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ORIGINAL ARTICLE

Dietary pattern derived by reduced rank regression and depressive symptoms in a multi-ethnic population: the HELIUS study

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BACKGROUND/OBJECTIVES: To investigate the association of dietary patterns derived by reduced rank regression (RRR) with depressive symptoms in a multi-ethnic population.

SUBJECTS/METHODS: Cross-sectional data from the HELIUS study were used. In total, 4967 men and women (18–70 years) of Dutch, South-Asian Surinamese, African Surinamese, Turkish and Moroccan origin living in the Netherlands were included. Diet was measured using ethnic-specific food frequency questionnaires. Depressive symptoms were measured with the nine-item patient health questionnaire.

RESULTS: By performing RRR in the whole population and per ethnic group, comparable dietary patterns were identified and therefore the dietary pattern for the whole population was used for subsequent analyses. We identified a dietary pattern that was strongly related to eicosapentaenoic acid+docosahexaenoic acid, folate, magnesium and zinc (response variables) and which was characterized by milk products, cheese, whole grains, vegetables, legumes, nuts, potatoes and red meat. After adjustment for confounders, a statistically significant inverse association was observed in the whole population (B: −0.03, 95% CI: −0.06, −0.00, $P=0.046$) and among Moroccan (B: −0.09, 95% CI: −0.13, −0.04, $P=0.027$) and South-Asian Surinamese participants (B: −0.05, 95% CI: −0.09, −0.01, $P= <0.001$), whereas no statistically significant association was found in the remaining ethnic groups. No statistically significant associations were found between the dietary pattern and significant depressed mood in any of the ethnic groups.

CONCLUSIONS: No consistent evidence was found that consumption of a dietary pattern, high in nutrients that are hypothesized to protect against depression, was associated with lower depressive symptoms across different ethnic groups.

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INTRODUCTION

Depression is a severe mental disorder predicted to be the second leading cause of disability globally by 2020.[1] In the Netherlands, differences in health are observed between ethnic groups, with ethnic minority groups mostly having a higher disease risk profile compared with the Dutch host population.[2] A well-documented example is the higher depression prevalence among Turkish and Moroccan ethnic groups, which may be associated with lower social-economic status in these groups.[3] Like other mental disorders, it has a multi-causal pathogenesis including genetic, environmental and lifestyle factors.[4] Regarding the latter, there is increasing evidence for nutrition as a crucial factor in relation to depression.[5–8]

A mechanism by which diet might affect mental health is through its influence on inflammatory and oxidative stress levels. Recent research observed higher inflammatory and oxidative stress levels in people with depression compared with people without depression.[9–11] Further studies have indicated that several brain-essential nutrients, including fish fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA),[12,13] folate,[14–16] magnesium[17,18] and zinc,[19] are protective for depression,[20] possibly due to their anti-inflammatory effects.

Despite the fact that the above-mentioned nutrients might be protective for depressive symptoms, dietary patterns may be more informative for investigating diet–disease relationships as they take into account the synergistic and correlated effects of separate nutrients and foods.[21,22] A number of studies, performed in adults, indicate that healthy dietary patterns high in fatty fish, vegetables, fruit, olive oil, whole grains, legumes and nuts, may be protective for depressive symptoms,[6] of which four studies derived dietary patterns through *a priori* methods[23–27] while two studies identified dietary patterns by using *a posteriori* methods.[28,29] While *a posteriori* methods are used to describe food patterns of a specific population, it may not optimally represent dietary patterns most relevant to the outcome under study due to sole reliance on inter-correlations among dietary variables. *A priori* methods are often used to investigate to what extent a population adheres to a specific diet, however it does not reflect the overall

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effect of diet in general but only takes into account the formal sum of not-adjusted single effects.[30,31] Reduced rank regression (RRR) combines both methods by deriving dietary patterns in an exploratory way that is based on *a priori* knowledge, which is used in the selection of response variables that are thought to link dietary patterns to disease risk. Hereby it is more likely to identify food groups that are strongly related to depressive symptoms. Furthermore, due to the data-driven approach, RRR is able to identify and incorporate ethnic-specific patterns.

Thus far, two previous studies found that RRR-derived dietary patterns were associated with lower depressive symptoms in a Japanese population[32] and an Italian population (our previous study),[33] where they predominantly consume a healthy dietary pattern. In the Italian study, we found that a dietary pattern rich in vegetables, olive oil, grains, fruit, fish and moderate in wine, red and processed meat was protective for depressive symptoms.[33] In the current study, we aimed to identify a similar dietary pattern as the Italian study by using RRR and to investigate if this dietary pattern is associated with lower depressive symptoms in a multi-ethnic western population, where heterogeneity is present due to differences in nutritional intake across ethnic groups. Some aspects of the diet are less favourable (including lower intakes of several micronutrients, higher consumption of high-sugar and high-fat snacks) and some more favourable (generally lower intake of saturated fat and, in some groups, higher fruit intake) in ethnic minority populations.[34–36]

Therefore, the objective of our study is to investigate the association between dietary patterns derived by RRR and depressive symptoms in a multi-ethnic population.

