,15] we did not assess the intakes of fortified food sources of vitamin B12. About a third of our sample (203/620) reported regularly supplementing vitamin D, 92 (45%) of whom were VG, the highest group, however, there was no significant differences among groups. There were also no differences in DASS-21 scores in VG who used vitamin B12, vitamin D, or multivitamin mineral supplements and those who did not use these supplements.

Discussion

VG in our survey reported less anxiety and stress than OMN. This is the first study, we are aware, which

specifically aimed at investigating VG and self-reported mood. Results support and extend our previous studies[9,10] that found VEG report better mood than non-VEG, suggesting that even less animal food intake is associated with better mood. Results from a combined analysis with data from a pilot survey confirm and strengthen our results.

In addition to studies of mood risk in VEG and VG, other studies have examined the relationship between meat consumption and mental health. In a large cross-national study that investigated the relationship of fish and meat intakes with health and socio-demographic characteristics in older adults, fish consumption was associated with a lower prevalence of dementia and meat consumption was associated with a higher prevalence of dementia.[16] In the Adventist Health Study-2 cohort, increased red meat was associated with higher scores of negative affect.[17] The Boston Puerto Rican Health Study investigated dietary patterns and the physiological effects of chronic stress (allostatic load) and found that increasing quintiles of meat and French fries were associated with increasing the odds of high allostatic load.[18]

As this is a correlational research, there are other possible models that can account for our findings. Stress and anxiety can certainly contribute to consuming a diet with few fruits and vegetables,[19] and persons who cope better with stress and anxiety may be better prepared to take on the challenges of maintaining a plant-based diet. However, there is now a large body of research that has linked depression as well as prolonged psychological stress to activated inflammatory pathways in the brain; inflammation is accompanied by melancholic symptoms or what is termed 'sickness behavior' characteristic in mood disorders.[20] The research investigating how diet impacts mental health has also been accumulating. Dietary factors modulate inflammatory and other brain pathways, thereby affecting mood symptoms as well.[21,22]

A Western dietary pattern with characteristically high intake of meat, refined grains, and processed foods, and low intake of fruits, vegetables, whole grains, and fish is associated with increased blood inflammatory markers.[23] In fact, the lower stress and anxiety reported by VG and some VEG in our sample may be associated in part with their avoidance of animal fats. Since the 1950's, the vast majority of animal products consumed in the USA are from grain-fed animals raised in a feed lot; the fatty acid profile of these animal products are characteristically higher in certain pro-inflammatory long-chain saturated fats that negatively impact brain cell membranes and lower in the anti-inflammatory long-chain omega-3 polyunsaturated fatty acids than what was characteristic of animals raised in a natural setting consuming their evolutionary diet.[24,25] This modern animal fatty acid profile has long been associated with heart disease and more recently with cognitive decline.[26] Specifically, long-chain saturated fatty acids such as palmitic acid and lauric acid can trigger the release of inflammatory cytokines such as TNFα and IL-6 from astrocytes, altering their physiology and contributing to mood disorders.[27]

Lower stress and anxiety reported by VG vs. OMN may also be attributed to healthier dietary patterns. Not surprisingly, VG in our study consumed more fruits and vegetables than both VEG and OMN, and fruit and vegetable intakes were inversely correlated with anxiety in males. Fruits and vegetables supply abundant antioxidant nutrients and phytochemicals, and intake has been associated with lower biomarkers of oxidative stress and inflammation[28] and better mental health.[29] Studies have shown that VEG have higher plasma concentrations of various antioxidants and lower oxidative stress and inflammation than OMN.[30,31] VG in our study also reported consuming fewer daily sweets than OMN, confirming earlier research,[32] and sweets intake was positively correlated with stress in females. Perceived stress has been associated with higher sweets intakes in females;[33] however, it is unclear whether stress precedes food selection or vice versa.[34] In a study of more than 1300 adolescents, those who reported eating a diet characterized by higher intakes of fast foods, red meat and sweets had increased internalizing and externalizing behaviors, while intake of fruits and vegetables showed the opposite association.[35]

The gender differences we observed in our results suggest that there may be a sex difference in the benefits of a totally plant-based diet. Research has revealed gender to be a moderator of mental health outcomes, and expressions of stress and anxiety as well as coping styles are typically slightly different by gender, although it is not known whether differences are cultural or biological.[36,37] Gender differences have been found with respect to physical health outcomes of the vegetarian diet,[2] and are emerging with respect to mental health outcomes. For example, intakes of meat and sweets were positively associated with anxiety in female adults only in the Greek ATTICA study, and a vegetarian dietary pattern was found among the less anxious females.[38] The results of our pilot vegan survey (unpublished data) found only vegan females were less depressed than female OMN, and a mostly female sample in our randomized controlled trial was found to have improved mood with reductions of meat, fish, and poultry.[10]

