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Trans fatty acid intake is related to emotional affect in the Adventist Health Study-2

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Abstract

Trans fatty acids in Western diets increase health risks, and have been associated with the risk of depression. We hypothesized that intakes of *trans* fatty acids (primarily from margarines and baked goods) were inversely associated with positive affect and positively associated with negative affect in a longitudinal study. Church attendees residing in North America completed a food frequency questionnaire in 2002–6 as part of the Adventist Health Study-2. A subset in which we excluded participants with established cardiovascular disease ($n = 8,771$) completed the Positive and Negative Affect Schedule (PANAS) in 2006–7. The associations between dietary intakes of fatty acids to positive and negative affect were tested with linear regression analysis controlling for age, gender, ethnicity, education, body mass index, exercise, sleep, sleep squared, Mediterranean diet, total energy intake and alcohol. Intakes of *trans* fatty acids were inversely associated with positive affect ($\beta = -0.06$, $B = -0.27$ [95% CI -0.37 , -0.17], $p < .001$) and positively associated with negative affect ($\beta = 0.05$, $B = 0.21$ [95% CI 0.11 , 0.31], $p < .001$). In comparison, we found no association between n-3 polyunsaturated fatty acids (PUFA) intakes with affect. The n-6:n-3 PUFA ratio was inversely associated with positive affect ($\beta = -0.03$, $B = -0.34$ [95% CI -0.58 , -0.10], $p = 0.006$). The findings suggest that a lower dietary *trans* fatty acid intake has beneficial effects on emotional affect while the n-6: n-3 ratio is detrimental to positive affect.

Keywords

Diet; Fatty acids; Longitudinal studies; Mental health; Mood; *Trans* fatty acids

1. Introduction

Dietary fats are found in three forms: (a) saturated, (b) monounsaturated, (c) polyunsaturated including the essential fatty acids and two major n-3 dietary fatty acids from marine sources,

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eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). In the last 50 years, American diets have replaced n-3 polyunsaturated fatty acids from marine and plant sources with n-6 polyunsaturated fatty acids (PUFA) found in common vegetable oils, desserts, dressings, meats, and chips [1].

Currently, in Western diets, the ratio of n-6:n-3 PUFA ranges from approximately 20–30:1 instead of the ratio of 1–2:1 observed in people eating more traditional and less processed diets [2]. An increased amount of n-6 PUFA may lead to cardiovascular and mental health problems [2,3]. In addition, biological pathways supporting the relationship between fatty acid metabolism and mental health have been identified. The two long-chain n-3 PUFA, EPA and DHA, decrease the production of the inflammatory eicosanoids derived from n-6 PUFA, including arachidonic acid, by competing with or inhibiting pro-inflammatory cytokines [1]. Individuals with mental disorders show an increase in inflammatory eicosanoids derived from arachidonic acid metabolism [4,5]. Treatment with n-3 PUFA may play a role in the treatment of depressive disorders [6]. Recently evidence from a Mendelian randomization study weakly supported the association between EPA and perinatal onset depression giving further credence to the notion of causality [7]. Diets with higher n-6: n-3 PUFA ratios have been observed to enhance the risk for depression [8,9]. Recently among US adults, a higher n-3:n-6 ratio was associated with longitudinal slower increases in depressive symptoms [10].

Trans fatty acids are a type of unsaturated fatty acids formed by the hydrogenation of vegetable oils and found mainly in industrial products [11]. In 2006, the Federal Drug Administration (FDA) required that food labels list *trans* fats, and in 2013 the FDA determined that partially hydrogenated oils are not generally recognized as safe for use in food. In June 2015, food companies were advised to eliminate the *trans* fat in food products within the next three years. From 1991 to 2008 *trans* fat was the only type of dietary fat to decrease in the Framingham study population [12] while *trans* fat intake among American consumers in general declined from 4.6 grams per day in 2003 to about 1 gram per day in 2012. These changes have been based on growing evidence that *trans* fatty acids adversely affect cardiovascular health [13] and increase serum cholesterol levels [14]. Experimental evidence has demonstrated that intakes of *trans* fatty acids are pro-inflammatory [15]. Pro-inflammatory eicosanoids and downstream cytokines can adversely influence mental health [16,17]. A longitudinal study in Spain found a detrimental relationship between *trans* fatty acid intake and depression risk [18]. Furthermore, the Whitehall II Study found that *trans* fat intake was associated with recurrent depressive symptoms in women [19].