MATERIALS AND METHODS

The HELIUS (HEalthy LIfe in an Urban Setting) study is a large, multi-ethnic cohort study, which aims to unravel the causes of the unequal burden of disease among the largest ethnic groups living in Amsterdam, the Netherlands.[2] Baseline data collection took place from 2011 to 2015 among nearly 25 000 participants, and were carried out by the Academic Medical Centre (AMC) and the Public Health Service of Amsterdam. People (aged 18–70 years) with Surinamese, Turkish, Moroccan and Dutch ethnicity were randomly recruited through the municipality registry of Amsterdam, stratified by ethnicity. Ethnicity was defined according to the country of birth of the participant as well as that of his/her parents available from the registry.[37] Surinamese subgroups were classified according to self-reported ethnic origin. We accounted for South-Asian Surinamese and African Surinamese separately due to differences in characteristics, such as migration history and genetic profile.[2]

Data were collected by questionnaire and a physical examination. A sub-sample of the HELIUS study was asked to fill in an additional food frequency questionnaire (FFQ) to measure dietary intake ($n = 5188$).[38] All study protocols were approved by the AMC Ethical Review Board, and all participants provided written informed consent.

Measurement of depressive symptoms

Depressive symptoms and significant depressed mood were assessed using the nine-item patient health questionnaire (PHQ-9), which is a questionnaire that is used to estimate depressive symptoms in the previous 2 weeks.[39] Response categories of the nine items vary from never (coded as 0) to nearly every day (coded as 3) with total sum scores ranging from 0–27. Depressive symptoms were estimated by using the continuous sum scores.[40–42]

Significant depressed mood was defined by an algorithm in line with the DSM IV, including at least one of the following items: 'depressed mood' or 'loss of interest', and stating that more than five of the nine items were present 'on more than half the days' or 'nearly every day', of which the final item about suicidal thoughts counts if it was answered with 'on several days'. This algorithm showed a sensitivity of 0.77 and a specificity of 0.94 in high-risk populations in the Netherlands.[41]

Measurement of diet

Dietary intake information was obtained by ethnic-specific FFQ's, for Dutch, Surinamese, Turkish and Moroccan ethnic groups, which were developed for the HELIUS study and included questions on the portion size and frequency of food items eaten during the past month.[43] The ethnic-specific FFQs have the same layout concerning the order of questions and food items asked and consist of similar, comparable food items (except for ethnic-specific food groups) to maximize comparability. For each FFQ, a nutrient database was constructed based on the Dutch Food Composition Table 2014.[44] Data on ethnic-specific foods were based on information from food packaging, international food composition data, data from recipe calculations and were chemically analysed at the Wageningen University by taking multiple samples of each food which were mixed for analysis; these samples were based on brand and different sale locations.[43] The Dutch FFQ consisted of 238 food items, whereas the ethnic-specific FFQs included 228, 209 and 189 food items (for the Surinamese, Turkish and Moroccan FFQs, respectively).[43]

Dietary pattern analysis

RRR identifies linear functions of predictors that explain as much variation as possible in response variables, which were considered as intermediate markers of nutrients for depressive symptoms and significant depressed mood.[30,45,46] Hereby we build on *a priori* knowledge of biological relations, by including plausible intermediates between diet and the outcome of interest.[31] We selected the following nutrients as response variables *a priori*; EPA+DHA (g/day), folic acid (mcg/day), magnesium (mg/day) and zinc (mg/day) because these response variables were used in our previous study where a RRR-derived dietary pattern was associated with lower depressive symptoms[31] and because these nutrients are indicated to be protective for depressive symptoms.[12–20] In total, 45 food groups (of which eight ethnic-specific food groups) were created based on nutrient profile, particular culinary use and ethnicity and were set as predictor variables (Table 1). Foods with factor loadings $\geqslant 0.20$ were considered to be characteristic for the dietary pattern and were reported for simplicity. Dietary pattern analyses were performed for the whole population and stratified by ethnicity to test for differences in dietary patterns between ethnic groups. Higher RRR scores indicate higher consumption of the food groups that are characteristic for the derived dietary pattern. Further explanation of the RRR procedure is given elsewhere.[30]