This study provides the information about intake of selected sources of vitamin D, such as fortified milk substitutes and hours spent outdoors in VG, VEG, and OMN. As mentioned earlier, the vegan diet may raise the risk of vitamin D inadequacy.[39] In the

EPIC Oxford study, those who ate meat had the highest plasma vitamin D levels, and VG had the lowest levels.[40] VG in our study spent the most time outdoors enabling endogenous production of vitamin D via skin exposure to ultraviolet light, the most important source of vitamin D. They also reported the highest intakes of selected vitamin D foods (soy milk and other fortified milk substitutes, button mushrooms), and intakes were inversely related to anxiety in males. Weak but significant inverse correlations were found in the whole population between intakes of foods high in vitamin D and anxiety, and between hours outdoors and anxiety and stress.

In terms of demographic and lifestyle characteristics, study results largely confirmed what was already known about VG but also added to their profile. Our VG were older than the other VEG and OMN by several years. This was an educated sample overall, but VG had less education than other groups and also had less social support than OMN. However, along with their dietary choices, other vegan lifestyle choices were healthier than OMN, as they exercised more, drank less alcohol, and spent more time outdoors weekly. These results are similar to those of the Adventist Health Study-2 which evaluated the association of dietary patterns with reduced mortality and found that VG were older, more highly educated but had lower personal income, drank less alcohol, smoked less, exercised more, and had lower BMI than non-VEG.[41] VG typically have lower mean BMI than other diet groups,[42] however, we did not find a significant difference in BMI between our three diet groups. Approximately 61% of the VG were classified as having normal weight (mean BMI of 24.1), and only about 5% were underweight. The German Vegan Study reported 25% of VG to be underweight,[4] and Clarys *et al.*[3] reported approximately 9% of VG were underweight.

Strengths and limitations

The major strength of our study was a focused online recruitment of VG which enabled us to capture a large, international vegan sample. However, because our survey link was found on social websites geared to VG and VEG, all participants, including OMN, were more likely to be diet- and health-conscious. While this may adversely affect the generalizability of our results to the general population, it underscores the significance of finding differences between VG and OMN.

Along with the inherent limitation of self-reported data, we were not able to inquire about all foods in the food frequency questions in order to accommodate a range of questions and to consider respondent burden, however, we included those foods which we felt had the most likely impact on mood and asked about their average intake per day which is likely more typical and preferable to a long recall period. We also provided a more specific definition of these general food types in order to provide clarity for responders and to avoid under- or over-estimation of the frequency of food consumption. For the analyses examining differences in eating patterns among diet groups, admittedly, there may be co-linearity between the independent variable of diet type and the dependent food intake variables of fruits and vegetables, sweets, omega-3, and vitamin D, however, we felt it was important to conduct these analyses in order to further delineate how these diet groups differ from one another beyond the basic differences that define them.

Another possible limitation we acknowledge is whether vegan and vegetarian respondents may have answered the DASS-21 questions in a manner calculated to make themselves appear more psychologically healthy in an effort to enhance the attractiveness of their diets, or whether OMN may have experienced guilt over consuming animal products which was reflected in their responses. Several considerations make it unlikely that either of these effects were at play. First, participants were initially told that the study was investigating food choices, health, and wellness, and were not informed of study hypotheses regarding the association between mood and diet patterns. Second, the DASS-21 was intentionally administered immediately after demographic questions and before diet questions were presented, so participants had rated their moods before becoming aware that their diet was a key focus. Third, we did not find significant effects for the depression variable, which we would expect to obtain if either of these biases were substantive. Moreover, the significant effects we found were mediated by gender, which further supports the idea that participant responses were not skewed.

Conclusion

The mood of individuals eating a plant-based diet, without intake of animal-derived nutrient forms known to be essential for mental health, does not appear to be adversely affected, and may be better than the mood experienced by similar individuals eating an animal-based diet. Considering our previous research, we have found that increasing restriction of animal foods (e.g. going from vegetarian to vegan) is associated with improved mood. The mood domain that improves, however, is not consistent across studies (e.g. depression in unpublished work, stress/anxiety here), but this may be due to methodological differences such as study design (survey vs. trial), population (e.g. Adventists vs. college community), survey format (online vs. paper), and geographic

differences (regional vs. international). Striving to eat a more plant-based diet with lower intake of animal fats may be linked to better mental health. Moderator variables such as gender, age, and lifestyle factors should also be considered as they may also affect mood through direct or interactive pathways. These data are relevant not only for the relatively small vegan population, but also for non-vegetarian individuals who are susceptible to or living with mood problems. Currently, dietary changes are not considered a front-line treatment for mood disorders; however, our findings suggest that further studies investigating the efficacy of a plant-based diet for reducing anxiety and stress may be warranted.

