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Plant-based dietary patterns and their association with mood in healthy individuals†

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Background: Healthy, plant-based dietary patterns, particularly the Mediterranean diet (MD), have been associated with positive effect on mood symptoms and have been proposed to help prevent age-related cognitive decline. However, to date no study has investigated which existing plant-based dietary pattern might be most likely to be associated with better mood in the general population. The aim of this study was to evaluate the relationship between different plant-rich dietary patterns and current mood in healthy individuals across a broad age range. *Methods*: We evaluated 333 healthy participants aged 8–79, who previously participated in dietary intervention studies. Current mood was assessed with the Positive and Negative Affect Schedule (PANAS) questionnaire, standardised by *Z* scores. Dietary patterns were estimated using food consumption data obtained from the European Prospective Investigation into Cancer (EPIC) Food Frequency Questionnaires (FFQ), and included the Plant-based Diet Index (PDI), Dietary Approaches to Stop Hypertension Diet (DASH), Mediterranean-DASH Diet Intervention for Neurodegenerative Delay (MIND), Original Mediterranean Diet (oMED) and Alternate Mediterranean Diet (aMED). *Results*: PDI, DASH, oMED and aMED diet scores were all significantly associated with positive mood (r_s = 0.12–0.16), but not with negative mood. Linear regression models suggested that after adjusting for potential confounders (sex and age), only the oMED and aMED diet scores were still significantly associated with positive mood (β = 0.119, p = 0.031 and β = 0.111, p = 0.048, respectively). Furthermore, the relationship between PDI diet scores and positive mood was only significant in children (β = 0.663, p = 0.003), pointing to a potential moderating effect of age in the relationship between PDI and positive mood. *Conclusion*: Adherence to oMED and aMED diets is associated with better mood in healthy adults, while the PDI diet might be more specifically associated with positive mood in children.

1. Introduction

Emerging evidence indicates that plant-based dietary patterns may have a positive impact on mental health. For instance, a recent *meta*-analysis concluded that healthy dietary patterns (defined as high vegetables and fruits intake or Mediterranean diet) were associated with less internalising and depressive symptoms in children and adolescents,[1] while another *meta*-analysis has suggested that dietary interventions (including following a high vegetables and fruits diet, Mediterranean diet or low-calorie diet) reduced depressive symptoms in adults.[2] However, to date very few studies have focused on the association between diet and general mood state in non-clinical populations. Moreover, most existing studies have focused on older people, with very few investigating the relationship between diet and mood in young individuals. This is important as a recent systematic review highlighted emerging adulthood (18–29 years) as a critical period for both mental health and diet quality,[3] therefore pointing to this population as an optimal target for prevention strategies.

Many definitions of what constitutes a healthy dietary pattern have been proposed, although generally a healthy diet is considered as predominantly plant-forward, with high

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intake of vegetables, fruits, wholegrains, and fish, and limited intake of other animal-based foods.[4] Existing systematic reviews and *meta*-analyses have summarised the relationship between fruits and vegetables consumption and mood disorders, with a main focus on depression.[5–7] For instance, a *meta*-analysis of four cohort and seven cross-sectional studies showed that higher consumption of fruits and vegetables was negatively associated with the risk of depression in a community population, with a pooled risk ratio (95%CI) of depression for the highest *versus* lowest category of fruit and vegetable intake being 0.86 (0.81, 0.91) and 0.89 (0.83, 0.94), respectively.[5] A more recent systematic review of observational studies indicated that total intake of fruits and vegetables may protect against adults' depressive symptoms.[6] However, with an emphasis on fruits and vegetables only, these studies did not include other widely consumed plant foods which may have beneficial effects, such as wholegrains, legumes or nuts.

The Mediterranean diet, which is rich in fruit and vegetables, wholegrains, legumes, nuts, fish, white meats, and olive oil is currently considered one of the most important healthy dietary models worldwide.[8] Although a recent review of clinical trials indicated that the Mediterranean diet may be potentially protective for mental health,[8] a recent *meta*-analysis found that adherence to the Mediterranean diet could only reduce the likelihood of depression in 9 out of 14 observational studies (overall odds ratio = 0.72; 95% CI, 0.60–0.87), and not in the other five (overall hazard ratio = 0.95; 95% CI, 0.79–1.16).[9] Similarly, the Dietary Approaches to Stop Hypertension (DASH) diet, originally developed to prevent hypertension,[10] has also been associated with a lower risk of depression, in both an intervention[11] and an observational study,[12] possibly due to its high intake of wholegrains, vegetables, fruits, and reduced-fat dairy products. Furthermore, the combination of the DASH and the Mediterranean diet has been proposed as the MIND diet (Mediterranean-DASH Diet Intervention for Neurodegenerative Delay), characterised by higher intake of berries and green leafy vegetables and lower intake of animal-based and high saturated fat foods.[13] Interestingly, a community-based study of older people (mean age 81.4 years, SD = 7.2), suggested that the MIND diet was more predictive of slowing cognitive decline than either the DASH or the Mediterranean diets.[13] This is in agreement with the findings from three other studies comparing the MIND and DASH diets, showing a significant association between better cognitive performance and adherence to the MIND diet but not to the DASH diet.[14–16]

To date no existing studies have compared the associations between different plant-based dietary patterns and mood in healthy individuals. Here, we directly compared the relationship between the adherence to five plant-based diets, including the DASH, MIND and Mediterranean diets, and current mood in a group of healthy individuals. We hypothesised that higher adherence to these plant-based dietary patterns is associated with better mood after adjusting for potential confounders.