Statistical analysis

Baseline characteristics of the study population were described by numbers (%) for categorical variables and means (s.d.) for continuous variables. Multivariable linear regression models were performed with continuous dietary pattern scores as exposure and continuous PHQ-9 sum scores as outcome (statistically significant = two-sided P-value < 0.05). To check whether the diet–depression relationship was similar among ethnic groups and for sex, interaction by ethnicity and by sex was tested, but no interaction was present. Because the PHQ-9 scale was skewed with a minimum of 0, analyses were performed using a logarithmic transformation of the scale score +1.[47] Potential confounders were included in the analyses when they changed the diet–depression relationship ($P < 0.05$). The first model was adjusted for age (years), sex, ethnicity (Dutch, South-Asian Surinamese, African Surinamese and Turkish, Moroccan) and ethnicity*diet (model 1). Model 2 was also adjusted for employment status (employed, not part of labour force, unemployed), Dutch norm of physical activity (30 min of moderate exercise at least 5 days a week)(yes or no) and smoking status (never smoker, former smoker, current smoker). Model 3 was additionally adjusted for cardiovascular disease (according to the ROSE questionnaire) (yes or no) and body mass index (kg/m^2) and finally model 4 was additionally adjusted for energy intake (kJ/day). Marital status, educational level, hypertension and diabetes mellitus type 2 did not significantly change the diet–depression relationship. Additionally, alcohol intake was not considered separately, as it was included as predictor variable in the RRR analyses. To facilitate interpretations of the findings, we back transformed the betas using the following equation: ($eB - 1$). Similar analyses by logistic regression models were performed using significant depressed mood (yes or no) as outcome measure.

As sensitivity analysis, we excluded subjects with implausible energy intakes (females: < 500 kcal, > 3500 kcal) (males: < 800 kcal, > 4000 kcal).[47] Hereafter, we repeated RRR to assess the stability of the identified dietary patterns. Second, we additionally adjusted for supplementation use (including omega-3 supplementation) and the nutrients mono-disaccharides and saturated fatty acids, to account for the possible influence of less healthy foods (such as high-fat and high-sugar foods), which are consumed regularly in the Netherlands.

Table 1. Food groups of ethnic Dutch, Surinamese, Turkish and Moroccan participants used for reduced rank regression in the HELIUS study ($n = 4967$)

Red meat	All types of beef, veal, pork and other meat
Organ meat	Kidney[a], liver and liver products
Processed meat	Smoked sausage, hotdog sausage, salami, ham, bacon, other cold cuts, liver sausage, chatar[b] and susuk[b]
Chicken	Chicken
Vegetarian products	Tofu, tempeh, soy and other meat substitutes
Fatty fish	Herring, mackerel, salmon, eel, sardines, anjovis and so on
Lean fish, crustaceans and molluscs	Tuna, cod, pangasius, trout, tilapia, fish finger, shellfish and so on, crustaceans, molluscs
Eggs	Eggs (boiled egg and omelette)
Butter	Butter, herb and garlic butter, coconut fat
Other fat	Frying fats and oils, vegetable oils, high-fat margarine spread, margarine for cooking and baking, and low-fat margarine spread
Olive oil	Olive oil
Milk products	All types of milk and milk products (including yoghurt, pudding, mousse, whipped cream, custard, quark, milk-based ice cream, cream for hot dishes, coffee creamer, coconut milk[a], Turkish yoghurt 10% fat)[b], ayran[b]
Cheese	All types of cheese (low-fat and high-fat cheese)
Soy dairy products	Soy milk, soy yoghurt products, soy coffee milk and soy ice cream
Fruit	Apple, banana, orange, mandarin, grapefruit, kiwi, strawberries, grapes, melon and other fruit
Nuts and seeds	Nuts and seeds in hot dishes or as snack
Vegetables	Tomatoes, bell pepper, cooked eggplant, antroewa[a], spinach, raw salad, bitawiri[a], amsoi[a], cucumber, onion, carrots, green beans, courgette, other raw vegetables, other cooked vegetables, peas, sopropo[a], root vegetables[a], cauliflower, broccoli, Brussels sprouts, white cabbage and green cabbage
Legumes	Legumes, leblebi (Turkish roasted peas)[b]
Potatoes	Potatoes (boiled, baked and mashed), oven prepared French fries
Fried potatoes	All types of fried French fries
Whole grains	Whole grain and dark bread, whole grain crackers and rusks, high fibre breakfast cereals, rye bread, whole grain breakfast cereals, whole grain pasta, whole grain rice and bulgur[b]
Refined grains	White bread, bread rolls, croissants, raisin bread, low fibre crackers and rusks, cornflakes, gingerbread, Turkish white bread[b,c], corn bread, breakfast drinks, white pasta and noodle dishes, white rice and fried rice[a], pancakes and manti[b],
Alcoholic beverages	Wine, port, sherry, vermouth, beer, spirits, liquor, distilled drinks, mixed drinks (including breezer)
Coffee and tea	Coffee, tea
Water	Water
Natural fruit juices	Fruit juices (100% natural)
Sugar-sweetened beverages	Carbonate drinks, soft drinks, sport and energy drinks, fruit and vegetable juices with added sugar, ice lollypop
Light beverages, sweeteners	All types of light and diet soft drinks and fruit juices, added sweeteners to breakfast cereals or desserts
Chocolate, sweets, cakes and cookies	Candy, candy bars, all types of chocolate, cake, pie, pastries, nutritional cookies, baklava[b] and South-Asian sweets[a]
Sugar, honey, jam	Sugar, honey and sweet bread fillings
Savoury bread fillings	Sandwich spread and peanut butter
Fish savoury snacks	All types of fried fish, crackers with fish and fish salad
Cold savoury snacks	Chips, other salty snacks (including cheese biscuits and salty crackers), pate and other toppings
Fast foods and warm savoury snacks	Shoarma, hamburger, croquette, sate, spring rolls, sausage rolls, fish sticks, Turkish, Italian or American pizza, fried snacks, other hot snacks, bara[a], içli köfte[b], brioaut[c] and deep fried plantain[a]
Mayonnaise and similar sauces	All types of mayonnaise, garlic sauce and sate sauce
Other sauces	Unclassified other sauces, ketchup or red sauce used with snacks and hot dishes, apple sauce, oils for salad and fresh and prepared tomato sauce
Soups	Soups with legumes and other soups
Ethnic-specific foodgroups	
Börek/pogaca[b]	Börek/pogaca (savoury breakfast pastry)
Moroccan pancakes[c]	Rghaif and beghrir
Filled wine leaves[b]	Filled wine leaves with rice and/or meat
Roti[a]	Indian flat bread with potatoes, yellow peas or sada roti
Pom[a]	Pom (Surinamese festive dish)
Couscous[c]	Couscous
Olives[c]	Olives
Avocado[a]	Avocado