The concept of subjective well-being is used to describe a domain of mental health beyond the absence of symptoms of depression and distress to also include the presence of happiness and life satisfaction [20]. Negative affective states, such as depression, anxiety and psychological distress have long been associated with disease [21]. Studies have associated positive well-being with reduced mortality [21]. Prudent dietary patterns are associated with a lower likelihood of negative mood states [4,22–25]. In contrast, Western dietary patterns associate with negative mood states [26–28]. The relation between *trans* fatty acid consumption and affective state has not been much studied. This relation is of interest given the potential role of diets in targeting fatty acids in the brain [29].

Given the findings from observational studies associating *trans* fatty acids with depression [18,19], we hypothesized that intakes of *trans* fatty acids (primarily from margarines and baked goods) were inversely associated with positive affect and positively associated with negative affect in an analysis of a largely healthy cohort of Seventh-day Adventists followed longitudinally. This population spanned a wide range of geographical locations, educational levels, has limited alcohol intake, and includes both genders [30]. Most importantly, this almost exclusively non-smoking population followed a range of dietary patterns from vegan to non-vegetarian. Our research objectives were to examine 1) the relation of *trans* fatty acids intakes longitudinally to positive affect and 2) the relation of *trans* fatty acids longitudinally to negative affect. We also studied associations of n-3 PUFA intakes and the n-6:n-3 PUFA ratio to affect. We hypothesized that these nutrients would be associated with affect.

2. Methods and materials

2.1. Setting and study population

Two sets of archival data were examined using an observational longitudinal study design. The predictor (dietary) variables were assessed in 2002–6 among participants in the Adventist Health Study-2 (AHS-2) cohort. In brief, the AHS-2 cohort [30] included approximately 96,000 subjects who were over 30 years of age who filled out a 50 page mailed questionnaire regarding their medical histories, lifestyle and dietary intakes. Between 2006–7, the outcome variable (affect) was assessed from the sub-study of AHS-2, the Biopsychosocial Religion and Health Study which included the Psychosocial Manifestations of Religion Sub-Study (PsyMRS) questionnaire [31]. The PsyMRS aimed to study connections between religion and health and randomly sampled approximately 21,000 AHS-2 participants of which 10,988 responded to the 20-page PsyMRS questionnaire. The PsyMRS questionnaire included questions on religion, spirituality and mental health. Recruitment methodologies of subjects in both studies are described in previous literature [30,31].

All respondents that completed both AHS-2 and PsyMRS surveys were eligible for analyses (N = 10,988). Because of low numbers in these subgroups, subjects less than 35 years of age (N = 132), ethnicities other than Black or White (N = 700), nonSeventh Day Adventists (N = 363), current smokers (N = 87), subjects with body mass index (BMI) <15 kg/m² (N = 43), subjects with an estimated energy intake <500 kcal/day or >4,500 kcal/day or incomplete dietary data (N = 585), error in questionnaire dates (N = 5), and subjects with established cardiovascular disease, including heart attack, stroke, transient ischemic attack or heart failure (N = 302) were excluded, leaving 8,771 participants. The Institutional Review Board of Loma Linda University approved both the AHS-2 and PsyMRS studies.

2.2. Dietary assessments

Dietary intake was assessed by a self-administered food frequency questionnaire (FFQ), which contains a list of over 200 food items including fruits, vegetables, legumes, grains, oils, dairy, fish, eggs and beverages, and commercially prepared products such as dietary supplements, dry cereals, meat substitutes, and soy milk. This FFQ was designed to

specifically assess dietary intake among a population where a large proportion is vegetarian. Respondents were asked about their intake of foods and supplements during the past year. Frequency categories range from *never or rarely*, *1–3 times per month*, *X times per week* (where X was 1, 2 to 4, or 5 to 6) or *Y time per day* (where Y was 1, 2 to 3, or 4+). Portion sizes include standard (amount was dependent upon food item), *½ or less* or *1½ or more*. The FFQ was previously validated against six 24-hour dietary recalls for intake of nutrients and selected foods/food groups [32]. The de-attenuated validity correlations in Whites for total n-3, the n-6 PUFA, 18:2n-6 & 20:4n-6, and *trans* fatty acids were 0.53, 0.71, 0.77, and 0.51, respectively. In Blacks, these were 0.43, 0.50, 0.67, and 0.51, respectively [33]. Dietary supplements were included in the total n-3 intakes. Of the total 10.1% took fish oil supplements. Each nutrient was regressed upon energy (kilocalorie) intake, allowing for control of energy intake for each participant with the residual method [34]. A Mediterranean diet score was calculated following the methods similar to that of Trichopoulou et al. [35]. The FFQ included nine dietary constituents, which are either characteristic or not characteristic of a Mediterranean diet and these were used to create a Mediterranean diet score, as described in a previous publication [36].