2. Materials and methods

2.1. Study population

We analysed individual participant-level baseline data from six studies assessing different dietary interventions in individuals from the general population. All studies were conducted in the Department of Nutritional Sciences of King's College London between 2018 and 2021. Although the studies involved different dietary interventions, in this analysis we use standard measures of habitual dietary patterns and current mood data obtained at baseline before these interventions were started. Studies had substantial overlap in their basic protocol allowing their joint analysis for this report. All studies were conducted in accordance with the guidelines of the Declaration of Helsinki and approved by King's College London Ethics Committee (HR-18/19-8999, HR-18/19-9036, HR-17/18-5338, HR-18/19-9091, HR-17/18-5353, HR-17/18-5703). The trials were registered at ClinicalTrials.gov as NCT04179136, NCT03995602, NCT03592966, NCT04084457, NCT03573414, and NCT03553225, respectively. Written informed consent was provided by all participants.

Participants who fulfilled the following criteria were included in the analyses: (1) completed both dietary intake and mood assessments; (2) females whose daily intake was between 500–3500 kcal and males whose daily intake was between 800–4000 kcal; (3) within two standard deviations (SD) of the mean of Energy intake/Basal metabolic rate (EI/BMR), which is also applicable in children.[17] The selection process is shown in Fig. 1. Participants' health was ascertained in a routine clinical physical examination and with a medical history questionnaire. Common to all 6 studies, participants were excluded at screening if they had (1) medical history of cardiovascular disease, including coronary artery disease, cerebrovascular disease, and peripheral artery disease; (2) hypertension (≥140 mmHg systolic blood pressure and ≥90 mmHg diastolic blood pressure); (3) medical history of diabetes melli-

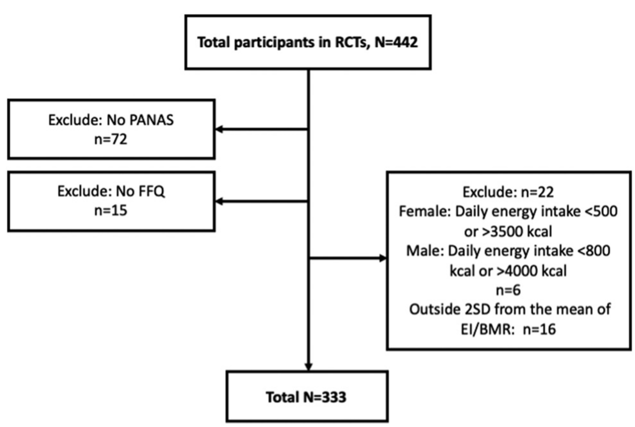

Fig. 1 Study participant selection process. RCTs: randomised controlled trials; PANAS: the positive and negative affect schedule; FFQ: food frequency questionnaires; EI/BMR: energy intake/basal metabolic rate.

tus, metabolic syndrome, terminal renal failure or malignancies; (4) abnormal heart rhythm (lower or higher than 60–100 bpm; (5) smoked an inconsistent amount of cigarettes every day; (6) lost more than 10% of their weight in the past 6 months or were, currently on a diet; (7) not willing to maintain their normal eating/drinking habits and exercise habits over the duration of the study; (8) pregnant or planning to become pregnant in the next 6 months.

2.2. Mood assessment

The Positive and Negative Affect Schedule – Short Form (PANAS – SF) and PANAS – Children (PANAS – C) were used to assess current mood in the morning of each study visit. The PANAS – SF is a 20-item (10 positive and 10 negative mood states),[18] and PANAS – C is a 30-item (15 positive and 15 negative mood states) self-report measures of Positive Affect (PA) and Negative Affect (NA).[19] Participants were asked to rate the degree to which they were currently experiencing the state described in each item, on a five-point Likert scale (Very slightly or not at all, A little, Moderately, Quite a bit, Extremely). Positive and negative item ratings were summed to calculate an overall positive affect score and negative affect score, ranging from 10–50 for PANAS – SF and 15–75 for PANAS – C, with lower scores indicating lower levels of positive or negative affect. All scores were standardised to Z scores to allow comparability.

2.3. Habitual dietary intake assessment

The European Prospective Investigation into Cancer Food Frequency Questionnaire (EPIC FFQ) was used to assess participants' dietary intake. Participants completed this 130-item semiquantitative questionnaire about their habitual diet in the past year.[20] Participants were asked to report the frequency of consumption of each food item on a 9-point scale for a "medium serving" from "never or once per month" to "more than 6 times per day". Parents of children participants aged 10 years or below (n = 8) completed the questionnaire on behalf of their children. The original data of the FFQ were analysed by the FFQ EPIC Tool for Analysis (FETA) software, which exported all nutrients' daily intake and food groups' daily intake.[21]

2.4. Dietary pattern estimate

As shown in Table 1, a total of seven *a priori* habitual dietary patterns' scores were calculated based on the daily food intake from the FFQ, using concepts established by previous studies, as described below. Higher scores reflected higher adherence to each dietary pattern. For dietary patterns containing alcohol as one of the components, participants below the age of 18 years were excluded from the analysis.