[a]Food items only assessed in the Surinamese FFQ. [b]Food items only assessed in the Turkish FFQ. [c]Food items only assessed in the Moroccan FFQ.

The RRR analyses were performed in SAS version 9.4. Remaining statistical analyses were conducted using SPSS version 21.

RESULTS

Of the 5188 participants with dietary intake data available, we excluded participants with missing data on depressive symptoms ($n = 26$) and on demographics ($n = 195$), which left us with 4967 participants for our analyses. Baseline characteristics for the whole population and per ethnic group are presented in Table 2. The mean energy intake was 9194 kJ/day for the whole study population and was the highest for the Turkish group. Thirty-four per cent of the participants used vitamin supplementation with the highest vitamin use among both Surinamese groups. Among all groups, mean daily intakes of EPA+DHA, magnesium and zinc were adequate according to the Dutch Dietary

Table 2. Baseline characteristics of study participants for the whole population and according to ethnicity in the HELIUS study ($n = 4967$)

Characteristic	*Whole population* (n = *4967)*	*Dutch* (n = *1471)*	*South-Asian Surinamese* (n = *1056)*	*African Surinamese* (n = *1033)*	*Turkish* (n = *644)*	*Moroccan* (n = *763)*
Age (years) (mean, s.d.)	46 (±13)	48 (±14)	47 (±12)	50 (±11)	42 (±11)	41 (±12)
Female, *n* (%)	2 912 (59%)	807 (55%)	617 (58%)	697 (68%)	335 (52%)	456 (60%)
Employment status, n *(%)*						
Employed	3225 (65%)	1076 (73%)	688 (65%)	680 (66%)	376 (58%)	405 (53%)
Not part of labour force	818 (17%)	282 (19%)	142 (13%)	102 (10%)	113 (18%)	179 (24%)
Unemployed	924 (19%)	113 (8%)	226 (21%)	251 (24%)	155 (24%)	179 (24%)
Smoking status						
Never smoker	2591 (52%)	546 (37%)	650 (62%)	538 (52%)	303 (47%)	554 (73%)
Former smoker	1268 (26%)	590 (40%)	153 (15%)	245 (24%)	153 (24%)	127 (17%)
Current smoker	1108 (22%)	335 (23%)	253 (24%)	250 (24%)	188 (29%)	82 (11%)
Achieving the Dutch norm physical activity, *n* (%)	2932 (59%)	1 101 (75%)	551 (52%)	612 (59%)	297 (46%)	371 (49%)
CVD, *n* (%)	592 (12%)	59 (4%)	178 (17%)	122 (12%)	106 (17%)	127 (17%)
BMI (kg/m^2) (mean, s.d.)	27 (±5)	25 (±4)	27 (±5)	28 (±6)	28 (±5)	28 (±5)
Energy intake (kJ/day) (mean, s.d.)	9194 (±3984)	9158 (±2948)	8933 (±4136)	9134 (±4193)	9819 (±4852)	9174 (±4345)
Vitamin supplement use, *n* (%)	1681 (34%)	526 (36%)	439 (42%)	453 (44%)	125 (19%)	138 (18%)
Dietary pattern score (mean, s.d.)	− 0.00 (±1.58)	0.25 (±1.26)	− 0.23 (±1.60)	− 0.22 (±1.64)	0.21 (±1.77)	− 0.04 (±1.74)
EPA+DHA intake in g/day (median, IQR)[a]	0.24 (0.12, 0.47)	0.19 (0.10, 0.34)	0.37 (0.17, 0.70)	0.30 (0.16, 0.62)	0.18 (0.10, 0.33)	0.25 (0.13, 0.45)
Folate intake in mcg/day (median, IQR)[a]	249 (189, 314)	265 (209, 323)	229 (171, 294)	227 (175, 292)	272 (205, 337)	251 (190, 326)
Magnesium intake in mg/day (median, IQR)[a]	331 (255, 420)	367 (300, 443)	305 (235, 389)	297 (227, 393)	339 (267, 428)	321 (248, 419)
Zinc intake in mg/day (median, IQR)[a]	10 (8, 13)	11 (9, 13)	9 (7, 12)	10 (7, 13)	12 (9, 16)	11 (8, 14)
PHQ-9 sum score (median, IQR)[a]	3 (1, 6)	2 (1, 4)	4 (1, 8)	2 (0, 5)	5 (2, 8)	4 (1, 8)
Significant depressed mood, *n* (%)	326 (7%)	27 (2%)	101 (10%)	42 (4%)	72 (11%)	84 (11%)

Abbreviations: BMI, body mass index; CVD, cardiovascular disease; DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid; PHQ-9, nine-item patient health questionnaire. [a]Median scores and interquartile range (IQR) are indicated due to not-normally distributed variables.