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Ethics approval This survey study was categorized as exempt and was approved by the Institutional Review Boards of Benedictine University and Fairleigh Dickinson University.

References

1 Mishra S, Xu J, Agarwal U, Gonzales J, Levin S, Barnard ND. A multicenter randomized controlled trial of a plant-based nutrition program to reduce body weight and cardiovascular risk in the corporate setting: the GEICO study. Eur J Clin Nutr 2013; 67(7):718–24.
2 Le LT, Sabate J. Beyond meatless, the health effects of vegan diets: findings from the Adventist cohorts. Nutrients 2014;6(6): 2131–47.
3 Clarys P, Deliens T, Huybrechts I, Deriemaeker P, Vanaelst B, De Keyzer W, *et al.* Comparison of nutritional quality of the vegan, vegetarian, semi-vegetarian, pesco-vegetarian and omnivorous diet. Nutrients 2014;6(3):1318–32.
4 Waldmann A, Koschizke JW, Leitzmann C, Hahn A. Dietary intakes and lifestyle factors of a vegan population in Germany: results from the German Vegan Study. Eur J Clin Nutr 2003; 57(8):947–55.
5 Katcher HI, Ferdowsian HR, Hoover VJ, Cohen JL, Barnard ND. A worksite vegan nutrition program is well-accepted and improves health-related quality of life and work productivity. Ann Nutr Metab 2010;56(4):245–52.
6 McEvoy CT, Temple N, Woodside JV. Vegetarian diets, low-meat diets and health: a review. Public Health Nutr 2012; 15(12):2287–94.
7 Craig WJ, Mangels AR, American Dietetic Association. Position of the American Dietetic Association: vegetarian diets. J Am Diet Assoc 2009;109(7):1266–82.
8 Michalak J, Zhang XC, Jacobi F. Vegetarian diet and mental disorders: results from a representative community survey. Int J Behav Nutr Phys Act 2012;9:67.
9 Beezhold BL, Johnston CS, Daigle DR. Vegetarian diets are associated with healthy mood states: a cross-sectional study in seventh day adventist adults. Nutr J 2010;9:26.
10 Beezhold BL, Johnston CS. Restriction of meat, fish, and poultry in omnivores improves mood: a pilot randomized controlled trial. Nutr J 2012;11:9.
11 Godin G, Shephard RJ. A simple method to assess exercise behavior in the community. Can J Appl Sport Sci 1985;10(3): 141–6.
12 Bruwer B, Emsley R, Kidd M, Lochner C, Seedat S. Psychometric properties of the Multidimensional Scale of Perceived Social Support in youth. Compr Psychiatry 2008; 49(2):195–201.
13 Henry JD, Crawford JR. The short-form version of the Depression Anxiety Stress Scales (DASS-21): construct validity and normative data in a large non-clinical sample. Br J Clin Psychol 2005;44(Pt 2):227–39.
14 Sinclair SJ, Siefert CJ, Slavin-Mulford JM, Stein MB, Renna M, Blais MA. Psychometric evaluation and normative data for the depression, anxiety, and stress scales-21 (DASS-21) in a nonclinical sample of U.S. adults. Eval Health Prof 2012;35(3):259–79.
15 Lightowler HJ, Davies GJ. Micronutrient intakes in a group of UK vegans and the contribution of self-selected dietary supplements. J R Soc Promot Health 2000;120(2):117–24.
16 Albanese E, Dangour AD, Uauy R, Acosta D, Guerra M, Guerra SS, *et al.* Dietary fish and meat intake and dementia in Latin America, China, and India: a 10/66 Dementia Research Group population-based study. Am J Clin Nutr 2009;90(2): 392–400.
17 Ford PA, Jaceldo-Siegl K, Lee JW, Youngberg W, Tonstad S. Intake of Mediterranean foods associated with positive affect and low negative affect. J Psychosom Res 2013;74(2):142–8.
18 Mattei J, Noel SE, Tucker KL. A meat, processed meat, and French fries dietary pattern is associated with high allostatic load in Puerto Rican older adults. J Am Diet Assoc 2011; 111(10):1498–506.
19 Walsh JL, Senn TE, Carey MP. Longitudinal associations between health behaviors and mental health in low-income adults. Transl Behav Med 2013;3(1):104–13.
20 Slavich GM, Irwin MR. From stress to inflammation and major depressive disorder: a social signal transduction theory of depression. Psychol Bull 2014;140(3):774–815.
21 Kiecolt-Glaser JK, Belury MA, Porter K, Beversdorf DQ, Lemeshow S, Glaser R. Depressive symptoms, omega-6: omega-3 fatty acids, and inflammation in older adults. Psychosom Med 2007;69(3):217–24.
22 Brody S, Preut R, Schommer K, Schurmeyer TH. A randomized controlled trial of high dose ascorbic acid for reduction of blood pressure, cortisol, and subjective responses to psychological stress. Psychopharmacology (Berl) 2002;159(3):319–24.
23 Lopez-Garcia E, Schulze MB, Fung TT, Meigs JB, Rifai N, Manson JE, *et al.* Major dietary patterns are related to plasma concentrations of markers of inflammation and endothelial dysfunction. Am J Clin Nutr 2004;80(4):1029–35.
24 Cordain L, Eaton SB, Miller JB, Mann N, Hill K. The paradoxical nature of hunter-gatherer diets: meat-based, yet non-atherogenic. Eur J Clin Nutr 2002;56(Suppl 1):S42–52.
25 Daley CA, Abbott A, Doyle PS, Nader GA, Larson S. A review of fatty acid profiles and antioxidant content in grass-fed and grain-fed beef. Nutr J 2010;9:10.
26 Okereke OI, Rosner BA, Kim DH, Kang JH, Cook NR, Manson JE, *et al.* Dietary fat types and 4-year cognitive change in community-dwelling older women. Ann Neurol 2012;72(1):124–34.
27 McNamara RK, Lotrich FE. Elevated immune-inflammatory signaling in mood disorders: a new therapeutic target? Expert Rev Neurother 2012;12(9):1143–61.
28 Hermsdorff HH, Zulet MA, Puchau B, Martinez JA. Fruit and vegetable consumption and proinflammatory gene expression