The most common foods contributing to *trans* fatty acid were solid fats, specifically margarine. The top 31 foods in the AHS-2 FFQ contributing to the *trans* fatty acid nutrient data are found in Table 1.

Nutrient intake was calculated using the product-sum method [34]. Thus, $I = \sum (F \times A \times S)$ where I = intake, F = weighted frequency, A = amount of nutrient consumed and S = standard weight of a standard serving size in grams. Missing values for amount of foods were coded as the standard serving size only if frequency was marked and amount was missing. If frequency was missing and amount of diet variable was missing, this diet variable was coded as zero. If frequency was missing and amount was marked, the diet variable was still coded as zero. Nutrient composition data were based on the NDS-R 2008 database (The Nutrition Coordinating Center), information from manufacturers, and the Caribbean Food and Nutrition Institute.

2.3. Assessment of affect

Positive and negative affect were measured by a short form of the Positive and Negative Affect Schedule (PANAS) [37]. PANAS has been validated in a cross-sectional and correlational analysis [38]. This 10-item scale includes five items on positive emotion: inspired, alert, excited, enthusiastic, and determined and five items on negative emotion: afraid, upset, nervous, scared and distressed. The items are assessed on a 5-point rating scale ranging from *very slightly or not at all* to *extremely*, based on the statement “This set of questions consists of a number of words and phrases that describe different feelings and emotions. Mark a bubble to show to what extent you have felt this way during the past year.” High internal reliability was indicated by Cronbach’s α which were 0.85 and 0.87 for positive and negative affect, respectively.

2.4. Control variables

Control variables were chosen *a priori* based on expected confounders of relations between diet and affect. These included age, gender, ethnicity, age, BMI, education level, frequency of vigorous exercise, alcohol intake, sleep, sleep squared, Mediterranean diet pattern, total energy intake and time between two questionnaires. Ethnicity was self-defined. BMI was calculated from current height and weight. Education level was represented by highest level attained: grade school, some high school, high school diploma, trade school diploma, some college, Associate degree, Bachelor's degree, Master's degree, or Doctoral degree. Frequency of vigorous exercise was assessed by the question "How many times per week do you usually engage in regular vigorous activities, such as brisk walking, jogging, bicycling, etc., long enough or with enough intensity to work up a sweat, get your heart thumping or get out of breath?" This questionnaire has been shown to be validated and reliable in Adventist Whites and Blacks [39,40]. Alcohol use was queried by asking participants "Have you ever used alcoholic beverages even if only occasionally?" If they responded "yes" they were asked the age started and the age stopped. For the latter they could check a box that said "I still drink alcoholic beverages." A checkmark to that box was used to indicate current alcohol drinking. However, because use of alcohol is strongly discouraged by the Adventist church, a certain amount of misclassification bias is possible. Participants categorized the number of hours of sleep at night as <6, 7–8 and 9. Because low and high amounts of sleep may be associated with poor health [41], a quadratic relationship was investigated between sleep and affect and found to exist so sleep squared was included as a control. Time between the two questionnaires was calculated as the return date of the PsyMRS questionnaire minus the return date of the AHS-2 questionnaire in years.

2.5. Statistical analyses

Missing values constituted less than 3% of the cases for all variables. Thus, missing value for all control variables were coded as the mean of the values for each variable.

Descriptive statistics were reported for all measures and data for continuous variables are reported as mean, median, minimum, maximum and SD values. Pearson's coefficients were calculated for correlations.