2.4.1. Plant-based diet index (PDI), healthful PDI (hPDI), unhealthful PDI (uPDI). These diets contain 18 food groups based on nutrients and culinary similarities, which were grouped into three larger categories of healthy plant foods, less healthy plant foods and animal foods.[22] Intake of the 18 food groups (servings per day) was categorized into quintiles (Q), and each quintile was assigned a score between 1 and 5. For the PDI, healthy and less healthy plant food groups were given positive scores, whereas animal food groups were given reverse scores (Table S1†). For the hPDI, positive scores were assigned to healthy plant food groups and reverse scores to less healthy plant and animal food groups. For the uPDI, positive scores were assigned to less healthy plant food groups and reverse scores to healthy plant and animal food groups. All three dietary patterns' scores ranged from 18 to 90.

2.4.2. Dietary approaches to stop hypertension diet index (DASH). The DASH dietary pattern scores were estimated using the method of Fung *et al.*[23] For fruits, vegetables, nuts and legumes, low-fat dairy products, and wholegrains, positive scores were given to study participants based on their quintiles of intake. For sweetened beverages, salt, red and processed meats, participants were assigned reverse scores of their quintiles of intake. Finally, a DASH score for each participant was calculated by adding the scores of the eight components and ranged from 8 to 40. Detailed compounds in each food groups are shown in Table S2.†

2.4.3. Mediterranean-DASH intervention for neurodegenerative delay diet index (MIND). The MIND diet index consists of ten brain-healthy food groups (green leafy vegetables, other vegetables, nuts, berries, beans, wholegrains, fish, poultry, olive oil, and wine) and five brain-unhealthy food groups (red meats, butter and stick margarine, cheese, pastries and sweets, and fried/fast food).[13] If olive oil was indicated as the primary oil used at home by the participant, it was given a score of 1; otherwise, it received a 0. All other diet score components were assigned a concordance score of 0, 0.5, or 1, based on the consumption frequency of each food group. The total MIND diet index was calculated by adding all 15 component scores (Table S3†) and ranged from 0 to 10.

2.4.4. Original mediterranean diet index (oMED). Trichopoulou and colleagues developed a scale indicating the degree of adherence to the traditional Mediterranean diet, which was amended to add fish intake.[24] Each of the nine components was given a value of 0 or 1, with a sex-specific median as the cut-off. Participants whose consumption was below the median for health-beneficial components (vegetables, legumes, fruits and nuts, cereal, and fish) were assigned a score of 0, while those whose consumption was at, or above the median were given a value of 1. A reverse score was assigned for health-detrimental components (meat and dairy products). For ethanol, a score of one was assigned to males who consumed 10–50 g d^{-1} and to females who consumed 5–25 g d^{-1}. For fat intake, the ratio of monounsaturated to saturated fatty acids was used as the component score. Eventually, the total oMED scores ranged from 0 to 9 (detailed compounds in each food groups are shown in Table S4†).

2.4.5. Alternate mediterranean diet index (aMED). The aMED score differs from the oMED in that it excludes potato products from the vegetable group, subdivides fruit and nuts into two groups, eliminates the dairy group, only includes whole-grain products, only includes red and processed meats

Table 1 Dietary components for the PDI, DASH, MIND, Mediterranean diet scores

PDI	hPDI	uPDI	DASH	MIND	oMED	aMED
Fruits	Fruits	Fruits [a]	Fruits	Berries	Fruits and nuts	Fruits
Vegetables	Vegetables	Vegetables [a]	Vegetables	Green leafy vegetables	Vegetables, including potatoes	Vegetables
Nuts	Nuts	Nuts [a]	Nuts and legumes	Other vegetables, including potatoes	Legumes	Legumes
Legumes	Legumes	Legumes [a]	Whole grains	Whole grains	Cereals	Whole grains
Whole grains	Whole grains	Whole grains [a]	Low-fat dairy	Cheese[a]	Dairy [a]	Nuts
Vegetable oils	Vegetable oils	Vegetable oils [a]	Red and processed meats [a]	Butter, margarine[a]	Meat [a]	Red and processed meat [a]
Tea & coffee	Tea & coffee	Tea & coffee [a]	Sweetened beverages [a]	Olive oil	Fish	Fish
Fruit juices	Fruit juice [a]	Fruit juice	Sodium [a]	Nuts	Alcohol/ethanol [a]	Alcohol/ethanol [a]
Refined grains	Refined grains [a]	Refined grains		Fish (not fried)	Ratio of monounsaturated fatty acids to saturated fatty acids	Ratio of monounsaturated fatty acids to saturated fatty acids
Potatoes	Potatoes [a]	Potatoes		Beans		
Sugar sweetened beverages	Sugar sweetened beverages [a]	Sugar sweetened beverages		Poultry		
Sweets & desserts	Sweets & desserts [a]	Sweets & desserts		Red meat and products [a]		
Animal fat [a]	Animal fat [a]	Animal fat [a]		Fast fried foods [a]		
Dairy [a]	Dairy [a]	Dairy [a]		Pastries & sweets [a]		
Egg [a]	Egg [a]	Egg [a]		Wine [a]		
Fish [a]	Fish [a]	Fish [a]				
Meat [a]	Meat [a]	Meat [a]				
Misc. animal-based foods [a]	Misc. animal-based foods [a]	Misc. animal-based foods [a]				