guidelines, whereas folate intake was below the guidelines. For the total study population, 7% suffered from significant depressed mood and was the highest in Turkish and Moroccan participants (Table 2).

Dietary pattern analysis

For the whole population, we identified a dietary pattern with foods that could be considered healthy (whole grains, vegetables, legumes, potatoes and nuts) as well as less healthy foods (red meat, milk products and cheese) (Table 3). The food groups included in the derived dietary pattern for the whole population mainly comprised comparable food groups to those derived in ethnicity-stratified analyses (Table 3). Additionally, the correlation coefficient was high between the dietary pattern score for the whole population and the ethnic-specific dietary pattern scores of the Dutch, South-Asian Surinamese, African Surinamese, Turkish and Moroccans (0.980, 0.990, 0.987, 0.979 and 0.982, respectively). Therefore, we decided to use the dietary pattern derived in the whole population in further analyses. The comprised diet score explained 58% of the variation in the response variables and was highly associated with all response variables (EPA+DHA, folate, magnesium and zinc).

Regression analyses

In the whole population, higher dietary pattern scores were associated with lower depressive symptoms after full adjustment for confounders (B: − 0.03, 95% CI: − 0.06, − 0.00, $P = 0.046$). When performing the analyses per ethnic group, initial positive associations between dietary pattern scores and depressive symptoms (model 1 − 3) became negative after additional adjustment for energy intake in model 4 and were statistically significant for South-Asian Surinamese and Moroccan participants (Table 4).

The association between the dietary pattern score and significant depressed mood is shown in Table 5. Again, initial positive associations became negative after additional adjustment for energy intake, although we did not observe a statistically significant association between the dietary pattern and significant depressed mood in any of the ethnic groups nor in the whole population.

Sensitivity analysis

We excluded 314 participants (3% Dutch, 7% South-Asian Surinamese, 7% African Surinamese, 9% Turkish and 9% Moroccan) because they reported implausible energy intakes. Similar dietary patterns were generated for the different ethnic groups separately as compared with the whole population. (data not shown). When repeating regression analyses, we observed somewhat weaker associations among Turkish and Moroccan participants in relation to depressive symptoms, however, these differences were not statistically significant (online Supplementary material Table 1). Finally, we used the original dietary pattern scores and repeated regression analyses with exclusion of the participants that reported implausible energy intakes. Again, no major differences were observed in the diet–depression relationship (data not shown). After additional adjustment for use of vitamin supplementation (including omega-3 fatty acids), mono-disaccharides and saturated fatty acids, no changes were observed in the association in any of the ethnic groups. Finally, we investigated the influence of omega-3 supplementation ($n = 60$). After additional adjustment for this supplement, again no changes were observed in the diet–depression association (data not shown).