After controlling for age, gender, ethnicity, BMI, educational level, frequency of vigorous activity, alcohol intake, sleep, sleep squared, Mediterranean dietary pattern, total energy intake, and time between two questionnaires, positive and negative affect were regressed for each of the fatty acid intake variables and the n-6:n-3 PUFA ratio. Finally regressions with positive affect as the dependent variable were controlled for negative affect, and regressions with negative affect as the dependent variable were controlled for positive affect in addition to other control variables. We tested interactions for all 12 control variables with each of the nutrient outcomes (*trans* fatty acids, n-3 and n-6 PUFA and the n-6:n-3 ratio). With a total of 48 interactions, the Bonferroni-adjusted cut-off for statistical significance was $0.05/48 = 0.001$. None of the interactions were statistically significant at this level. We tested possible nonlinear associations, however, these associations were not statistically significant.

Because of the multiplicity of statistical tests (positive and negative affect, and three fatty acid intake variables and one ratio variable equating to 8 statistical hypotheses), a Bonferroni adjustment of the cut-off P-value for statistical significance was determined at $p < 0.006$. All data were analyzed using SPSS Version 20.0.

3. Results

The final population sample for this study consisted of 8,771 subjects who completed the AHS-2 and the PsyMRS. Characteristics of the study population are presented in Table 2. The median age was 61 years, and two-thirds of the sample was female. The mean interval elapsing between the baseline AHS-2 and the PsyMRS questionnaire was approximately 3 years. Scores for positive affect were higher than for negative affect.

Positive and negative affect were inversely but not strongly associated ($r = -.25$; $p < 0.01$). The proportion of energy from *trans* fatty acids to total energy was a median of 1.5% (range, 0–15%).

3.1. Regression of affect on fatty acid intakes

Intakes of *trans* fatty acids were inversely associated with positive affect and positively associated with negative affect (Tables 3 & 4). In comparison, we found no association between intakes of n-3 or n-6 PUFA with affect. The n-6:n-3 PUFA ratio was inversely associated with positive affect. Among control variables, younger age, Black ethnicity, lower BMI, higher education, more vigorous activity and hours of sleep, higher total dietary energy, and higher Mediterranean dietary score were associated with positive affect. Male gender was associated with less negative affect. Younger age, White ethnicity, lower education, less vigorous activity and hours of sleep, higher total dietary energy and lower Mediterranean dietary score were furthermore associated with negative affect.

Control for negative affect did not substantially change the inverse association between *trans* fatty acid intakes and positive affect ($\beta = -0.05$, $B = -0.22$ [95% CI $-0.31, -0.12$], $p < 0.001$); likewise, control for positive affect did not substantially change the association between *trans* fatty acid intakes and negative affect ($\beta = 0.03$, $B = 0.14$ [95% CI $.04, .24$], $p = 0.005$).

4. Discussion

The overall results show that intakes of *trans* fatty acids were associated with negative affect and inversely associated with positive affect. Positive and negative affect reflect different aspects of emotional state, and generally have a somewhat weak negative correlation with each other [42] as also observed in the current study. These results indicate that diets characterized by high intakes of *trans* fatty acid containing margarine, baked goods, popcorn, other snacks and processed foods may determine each of these independent affective states.

To our knowledge, this is the first study that associated *trans* fatty acids intakes with affect. Some of the most important confounders were considered in this analysis in regards to the

relationship between diet and mood including BMI, total energy intakes, dietary pattern, sleep, alcohol intake, and vigorous physical activity. Several of these variables showed expected associations with affect. Notably longer sleep, higher vigorous activity and a higher Mediterranean score were associated positively with positive affect and inversely with negative affect underscoring the relation between lifestyle and affect. As the population consisted of church-goers, who are strongly discouraged from using tobacco, smokers were few, and excluded, thus isolating the relationship between food and affect from smoking. Further strengths of this study include the representation of major ethnic groups, the use of a validated food frequency questionnaire covering most aspects of the diet, and the prospective time course. The validity of the present findings are strengthened by our observations that positive affect was associated with lower intakes of *trans* fatty acids and low positive affect associated with greater intakes of *trans* fatty acids and each of these associations was independent of the opposite affect.