[a] Reversed scoring components. Abbreviations: PDI, plant-based diet index; hPDI, healthful plant-based diet index; uPDI, unhealthful plant-based diet index; DASH, dietary approaches to stop hypertension diet; MIND, mediterranean-DASH intervention for neurodegenerative delay (MIND) diet; oMED, original mediterranean diet index; aMED, alternate mediterranean diet index.

in the meat group, and it assigns 1 point to alcohol intake between 5 and 15 g d^{-1}.[25] These changes were made based on European dietary patterns and eating habits that have been linked to a lower risk of chronic disease in epidemiological studies. The range of aMED index was from 0 to 9 (Table S5†).

2.5. Sociodemographic and lifestyle factors

Sociodemographic and lifestyle information were collected on participants' age, sex, ethnicity, height, weight, smoking history, alcohol use (units per week) and physical activity. Ethnicity was categorised into White (English, Welsh, Scottish, Northern Irish or British, Irish Gypsy or Irish Traveller, Roma, Any other White background), Black (Caribbean, African, Any other Black, Black British, or Caribbean background), Asian (Indian, Pakistani, Bangladeshi, Chinese, Any other Asian background), Mixed (White and Black Caribbean, White and Black African, White and Asian, Any other Mixed or multiple ethnic background) and Other ethnic group (Arab and Any other ethnic group) according to the list of ethnic groups from the 2021 Census of England and Wales.[26] Body mass index (BMI) was calculated as weight divided by height squared (kg m^{-2}) and participants were grouped into underweight (<18.5 kg m^{-2}), healthy weight (18.5–24.9 kg m^{-2}; 18.5–23.0 kg m^{-2} for Asian), overweight (25.0–29.9 kg m^{-2}; 23.0–27.5 kg m^{-2} for Asian) and obese (≥30.0 kg m^{-2}; ≥27.5 kg m^{-2} for Asian) according to WHO standards for different ethnic groups.[27,28] Children (aged under 18) were categorised according to BMI-for-age percentiles, that is underweight (on the 2nd centile or below), healthy weight (between the 2nd and 91st centiles), overweight (91st centile or above) and obese (98th centile or above). Physical activity was evaluated in participants aged 15 and above with the International Physical Activity Questionnaire (IPAQ) and participants were categorised into having low, moderate or high levels of activity.[29] Participants with high physical activity level engaged in (1) vigorous intensity activity on at least 3 days a week, achieving a minimum total physical activity of at least 1500 metabolic equivalent minutes (MET-minutes), OR (2) 7 or more days a week for any combination of walking, moderate intensity or vigorous intensity activities achieving a minimum total physical activity of at least 3000 MET-minutes. Those with moderate physical activity level engaged in (1) 3 or more days of vigorous intensity activity per week and/or walking of at least 30 minutes per day, OR (2) 5 or more days of moderate intensity activity per week and/or walking of at least 30 minutes per day, OR (3) 5 or more days a week of any combination of walking, moderate intensity or vigorous intensity activities achieving a minimum total physical activity of at least 600 MET-minutes. Participants not meeting any of the criteria for either Moderate or High levels of physical activity, were considered to have low physical activity levels.

2.6. Statistical analysis

All statistical analyses were performed using IBM SPSS Version 26.0 and the significance level was set at $p < 0.05$. Descriptive statistics were generated for sociodemographic and lifestyle characteristics and standardised mood scores were reported as mean and standard deviation (SD). Spearman correlation was used to test the association between dietary pattern scores and mood. We used a linear regression model to explore the individual effects of dietary patterns on mood after adjusting for potential confounders. Confounders were entered into the regression models if they had a marginally significant association with mood scores ($p < 0.1$). Moderation analyses and stratified analyses were conducted to test the role of age in the relationship between dietary patterns and mood.

3. Results

A total of 333 participants, 19 aged 8–17 and 314 aged 18–79, were included in our study. Participants characteristics, as well as means and standard deviations (SD) of standardised positive and negative mood scores are presented in Table 2. The age of participants ranged from 8 to 79 years (mean 40.6, SD 19.9). Two thirds of participants were female and nearly three fourths were white. Average alcohol consumption was 3.0 units per week and around 20% participants were former smokers.