DISCUSSION

In the current study, a dietary pattern was identified that was characterized by whole grains, vegetables, legumes, potatoes, nuts and seeds, red meat, milk products and cheese. Higher consumption of this dietary pattern was associated with lower depressive symptoms in the whole population and in South-Asian Surinamese and Moroccan participants, but not in the other three

Table 3. Overview of food groups derived by reduced rank regression with the explained variation and correlation coefficients for the whole population and stratified by ethnicity in the HELIUS study ($n = 4967$)

Whole population		*Dutch*		*South-Asian Surinamese*		*African Surinamese*		*Turkish*		*Moroccan*	
Food group	*Load*	*Food group*	*Load*	*Food group*	*Load*	*Food group*	*load*	*Food group*	*Load*	*Food group*	*Load*
Positive loadings											
Whole grains	0.28	Whole grains	0.33	Fish savoury snacks	0.27	Fish savoury snacks	0.24	Red meat	0.30	Whole grains	0.30
Red meat	0.25	Vegetables	0.25	Whole grains	0.23	Whole grains	0.24	Chicken	0.22	Red meat	0.27
Milk products	0.23	Milk products	0.24	Milk products	0.23	Vegetables	0.24	Potatoes	0.22	Chicken	0.23
Vegetables	0.22	Cheese	0.24	Vegetables	0.21	Red meat	0.23	Milk products	0.21	Potatoes	0.22
Nuts and seeds	0.21	Red meat	0.23	Refined grains	0.21	Milk products	0.22	Legumes	0.21	Fatty fish	0.21
Legumes	0.21	Nuts and seeds	0.23	Legumes	0.20	Refined grains	0.21	Fast foods and warm snacks	0.21	Milk products	0.20
Cheese	0.21	Fatty fish	0.20			Legumes	0.21	Lean fish, crustaceans and molluscs	0.21		
Potatoes	0.20					Lean fish, crustaceans and molluscs	0.21	Chocolates, sweets, cakes and cookies	0.20		
						Fruit	0.20	Whole grains	0.20		
						Nuts and seeds	0.20				
						Fatty fish	0.20				
Explained variation											
Food groups	6.9%		5.7%		9.4%		8.6%		10.1%		8.8%
Response variables	57.8%		58.0%		65.4%		62.3%		65.6%		57.0%
Explained variable weights of response variables											
EPA+DHA	0.29		0.29		0.31		0.33		0.36		0.42
Folate	0.54		0.54		0.53		0.54		0.53		0.53
Magnesium	0.56		0.57		0.56		0.56		0.55		0.52
Zinc	0.55		0.55		0.55		0.54		0.54		0.52

Table 4. Regression coefficient (95% CI) for the association between continuous dietary pattern scores and depressive symptoms in the HELIUS study ($n = 4967$)

	Model 1		Model 2		Model 3		Model 4	
	β (95% CI)[a]	P	β (95% CI)[a]	P	β (95% CI)[a]	P	β (95% CI)[a]	P
Dutch	0.05 (0.02, 0.09)	0.004	0.06 (0.02, 0.09)	0.001	0.06 (0.02, 0.09)	0.001	0.01 (−0.04, 0.05)	0.820
South-Asian Surinamese	0.04 (0.00, 0.07)	0.038	0.02 (−0.01, 0.05)	0.175	0.02 (−0.02, 0.05)	0.312	− 0.05 (−0.09, − 0.01)	0.027
African Surinamese	0.05 (0.02, 0.08)	0.003	0.04 (0.01, 0.08)	0.005	0.04 (0.01, 0.07)	0.007	− 0.02 (−0.06, 0.02)	0.372
Turkish	0.02 (−0.02, 0.06)	0.312	0.03 (−0.01, 0.07)	0.115	0.03 (−0.01, 0.06)	0.134	− 0.04 (−0.08, 0.01)	0.090
Moroccan	− 0.03 (−0.07, 0.01)	0.097	− 0.03 (−0.06, 0.01)	0.150	− 0.03 (−0.06, 0.01)	0.146	− 0.09 (−0.13, −0.04)	< 0.001

Model 1: adjusted for ethnicity, diet*ethnicity, age and gender. Model 2: adjusted for model 1 and for employment status, physical activity and smoking status. Model 3: adjusted for model 2 and for CVD and BMI. Model 4: adjusted for model 3 and for energy intake. [a]Regression coefficients are log-transformed.