Hibbeln and Salem postulated nearly two decades ago that the sharp rises in the rate of depression in the 20th century may be associated with the increased consumption of vegetable oils and decreased consumption of n-3 fats [43], but the potential role of *trans* fatty acids was not evident at that time. Epidemiological and clinical evidence indicates that Western dietary patterns are associated with negative mental health states including depression and anxiety [4,44] though a systematic review found conflicting levels of evidence for associations between the Western diet and depression [45]. Furthermore, the Mediterranean and other healthy dietary patterns appear to be associated lower risk of depression [3,19]. Our results extend these observations, suggesting that one of the culprits in Western diets may be *trans* fatty acid intakes in regard to both positive and negative affective state. In addition to evidence linking *trans* fatty acids to depression [18], some data suggest an association between *trans* fatty acids and behavioral irritability and aggression [46]. The potential role of *trans* fatty acids appears to be independent of the source of the fat. Our study population consumed *trans* fatty acid intakes largely from sources that contain hydrogenated vegetable oils, typical of Western diets. In contrast, Sánchez-Villegas et al found that among Spanish subjects natural foods including cheese and whole-fat milk accounted for most of the variability in total *trans* fatty acid intakes [18].

Putative mechanisms for a deleterious effect of *trans* fatty acids on cardiovascular disease have been studied extensively and to a large extent are attributed to pro-inflammatory effects of *trans* fatty acids [11]. Likewise, increased inflammation may explain the association of *trans* fatty acids with mental health as inflammation is associated with both diet and depression [47]. A subgroup of depression characterized by high C-reactive protein levels was recently shown to respond to anti-inflammatory treatment [48]. Diet may influence inflammatory processes [13,49] through the modulation of sympathetic activity, oxidative stress, and pro-inflammatory cytokine production [50,51]. Several researchers have also implicated inflammatory processes and markers in the pathophysiology of depression and other mental health conditions [9,47,52,53]. *Trans* fatty acids are associated with pro-inflammatory effects [13,15]. In the Nurse's Health Study *trans* fatty acid intakes were associated with higher inflammatory markers [54]. Diets containing no *trans* fatty acids have been associated with lower oxidative stress and markers of inflammatory processes [50].

Our study did not identify associations between absolute intakes of n-3 and n-6 PUFA and affect in the total population. Diets with low intakes of n-3 PUFA have been associated with increased rates of mental illness including depressive disorders. A prospective analysis from the Nurse's Health study found that women who reported higher intakes of n-3 PUFA and lower intakes of n-6 PUFA experienced a reduced risk of depression [55]. However, other observational studies [56], cross-sectional evidence [57] and clinical trials [58,59] exist that in contrast suggest no benefits in negative moods from n-3 PUFA intakes. In meta-analysis n-3 PUFA are associated with mental affective states only in individuals with mental disorders [60] though a more recent meta-analysis found an adjuvant effect of n-3 PUFA supplementation in treatment of depression [6]. One explanation for the lack of an association in the current study may be that more than one-half of the population followed vegan or lacto-ovo vegetarian diets, and results in this population may not be comparable to results obtained in populations following usual Western patterns of eating. Furthermore, intakes of n-3 were low in this population [61].

Notably, the n-6:n-3 PUFA ratio was detrimentally associated with positive affect, but did not predict negative affect, a finding that requires further research. Sparse evidence links diet to positive affect [22,23] and evidence regarding the relationship between fatty acid intakes and positive affect is lacking [62]. McMillan et al restricted foods like red meat, refined sugars, and pre-packaged and processed foods while increasing subjects' intakes of fruit, vegetables, fatty fish, nuts and seeds, low-fat dairy, and wholegrain cereals and found improvements in mental health domains [23].

Because diet was assessed a mean of 3 years prior to assessment of affect the results may indicate the influence of diet on affect. However, reverse causality remains a possibility, as subjects may have changed diets prior to dietary assessment due to underlying disease. We attempted to reduce this possibility by excluding subjects with established cardiovascular disease, who may be likely to change their diet after a diagnosis. The number of other exclusions, done for *a priori* reasons, limits the external validity of the study. We were unable to control for mental disorder, affect or mood state at baseline, as none of these variables were measured then. These analyses are hypothesis generating, therefore, more research is required to understand and examine a cause and effect relationship. Dietary intakes tend to be correlated with each other. As an example, lower intakes of *trans* fatty acids are correlated with higher intakes of fruit and vegetables [63]. Thus, it remains possible that the association between *trans* fatty acid intakes and affect was confounded by other foods associated with *trans* fatty acids or by eating behavior, which was not assessed in this study. Whether the foods that contained large amounts of *trans* fatty acids, or *trans* fatty acids per se associated with affect in the current study cannot be entirely disentangled.