Table 2 PANAS scores by participants' characteristics (N = 333)

Characteristics	N (%)	Positive mood Mean (SD)	Negative mood Mean (SD)
Sex			
Male	113 (33.9)	0.15 (0.93)	−0.07 (0.95)
Female	220 (66.1)	−0.08 (1.02)	0.04 (1.02)
Ethnicity			
White	246 (74.5)	0.03 (0.96)	−0.05 (0.90)
Black	14 (3.5)	0.64 (0.91)	0.17 (1.10)
Asian	57 (17.5)	−0.38 (1.07)	0.14 (1.18)
Mixed	16 (4.5)	0.41 (0.96)	0.14 (1.52)
Age group			
<18 years	19 (5.7)	−0.06 (0.98)	0.60 (1.41)
18–25 years	80 (24.0)	−0.28 (1.02)	0.02 (0.90)
26–45 years	105 (31.5)	−0.08 (0.95)	0.03 (1.03)
46–64 years	54 (16.2)	0.17 (0.91)	−0.03 (1.10)
≥65 years	75 (22.5)	0.31 (1.02)	−0.20 (0.79)
Smoking history			
Yes	71 (21.3)	−0.04 (0.88)	−0.04 (0.92)
No	262 (78.7)	0.01 (1.03)	−0.01 (1.02)
Alcohol use			
<3 units per week	221 (66.4)	−0.01 (1.05)	−0.04 (0.99)
≥3 units per week	112 (33.6)	0.02 (0.90)	0.09 (1.02)
BMI			
Underweight	15 (4.5)	0.10 (1.15)	0.24 (1.00)
Healthy weight	221 (66.4)	−0.06 (0.97)	0.01 (1.01)
Overweight	76 (22.8)	0.06 (1.02)	−0.18 (0.79)
Obesity	21 (6.3)	0.28 (1.11)	0.34 (1.37)
Physical activity (MET per week)			
Low	10 (3.0)	−0.35 (1.08)	−0.22 (0.75)
Moderate	78 (23.4)	−0.05 (0.97)	−0.05 (1.15)
High	221 (66.4)	0.01 (1.00)	0.00 (0.97)

3.1. Dietary patterns

The means (SDs) of all dietary patterns by participants' characteristics are shown in Table 3. Females had a higher score in hPDI, DASH, MIND and aMED, and a lower uPDI score than males ($p < 0.05$). Additionally, compared to younger people below the age of 45, older people aged 65 or above had a higher score in hPDI and DASH, and a lower score in uPDI ($p < 0.05$), while older people aged 65 or above had a higher score in aMED than younger people aged below 25 ($p < 0.05$). Similarly, participants with high physical activity levels had a higher score in hPDI, DASH and oMED, and a lower uPDI score than participants with moderate physical activity levels ($p < 0.05$).

Correlations between different dietary patterns are shown in Fig. 2. We found significant correlations between different dietary pattern indices, with aMED and oMED having the strongest correlation ($r_s = 0.845$, $p < 0.001$), while the PDI and uPDI had the weakest correlation ($r_s = 0.114$, $p = 0.037$).

3.2. Relationship between dietary patterns and mood

Spearman correlation analyses revealed that a higher positive mood score was significantly associated with higher scores in the PDI ($r_s = 0.120$, $p = 0.028$), DASH ($r_s = 0.122$, $p = 0.026$), oMED ($r_s = 0.130$, $p = 0.021$) and aMED ($r_s = 0.157$, $p = 0.005$) diets, but not with negative mood scores (Table 4). There was no correlation between the uPDI, hPDI, and MIND dietary patterns and either positive or negative mood scores. As shown in Table 5, the results of simple regression models were consistent with the Spearman correlations, which indicated that aMED has the highest correlation with positive mood compared to DASH and oMED patterns.

In a second step, we repeated the analysis adjusting for potential confounders. Since sex and age were both significantly associated with positive mood, we run a linear regression model adjusting for sex and age. As there was no significant association between BMI or physical activity and either positive or negative mood, these factors were not considered among potential confounders. Results indicated that only the oMED and aMED scores retained significant independent effects on positive mood scores ($p = 0.031$ and 0.048, respectively), after adjusting for sex and age (Table 6). In contrast, the effects of PDI and DASH on positive mood were no longer significant.

To investigate the association between food groups in each dietary pattern (Tables S1–S5†) and current mood scores, we conducted a series of Spearman correlations. We found that intake of vegetables and fruits in PDI, DASH, oMED and aMED, as well as the ratio of monounsaturated fatty acids to saturated fatty acids in oMED and aMED, were all significantly correlated with positive mood, with r_s ranging from 0.114 to 0.152 (Table S6†). Notably, the intake of vegetables in oMED had a higher correlation with positive mood than intake of vegetables in aMED, with r_s being 0.152 ($p = 0.007$) and 0.131 ($p = 0.020$) respectively. Interestingly, the higher intake of berries