Table 5. Odds ratio (95% CI) for the association between the continuous dietary pattern score and significant depressed mood[a] in the HELIUS study ($n = 4967$)

	Model 1		Model 2		Model 3		Model 4	
	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
Dutch	0.68 (0.35, 1.30)	0.676	0.69 (0.36, 1.34)	0.278	0.78 (0.40, 1.51)	0.456	0.58 (0.29, 1.14)	0.114
South-Asian Surinamese	1.11 (0.91, 1.36)	0.301	1.08 (0.87, 1.33)	0.505	1.11 (0.88, 1.39)	0.378	1.01 (0.71, 1.42)	0.979
African Surinamese	1.28 (1.04, 1.58)	0.020	1.19 (0.94, 1.51)	0.150	1.18 (0.93, 1.50)	0.175	0.97 (0.69, 1.37)	0.876
Turkish	0.93 (0.71, 1.22)	0.578	0.96 (0.73, 1.27)	0.792	0.95 (0.71, 1.25)	0.694	0.70 (0.46, 1.07)	0.097
Moroccan	0.69 (0.48, 1.00)	0.052	0.70 (0.47, 1.04)	0.078	0.74 (0.49, 1.11)	0.144	0.72 (0.44, 1.18)	0.194

Model 1: adjusted for diet*ethnicity, age and gender. Model 2: adjusted for model 1 and for employment status, physical activity and smoking status. Model 3: adjusted for model 2 and for CVD and BMI. Model 4: adjusted for model 3 and for energy intake. [a]Significant depressed mood is defined by an algorithm including at least one of the following items: 'depressed mood' or 'loss of interest' and stating that more than five of the nine items were present 'on more than half the days' or 'nearly every day', of which the final item about suicidal thoughts counts if it was answered with 'on several days'.

ethnic groups. No association was observed between the above-mentioned dietary pattern and significant depressed mood.

Previous studies investigated the association between *a priori*-derived dietary patterns (high in fatty fish, vegetables, fruit, olive oil, whole grains, legumes and nuts) and depressive symptoms. All studies found a statistically significant inverse association; higher adherence to these dietary patterns was associated with lower depressive symptoms.[23,24,26,27] These consistent results may be due to the fact that *a priori* dietary patterns mainly include healthy foods, with fewer 'unhealthy' foods being included in these scores.[30,31]

Additionally, five previous studies investigated *a posteriori*-derived dietary patterns with inconsistent results. Two studies found that higher intakes of fruit, vegetables, fish and poultry were inversely associated with depressive symptoms[28,29] while three other cohort studies failed to find an association between a healthy dietary pattern and depressive symptoms.[48–50] These inconsistent results may be explained by the fact that *a posteriori* methods are completely data driven, hereby the derived dietary pattern may not be specific for the disease under study.

Using RRR, two longitudinal studies have sought to identify a dietary pattern protective for depressive symptoms.[32,33] A Japanese study used folate, magnesium, zinc, vitamin C, calcium and iron as response variables because these nutrients were previously found to be associated with depressive symptoms in the same study. The obtained dietary pattern was characterized by high intakes of vegetables, soybean products, green tea, potatoes, fruit and fish and was associated with lower depressive symptoms.[32] Additionally, we previously performed a study in an Italian population and applied RRR with the same *a-priori*-defined response variables as used in the current study (EPA +DHA, folate, magnesium and zinc).We identified that a dietary pattern, high in vegetables, fruit, grains, potatoes, fish, olive oil and moderate in red and processed meat, was significantly associated with lower depressive symptoms.[33]

We were not able to identify a similar dietary pattern in the current study compared with our previous study, even though we applied RRR with the same response variables (EPA+DHA, folate, magnesium and zinc).[33] An explanation for these non-consistent findings could be that RRR is partly data-driven and reflects the actual intake of the population under study. People living in the Netherlands are more likely to consume a western dietary pattern, including less healthy foods like high-fat dairy products and red and processed meat, whereas the Italian dietary pattern is known to be high in foods such as vegetables, fruit, fish and olive oil.

A similar explanation could be given for the results of the current study and the study performed in Japan; the Japanese also tend to consume healthier foods such as vegetables, vegetable oils and fish and this study additionally included vitamin C, iron and calcium as response variables instead of EPA+DHA.[32] We tried to account for the influence of the western diet by adjusting for mono-disaccharides and saturated fat in sensitivity analyses, but this did not result in an attenuation of the observed associations.