Previous research supports the utility of the PANAS in large-scale normative data and the presence of internal consistency within the PANAS has been shown in the general adult population as well as adequate reliability [38]. However, critiques of PANAS suggest inconsistencies due to recall bias, influence of current mood states, the variables of affective states in everyday lives, and focusing illusions [64,65]. We did not have information to test the gold standard validity of the questionnaire in this population.

Our findings led to acceptance of the research hypotheses of the study. Higher intakes of *trans* fatty acids had detrimental effects on affect, independent of overall Mediterranean dietary pattern. The findings have implications for mental health, given that hydrogenated vegetable oils (a source of *trans* fatty acids) remain present in the current food supply in the United States and other parts of the world. The results from this study add to the harmful effects of trans fatty acids already established.

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Abbreviations:

AHS-2	Adventist Health Study-2
DHA	docosahexaenoic acid
EPA	eicosapentaenoic acid
FDA	Federal Drug Administration
PANAS	Positive and Negative Affect Schedule
PsyMRS	Psychosocial Manifestations of Religion Sub-Study
PUFA	Polyunsaturated Fatty Acids

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Table 1-

Top contributors of trans fatty acid intakes in the AHS-2 Food Frequency Questionnaire

Items	grams
Margarine, regular, stick	3.66
Margarine, Imperial	3.66
Margarine, I Can't Believe It's Not Butter	3.04
Margarine, Fleischmann's	2.55
Doughnuts, cinnamon rolls, pastries, sweet pies	2.53
Popcorn, microwaved popped	2.34
Margarine, regular, tub	2.05
Margarine, spread, reduced calorie	1.64
Margarine, Shedd's Spread Country Crock	1.32
French fries, hash browns, fried potatoes	1.20
Cookies, homemade	1.13
Corn bread, Johnnycake	1.12
Cereal, 100% Natural Granola-Oats & Honey	1.08
Cookies, store-bought	0.94
Butter, regular	0.68
Hamburger/ground beef, 25% fat (regular)	0.59
Whole grain bread, rolls, buns, or oatmeal bread	0.57
Beef or lamb as main dish	0.51
Eggs 1	0.50
White bread, rolls, buns or French bread	0.42
Cake	0.30
Processed beef, lamb	0.26
Ice cream, milk shakes	0.26
American processed, cheddar cheese	0.22
Milk (whole or 2%)	0.22
Canned tuna, tuna salad, tuna casserole	0.20
Chicken or turkey	0.19
Whipped or sour cream	0.17
Cream cheese, cheese spreads	0.16
Cottage cheese, regular or creamed (4% fat)	0.14

Table 2-

Descriptive characteristics of sample at baseline

		Percentage	N		
Gender					
Female		67.6%	5929		
Male		32.4%	2842		
Ethnicity					
Black		65.9%	5780		
White		34.1%	2991		
Education					
High school diploma or less		18.1%	1584		
Trade school diploma to associates degree			61.3%	5374	
Bachelors degree		14.4%	1264		
Graduate degree or higher		6.3%	549		
Sleep hours					
6 or less hours		32.9%	2890		
7–8 hours		62.1%	5445		
9 or more hours		5.0%	436		
Frequency of vigorous activities					
Never or rarely		16.9%	1481		
Less than once per week		15.6%	1368		
1–2 times per week		21.7%	1899		
3 times per week		18.4%	1614		
4 times per week		10.1%	885		
5 or more times per week		17.4%	1524		
Use alcohol currently					
No		94.6%	8294		
Yes		5.4%	477		
Continuous variables					
	Mean	Median	Maximum	Minimum	SD
Positive affect score [*]	3.54	3.60	5.00	1.00	0.70
Negative affect score [*]	1.73	1.60	5.00	1.00	0.70
Age, y	61.7	61.0	106.0	35.0	13.2
Interval between waves, y	3.09	3.33	5.92	0.01	1.10
BMI, kg/m ²	27.13	26.40	72.62	15.33	5.68
Energy (kcal/day)	1891.6	1780.1	4492.	501.8	734.2
<i>Trans</i> fatty acids, g/day	3.61	2.83	45.53	0.00	3.00
Omega-3 fatty acids, g/day	2.09	1.87	9.94	0.19	1.10
Omega-6 fatty acids, g/day	17.89	16.25	70.67	1.94	8.98
Mediterranean diet score [†]	4.38	4.00	9.00	0.00	1.83

Total n = 8,771.