Table 3 Diet pattern scores by participants' characteristics

	PDI (N = 333)			hPDI (N = 333)			uPDI (N = 333)			DASH (N = 333)			MIND (N = 314)			oMED (N = 314)			aMED (N = 314)		
	Mean (SD)	t/F value	p value	Mean (SD)	t/F value	p value	Mean (SD)	t/F value	p value	Mean (SD)	t/F value	p value	Mean (SD)	t/F value	p value	Mean (SD)	t/F value	p value	Mean (SD)	t/F value	p value
Sex		1.348	0.179		−3.020	0.003		2.967	0.003		−3.136	0.002		−3.072	0.002		−1.446	0.149		−2.052	0.041
Male	51.1 (6.7)			50.2 (8.7)			52.8 (6.7)			23.5 (5.3)			8.5 (1.3)			4.1 (1.9)			4.1 (2.2)		
Female	50.1 (6.1)			53.1 (8.2)			50.4 (7.1)			25.4 (4.6)			9.0 (1.5)			4.4 (1.7)			4.6 (2.0)		
Age group		0.089	0.986		10.298	<0.001		6.784	<0.001		8.935	<0.001		0.092	0.964		0.660	0.577		2.850	0.038
<18 years	49.7 (5.4)			42.7 (7.2)			54.9 (6.5)			20.8 (4.6)			—			—			—		
18–25 years	50.4 (7.0)			51.1 (9.2)			52.0 (7.5)			23.9 (5.0)			8.9 (1.5)			4.3 (1.8)			4.2 (2.3)		
26–45 years	50.5 (5.8)			52.0 (8.5)			52.6 (6.6)			24.2 (5.1)			8.8 (1.5)			4.1 (1.9)			4.2 (2.1)		
46–64 years	50.7 (6.0)			52.6 (6.7)			50.4 (7.1)			25.6 (4.3)			8.9 (1.4)			4.4 (1.5)			4.4 (1.9)		
≥65 years	50.4 (6.8)			55.5 (7.1)			48.1 (6.2)			27.0 (3.9)			8.9 (1.5)			4.5 (1.9)			5.0 (1.9)		
BMI		0.716	0.543		1.403	0.242		0.598	0.617		1.048	0.371		0.835	0.476		0.304	0.823		0.231	0.875
Underweight	50.3 (4.8)			50.9 (9.9)			53.4 (9.3)			22.7 (5.3)			8.8 (1.0)			4.6 (1.7)			4.1 (2.2)		
Ideal	50.5 (6.3)			52.8 (8.6)			51.2 (6.9)			25.0 (5.0)			8.9 (1.5)			4.4 (1.8)			4.5 (2.0)		
Overweight	49.8 (6.7)			50.8 (8.1)			50.7 (7.1)			24.6 (4.8)			8.7 (1.4)			4.2 (1.8)			4.4 (2.2)		
Obese	52.0 (6.0)			51.0 (7.6)			51.3 (6.9)			24.8 (3.6)			8.5 (0.9)			4.1 (1.9)			4.2 (1.9)		
Physical activity		0.297	0.743		4.976	0.007		4.450	0.012		4.929	0.008		0.646	0.525		4.246	0.015		3.338	0.037
Low	49.4 (7.6)			48.2 (5.6)			54.0 (5.4)			21.8 (4.5)			8.9 (1.6)			3.7 (1.9)			3.6 (1.8)		
Moderate	50.2 (6.2)			50.3 (7.3)			53.2 (6.3)			23.6 (5.1)			8.7 (1.5)			3.8 (1.7)			3.9 (2.0)		
High	50.6 (6.3)			53.3 (8.8)			50.6 (7.4)			25.3 (4.9)			8.9 (1.5)			4.5 (1.8)			4.6 (2.1)		

Abbreviations: PDI, plant-based diet index; hPDI, healthful plant-based diet index; uPDI, unhealthful plant-based diet index; DASH, dietary approaches to stop hypertension diet; MIND, mediterranean-DASH intervention for neurodegenerative delay (MIND) diet; oMED, original mediterranean diet index; aMED, alternate mediterranean diet index.

Fig. 2 Spearman correlations between dietary patterns. PDI: plant-based diet index; hPDI: healthful plant-based diet index; uPDI: unhealthful plant-based diet index; DASH, dietary approaches to stop hypertension diet; MIND: mediterranean-DASH intervention for neurodegenerative delay (MIND) diet; oMED: original mediterranean diet index; aMED: alternate mediterranean diet index.

in MIND was significantly correlated with less negative mood ($r_s = -0.113$, $p = 0.045$).

3.3. Moderating effect of age in the relationship between PDI and mood

There was a significant interaction between age and PDI dietary patterns and positive mood, with the effect of PDI dietary scores on positive mood decreasing with increasing age ($p < 0.05$). Furthermore, in a stratified analysis by age groups we found that PDI has significantly positive effect on positive mood only in children ($\beta = 0.663$, $p = 0.003$).

3.4. Sensitivity analysis

Given the limited number of existing publications using the FETA program to estimate dietary food intake in adolescents and children,[30,31] we performed a sensitivity analysis excluding participants under the age of 18 years ($n = 19$). Since the children sample was excluded when calculating MIND, oMED and aMED dietary scores, we only performed the sensitivity analysis for the other dietary patterns (PDI, hPDI, uPDI and DASH). We found that most results did not change substantially (Tables S6–S9†). Consistent with the results shown in the analysis stratified by age, we found that PDI was no longer significantly correlated with positive mood when excluding children ($r_s = 0.090$, $p = 0.110$), compared to the significant correlation when including children ($r_s = 0.120$, $p = 0.028$). This suggests that the PDI dietary pattern might be more important for children's mood than adults'.

4. Discussion

This is the first study that has evaluated the association between different plant-rich dietary patterns and current mood in healthy individuals. Our main finding is that among plant-rich dietary patterns, only the original and alternate Mediterranean diet is significantly associated with better positive mood, once potential confounders are taken into account. We also found that the PDI dietary pattern is only significantly associated with positive mood in children and not in adults, pointing to a potential moderating effect of age in the relationship between PDI and current mood.