To get more insight into the influence of the actual intake of food groups, we compared the most important food groups of the identified dietary pattern in the current study and our previous study. The Italian population had significantly higher absolute median intakes (g/day) of the more healthy foods vegetables, fruit, olive oil compared to the multi-ethnic Dutch population. Additionally, we compared the associations between the individual nutrients (that are used as response variables) and depressive symptoms in the Italian study[33] and the current study, and found statistically significant inverse associations for all nutrients in relation to depressive symptoms in the Italian study (results not shown), whereas we failed to find statistically significant associations in the current study between any of the nutrients and depressive symptoms (EPA+DHA: B = 0.01, $P = 0.564$, folate: B = 0.00, $P = 0.353$, magnesium: B = − 0.00, $P = 0.987$, zinc: B = 0.00, $P = 0.188$).

We found ethnic differences in the association between the identified dietary pattern and depressive symptoms, with the strongest association among the Moroccans. This difference might be explained by the fact that Moroccan participants originate from cultures that traditionally consume a Mediterranean diet. Although currently Southern European countries are going through a transition from a traditional dietary pattern towards a more unhealthy western dietary pattern, they may continue to consume specific components of that dietary pattern more frequently.[36] More specifically, we compared the median intake in g/day among ethnic groups to get more insight into the differences between the actual intake of the most important food groups. We observed that the Moroccans and South-Asian Surinamese consume more of the healthy foods (fruit, fish and olive oil), whereas the Turkish and Dutch groups reveal a higher consumption of the less healthy food groups (chocolates and sweets and red meat) that are characteristic for the identified dietary pattern. This could explain the stronger associations in the South-Asian Surinamese and Moroccan participants. However, the identified dietary pattern for the whole population and the ethnic-specific dietary patterns were highly correlated, hereby indicating that the obtained dietary patterns did not differ from each other.

Exclusion of participants with implausible energy intakes (sensitivity analysis) did not influence the observed associations. Therefore, we can imply that the derived dietary pattern is stable because we obtained comparable dietary patterns after repeating RRR without participants that reported implausible energy intakes.

Even though the same questionnaire is used to measure depressive symptoms and significant depressed mood, they do not measure the same construct. Significant depressed mood measure the presence of depressive disorders, whereas the continuous scores are used to measure the severity of depressive symptoms by the number of depressive symptoms. When using continuous scores, smaller changes can be observed in the diet-depressive symptoms association compared with the dichotomous outcome of significant depressed mood. Consequently, an explanation for the weaker associations between diet and significant depressed mood could be due to the lower sensitivity of significant depressed mood (0.77). This illustrates that some of the participants that actually have significant depressed mood will be missed, which could have attenuated the association.

The major strength of our study is the large samples of several ethnic groups with a great body of information on their demographics and physical health. Our study population resembles the heterogeneity of the real-world population because populations in Europe are becoming increasingly ethnically diverse. In the Netherlands, for example, ~ 10% of the population originally come from low- and middle-income countries, which is predicted to increase to 20% by 2060.[51] Furthermore, by studying a heterogeneous population with a wide variety of dietary intakes and depression prevalence, we can capture the more-extreme intakes of various diets and depression cases.

Some limitations need to be acknowledged. Even though ethnic-specific FFQs were used, using FFQs to measure usual diet is a limitation because the questionnaire relies on memory. Additionally, the selection of the response variables based on the literature might be a limitation because there are indications that other nutrients (calcium, B vitamins and iron) could also be protective for depressive symptoms. Hereby we may miss important nutrients. However, we particularly chose to use EPA +DHA, folate, zinc and magnesium because in our previous study we found a dietary pattern to be protective for depressive symptoms using these specific response variables and we wanted to get more insight into whether we could identify a similar dietary pattern in the current study. The cross-sectional design of this study means we cannot investigate causal relationships while reverse causation cannot be ruled out and there are indications that the diet–depression relationship is bi-directional.[52] Finally, the subjective self-administered PHQ-9 questionnaire is a limitation because it is not a physician-based diagnosis of depression and when using the algorithm for significant depressed mood, a sensitivity of 0.77 was previously reported which may indicate that 23% of high depressive symptom cases goes undetected. However, when using the PHQ-9 as screening instrument by using the continuous PHQ-9 sum scores, the sensitivity was higher (0.93).[41,42]

In conclusion, no consistent findings were observed between higher consumption of a dietary pattern high in dairy products, whole grains, vegetables, legumes, red meat, potatoes and nuts and lower depressive symptoms in a multi-ethnic population. Additionally, we were not able to identify a similar RRR-derived dietary pattern that was hypothesized to be protective for depressive symptoms, in a population with 'more unhealthy' dietary habits. Since these associations are cross-sectional, additional prospective studies performed in multi-ethnic populations, studying ethnic-specific dietary patterns, are required to get more insight into the differences in dietary intake and the associations with depressive symptoms between ethnic groups.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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