* Affect scales range from 1–5, 1 being very slightly or not at all and 5 being extremely.

[†] Mediterranean diet scores range from 0 to 9 with higher scores suggesting greater compliance.

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Table 3-

Associations of positive affect to nutrients and control variables

	Trans fatty acids				N-3 PUFA				N-6 PUFA				N-6:N-3							
	β	<i>B</i>	95% CI <i>B</i>		<i>p</i>	β	<i>B</i>	95% CI <i>B</i>		<i>p</i>	β	<i>B</i>	95% CI <i>B</i>		<i>p</i>	β	<i>B</i>	95% CI <i>B</i>		<i>p</i>
			Lower	Upper				Lower	Upper				Lower	Upper				Lower	Upper	
(Constant)		3.20	2.85	3.54	.000		2.40	1.81	2.98	.000		2.79	2.44	3.13	.000		2.93	2.54	3.31	.000
Nutrient Controls	-0.06	-0.27	-0.37	-0.17	.000	0.00	0.03	-0.19	0.26	.767	-0.02	-0.10	-0.18	-0.01	.023	-0.03	-0.34	-0.58	-0.10	.006
Age	-0.03	0.00	0.00	0.00	.002	-0.04	0.00	0.00	0.00	.001	-0.03	0.00	0.00	0.00	.002	-0.03	0.00	0.00	0.00	.002
Male	-0.01	-0.01	-0.04	0.02	.417	-0.01	-0.01	-0.04	0.02	.515	-0.01	-0.01	-0.04	0.02	.458	-0.01	-0.01	-0.04	0.02	.499
Black ethnicity	0.17	0.25	0.22	0.28	.000	0.17	0.25	0.22	0.29	.000	0.17	0.25	0.22	0.28	.000	0.17	0.25	0.21	0.28	.000
BMI	-0.03	0.00	-0.01	0.00	.006	-0.03	0.00	-0.01	0.00	.001	-0.03	0.00	-0.01	0.00	.001	-0.04	0.00	-0.01	0.00	.001
Education	0.08	0.03	0.02	0.04	.000	0.09	0.03	0.02	0.04	.000	0.09	0.03	0.02	0.04	.000	0.09	0.03	0.02	0.04	.000
Vigorous activity	0.12	0.04	0.03	0.04	.000	0.12	0.04	0.03	0.05	.000	0.12	0.04	0.03	0.05	.000	0.12	0.04	0.03	0.05	.000
Hours of sleep	0.25	0.15	0.09	0.22	.000	0.24	0.15	0.08	0.22	.000	0.25	0.15	0.09	0.22	.000	0.25	0.15	0.09	0.22	.000
Hours sleep squared	-0.23	-0.02	-0.02	-0.01	.000	-0.23	-0.02	-0.02	-0.01	.000	-0.23	-0.02	-0.02	-0.01	.000	-0.23	-0.02	-0.02	-0.01	.000
Time between waves	0.02	0.00	0.00	0.00	.089	0.02	0.00	0.00	0.00	.115	0.02	0.00	0.00	0.00	.096	0.02	0.00	0.00	0.00	.081
Total dietary energy	0.05	0.00	0.00	0.00	.000	0.05	0.00	0.00	0.00	.000	0.05	0.00	0.00	0.00	.000	0.05	0.00	0.00	0.00	.000
Current alcohol use	-0.01	-0.04	-0.10	0.03	.259	-0.01	-0.04	-0.10	0.02	.225	-0.01	-0.04	-0.11	0.02	.179	-0.02	-0.05	-0.11	0.02	.143
Mediterranean diet	0.06	0.02	0.01	0.03	.000	0.09	0.03	0.03	0.04	.000	0.09	0.03	0.03	0.04	.000	0.09	0.03	0.03	0.04	.000

Total n = 8,771. Regression coefficients with 95% confidence intervals (CIs) are shown.