In agreement with previous cross-sectional studies, our results suggest a significant positive relationship between a Mediterranean diet and positive mood. Of note, a recent *meta*-analysis has reported that cross-sectional, but not longitudinal studies found that adherence to the Mediterranean diet

Table 4 Spearman correlations between dietary patterns and mood

	PDI	hPDI	uPDI	DASH	MIND	oMED	aMED
Positive mood	0.120*	0.041	−0.086	0.122*	0.051	0.130*	0.157**
Negative mood	−0.018	−0.023	0.074	−0.061	−0.070	−0.073	−0.059

*$p < 0.05$; **$p < 0.01$.

Table 5 Simple linear regression analysis between dietary patterns and positive mood

	Model 1 (PDI)	Model 2 (hPDI)	Model 3 (uPDI)	Model 4 (DASH)	Model 5 (MIND)	Model 6 (oMED)	Model 7 (aMED)
Standardized coefficient (beta)	0.092	0.047	−0.075	0.120	0.051	0.121	0.128
P value	0.094	0.394	0.169	0.029	0.370	0.033	0.023
R^2	0.008	0.002	0.006	0.014	0.003	0.015	0.016

Abbreviations: PDI, plant-based diet index; hPDI, healthful plant-based diet index; uPDI, unhealthful plant-based diet index; DASH, dietary approaches to stop hypertension diet; MIND, mediterranean-DASH intervention for neurodegenerative delay (MIND) diet; oMED, original mediterranean diet index; aMED, alternate mediterranean diet index.

Table 6 Influencing factors of positive mood score: linear regression analysis

	Model 1 (PDI)			Model 2 (DASH)			Model 3 (oMED)			Model 4 (aMED)		
	B (95% CI)	β	p	B (95% CI)	β	p	B (95% CI)	β	p	B (95% CI)	β	p
Sex[a]	−0.250 (−0.473, −0.028)*	−0.199	0.028	−0.293 (−0.518, −0.068)*	−0.139	0.011	−0.255 (−0.486, −0.024)*	−0.119	0.031	−0.261 (−0.493, −0.028)*	−0.122	0.028
Age	0.010 (0.005, 0.015)***	0.201	<0.001	0.009 (0.003, 0.014)**	0.177	0.002	0.011 (0.005, 0.016)***	0.204	<0.001	0.010 (0.004, 0.016)***	0.193	<0.001
Diet pattern score	0.013 (−0.004, 0.029)	0.081	0.132	0.019 (−0.004, 0.042)	0.093	0.100	0.066 (0.006, 0.126)*	0.119	0.031	0.053 (0.001, 0.106)*	0.111	0.048
R^2	0.059			0.060			0.069			0.066		
Adjusted R^2	0.050			0.051			0.060			0.057		
F	6.824***			6.981***			7.164***			7.361***		

[a] Reference group: male; $*p < 0.05$; $**p < 0.01$; $***p < 0.001$. Abbreviations: PDI, plant-based diet index; DASH, dietary approaches to stop hypertension diet; oMED, original Mediterranean diet index; aMED, alternate Mediterranean diet index.

reduced the likelihood of depression,[9] pointing to the need of further longitudinal studies to establish causality and direction of effect.

The mechanism underlying the association between the Mediterranean diet and positive mood may involve the components of the diet, including fruits, vegetables, wholegrains, fish and nuts as well as the restricted consumption of red and processed meat. Emerging evidence has suggested that fruits, vegetables, and wholegrains contain high levels of potential beneficial compounds like polyphenols, which are associated with lower risk of inflammatory diseases, as polyphenols could downregulate some components of the inflammatory system.[32,33] Evidence also suggests that higher dietary intake of polyphenols is inversely associated with depressive symptoms.[34,35] For example, findings from a recent clinical trial suggested that the adoption of a polyphenol-rich diet could potentially lead to beneficial effects in improving mental health, especially depressive symtoms in hypertensive participants.[36] However, more studies are needed to confirm the benefits of a polyphenol-rich dietary pattern on mental health outcomes, further revealing the mechanism of beneficial effects of Mediterranean diets. In addition, fish and nuts are main dietary sources of omega-3 fatty acids, which could reduce inflammatory process and may be beneficial to depressive symptoms,[37] while red and processed meats could increase inflammation and increase the likelyhood of developing depressive symptoms.[38,39]

The DASH diet has been suggested as an effective approach to improve cognition and psychological disorders in previous studies.[40,41] In an 11-year longitudinal study higher adherence to the DASH diet was associated with better cognition in 3831 people who were over 65 years of age,[42] and with better mood in an intervention study conducted in 95 postmenopausal women.[11] This is probably due to its neuroprotective components, including high intake of vegetables and fruits which are rich in B and C vitamins and polyphenols, which are suggested to help with mental health problems.[43–45] However, in our study, the positive association between the DASH diet index and positive mood was no longer significant once sex and age were included as covariates in the linear regression model. This might be explained by the significant differences in the distribution of DASH scores across sex and age groups in our sample, with females and older adults having a higher DASH score than males and young adults.