from peripheral blood mononuclear cells in young adults: a translational study. Nutr Metab (Lond) 2010;7:42.
29 Milaneschi Y, Bandinelli S, Penninx BW, Corsi AM, Lauretani F, Vazzana R, *et al.* The relationship between plasma carotenoids and depressive symptoms in older persons. World J Biol Psychiatry 2012;13(8):588–98.
30 Szeto YT, Kwok TC, Benzie IF. Effects of a long-term vegetarian diet on biomarkers of antioxidant status and cardiovascular disease risk. Nutrition 2004;20(10):863–6.
31 Paalani M, Lee JW, Haddad E, Tonstad S. Determinants of inflammatory markers in a bi-ethnic population. Ethn Dis 2011;21(2):142–9.
32 Larsson CL, Johansson GK. Young Swedish vegans have different sources of nutrients than young omnivores. J Am Diet Assoc 2005;105(9):1438–41.
33 Laugero KD, Falcon LM, Tucker KL. Relationship between perceived stress and dietary and activity patterns in older adults participating in the Boston Puerto Rican Health Study. Appetite 2011;56(1):194–204.
34 Zellner DA, Loaiza S, Gonzalez Z, Pita J, Morales J, Pecora D, *et al.* Food selection changes under stress. Physiol Behav 2006; 87(4):789–93.
35 Oddy WH, Robinson M, Ambrosini GL, O'Sullivan TA, de Klerk NH, Beilin LJ, *et al.* The association between dietary patterns and mental health in early adolescence. Prev Med 2009; 49(1):39–44.
36 Davis MC, Matthews KA, Twamley EW. Is life more difficult on Mars or Venus? A meta-analytic review of sex differences in major and minor life events. Ann Behav Med 1999;21(1): 83–97.
37 Hanson RF, Borntrager C, Self-Brown S, Kilpatrick DG, Saunders BE, Resnick HS, *et al.* Relations among gender, violence exposure, and mental health: the national survey of adolescents. Am J Orthopsychiatry 2008;78(3):313–21.
38 Yannakoulia M, Panagiotakos DB, Pitsavos C, Tsetsekou E, Fappa E, Papageorgiou C, *et al.* Eating habits in relations to anxiety symptoms among apparently healthy adults. A pattern analysis from the ATTICA study. Appetite 2008;51(3):519–25.
39 Dunn-Emke SR, Weidner G, Pettengill EB, Marlin RO, Chi C, Ornish DM. Nutrient adequacy of a very low-fat vegan diet. J Am Diet Assoc 2005;105(9):1442–6.
40 Crowe FL, Steur M, Allen NE, Appleby PN, Travis RC, Key TJ. Plasma concentrations of 25-hydroxyvitamin D in meat eaters, fish eaters, vegetarians and vegans: results from the EPIC-Oxford study. Public Health Nutr 2011;14(2):340–6.
41 Orlich MJ, Singh PN, Sabate J, Jaceldo-Siegl K, Fan J, Knutsen S, *et al.* Vegetarian dietary patterns and mortality in Adventist Health Study 2. JAMA Intern Med 2013;173(13):1230–8.
42 Spencer EA, Appleby PN, Davey GK, Key TJ. Diet and body mass index in 38000 EPIC-Oxford meat-eaters, fish-eaters, vegetarians and vegans. Int J Obes Relat Metab Disord 2003; 27(6):728–34.