Table 4-

Associations of negative affect to nutrients and control variables

	<i>Trans fatty acids</i>						<i>N-3 PUFA</i>						<i>N-6 PUFA</i>						<i>N-6:N-3</i>							
	β	<i>B</i>	<i>95% CI B</i>		<i>p</i>	β	<i>B</i>	<i>95% CI B</i>		<i>p</i>	β	<i>B</i>	<i>95% CI B</i>		<i>p</i>	β	<i>B</i>	<i>95% CI B</i>		<i>p</i>	β	<i>B</i>	<i>95% CI B</i>		<i>p</i>	
			Lower	Upper				Lower	Upper				Lower	Upper				Lower	Upper				Lower	Upper		Lower
(Constant)		2.74	2.39	3.09	.000		3.30	2.70	3.89	.000		3.09	2.75	3.44	.000		3.01	2.62	3.40	.000		3.01	2.62	3.40	.000	
Nutrient Controls	0.05	0.21	0.11	0.31	.000	0.00	0.00	-0.22	0.23	.982	0.02	0.07	-0.02	0.15	.125	0.02	0.22	-0.02	0.46	.075		0.02	0.22	-0.02	0.46	.075
Age	-0.19	-0.01	-0.01	-0.01	.000	-0.18	-0.01	-0.01	-0.01	.000	-0.19	-0.01	-0.01	-0.01	.000	-0.19	-0.01	-0.01	-0.01	.000		-0.19	-0.01	-0.01	-0.01	.000
Male	-0.14	-0.20	-0.24	-0.17	.000	-0.14	-0.21	-0.24	-0.18	.000	-0.14	-0.21	-0.24	-0.17	.000	-0.14	-0.21	-0.24	-0.18	.000		-0.14	-0.21	-0.24	-0.18	.000
Black ethnicity	-0.05	-0.07	-0.10	-0.04	.000	-0.05	-0.07	-0.10	-0.04	.000	-0.04	-0.07	-0.10	-0.03	.000	-0.04	-0.06	-0.10	-0.03	.000		-0.04	-0.06	-0.10	-0.03	.000
BMI	0.01	0.00	0.00	0.00	.373	0.01	0.00	0.00	0.00	.226	0.01	0.00	0.00	0.00	.223	0.01	0.00	0.00	0.00	.198		0.01	0.00	0.00	0.00	.198
Education	-0.06	-0.02	-0.03	-0.01	.000	-0.06	-0.02	-0.03	-0.01	.000	-0.06	-0.02	-0.03	-0.01	.000	-0.06	-0.02	-0.03	-0.01	.000		-0.06	-0.02	-0.03	-0.01	.000
Vigorous activity	-0.04	-0.01	-0.02	-0.01	.000	-0.05	-0.02	-0.02	-0.01	.000	-0.05	-0.02	-0.02	-0.01	.000	-0.05	-0.02	-0.02	-0.01	.000		-0.05	-0.02	-0.02	-0.01	.000
Hours of sleep	-0.26	-0.16	-0.23	-0.09	.000	-0.26	-0.16	-0.23	-0.09	.000	-0.26	-0.16	-0.23	-0.09	.000	-0.26	-0.16	-0.23	-0.09	.000		-0.26	-0.16	-0.23	-0.09	.000
Hours sleep squared	0.21	0.01	0.01	0.02	.000	0.20	0.01	0.01	0.02	.000	0.20	0.01	0.01	0.02	.000	0.20	0.01	0.01	0.02	.000		0.20	0.01	0.01	0.02	.000
Time between waves	0.00	0.00	0.00	0.00	.902	0.00	0.00	0.00	0.00	.984	0.00	0.00	0.00	0.00	.932	0.00	0.00	0.00	0.00	.891		0.00	0.00	0.00	0.00	.891
Total dietary energy	0.04	0.00	0.00	0.00	.001	0.04	0.00	0.00	0.00	.000	0.04	0.00	0.00	0.00	.000	0.04	0.00	0.00	0.00	.000		0.04	0.00	0.00	0.00	.000
Current alcohol use	0.02	0.05	-0.02	0.11	.151	0.02	0.05	-0.02	0.11	.136	0.02	0.05	-0.01	0.12	.112	0.02	0.05	-0.01	0.12	.097		0.02	0.05	-0.01	0.12	.097
Mediterranean diet	-0.04	-0.01	-0.02	-0.01	.002	-0.06	-0.02	-0.03	-0.01	.000	-0.06	-0.02	-0.03	-0.01	.000	-0.06	-0.02	-0.03	-0.02	.000		-0.06	-0.02	-0.03	-0.02	.000

Total n = 8,771. Regression coefficients with 95% confidence intervals (CIs) are shown.