While the MIND diet has been associated with slower decline in cognitive abilities,[46] and found to be more predictive of slowing cognitive decline than either the DASH or Mediterranean diets,[13,47] we did not find any correlation between the MIND diet and mood. This finding is in line with two previous studies in adults in their 30s, which also did not find any relationship between adherence to the MIND diet and reduced risks of stress, anxiety and depression.[48,49] However, a prospective cohort study in adults in their late 70s found that the MIND diet score was associated with lower rates of depression over a 6.5 years of follow-up.[50] More studies are clearly needed to evaluate the true association between the MIND diet and mood, possibly on different age groups.

Interestingly, we also did not find any significant association between either hPDI and uPDI and mood, which is in contrast with previous research. For example, a cross-sectional study of 230 Iranian patients with diabetes with a mean age of 59.9 years indicated that greater adherence to uPDI could actually increase the risk of depression, anxiety and stress.[51] However, a cross-sectional study of 401 female college students in Saudi Arabia did not find any association between uPDI and stress, but reported that hPDI was associated with lower levels of psychological stress.[52] Interestingly, both of these studies were conducted in Middle Eastern populations, while the majority of our participants were white British, and it is possible that differences in dietary habits across different ethnic groups explain these inconsistencies in results. Furthermore, our results pointed to a role for age, indicating that the effect of PDI on positive mood might be more beneficial to children than adults. One explanation might be that the calculation of PDI (18 food groups) might be more informative, inclusive and comprehensive for assessing children's diet, which makes children's PDI diet score more sensitive to children's mental health outcomes. For instance, a case-control study in 345 Iranian children suggested that PDI diet was associated with a lower risk of attention deficit/hyperactivity disorder.[53] However, there are still very limited studies on children, therefore, more studies are needed to explain the associations between PDI and children' mental health.

Our study also compared the components of different dietary patterns and found that fruits, nuts, legumes, and vegetables were shared components of PDI, DASH, oMED and aMED. Although these dietary indices were highly correlated with each other, they were differently correlated with mood scores. Higher intake of fruits, vegetables and the ratio of monounsaturated fatty acids and saturated fatty acids explained the positive association between diet and positive mood. Therefore, these components could be the key for future research aimed at identifying the most appropriate dietary pattern for better mood, and clinical studies could consider them in dietary interventions. Some systematic reviews and *meta*-analyses have confirmed the relationship between fruits and vegetables consumption and mood disorders,[6,7] however, results from another systematic review found that these effects were inconsistent when vegetable consumption was analysed independently.[54] Also, some large-scale prospective cohort studies have demonstrated that a monounsaturated fatty acid -rich diet could reduce the risk of developing depression.[55–57] However, the potential molecular mechanisms explaining this relationship still remain to be investigated by future studies and to determine the role of specific components of Mediterranean diet in the outcomes of mental health.

There are a number of strengths and limitations that should be considered when interpreting our results. To our knowledge, this is the first study investigating the association between different prior habitual dietary patterns' indices and current mood in healthy individuals across a broad age range. It is also the first study exploring the moderating effect of age in this association. Nonetheless, possible recall bias due to the retrospective dietary assessments is one of its major limitations, which we minimised by data cleaning and strict inclusion criteria. Also, sex and ethnicity were not balanced in our sample, and this may limit the generalisability of our results. Furthermore, the EPIC-FFQ questionnaire was designed for adults and further validated in adolescents, but it has not yet been validated in younger children. Thus, the results in children should be interpreted with caution as more studies are needed to validate the EPIC-FFQ questionnaire in this age group. Similarly, applying dietary scores to adolescents and children needs to be investigated further, as young people require specific nutrients for healthy growth. However, some studies have applied these dietary scores in children, including PDI, DASH and Mediterranean dietary scores.[53,58,59] Additionally, we performed a sensitivity analysis to try and minimise this effect. Finally, due to the cross-sectional nature of the study, causality could not be inferred, and further longitudinal studies are needed to address the exact relationship between dietary patterns and mood.

5. Conclusions

Our study has highlighted that the Mediterranean diet may have a protective effect on current mood in healthy adults across a wide range of age, and that this diet may be more beneficial than other healthy plant-rich dietary patterns such as DASH or MIND in mood disorders. More longitudinal studies are needed to reveal the direction of causality between a Mediterranean diet and positive mood. Similarly, the specific association between PDI dietary pattern and positive mood in children needs to be replicated in a larger sample. Still, our findings point to the potential that key components of the Mediterranean diet such as fruits, vegetables, nuts and unsaturated fatty acids may have in dietary interventions aimed at improving mood symptoms, while providing a strong basis for further investigation of the biological mechanisms that can underly their potential beneficial effects.

Author contributions

Conceptualisation, X.M., C.N, P.D. and A.R.M.; data curation, X.M., Y.L. and Y.X.; data analysis, visualisation and writing – original draft, X.M.; methodology development, Y.L., Y.X., A.R. M. and R.G.; statistics advice, A.J.L.; writing – review and editing and supervision, C.N, P.D. and A.R.M.; writing – review, R.G. and C.W.; project administration and funding acquisition, A.R.M. All authors have read and agreed to the published version of the manuscript.

Informed consent statement

Written or digital informed consent was obtained from all study participants.

Data availability statement

The datasets generated and analysed in the study are available from the corresponding author upon reasonable request.

Conflicts of interest

The authors declare no conflict of interest.

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