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The association between dietary patterns and depressive symptoms in older adults: longitudinal evidence from the Czech Republic

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Abstract

Purpose Late-life depression is more likely to be modified by external factors, such as diet. We aimed to longitudinally assess the relationship of three dietary scores with depressive symptoms in Czech older adults. **Methods** We used data on 3519 participants from the Czech part of the prospective Health, Alcohol and Psychosocial factors In Eastern Europe cohort. Participants reported their depressive symptoms using the Centre for Epidemiological Studies-Depression Scale. Healthy Diet Indicator (HDI), Mediterranean Diet Score (MDS), and Eastern European Diet Score (EEDS), were calculated from a Food Frequency Questionnaire collected at baseline. Growth curve model was used to investigate the longitudinal relationship between adherence to various dietary scores and depressive symptoms. **Results** At baseline, women with high adherence to any of the three dietary scores had significantly lower depressive symptoms compared with those with low adherence (HDI: B=-0.65, 95% CI [-1.18; -0.12], MDS: -0.56 [-1.01; -0.10], EEDS: -0.88 [-1.37; -0.39]). In terms of longitudinal trajectories among women, depressive symptoms increased over time with similar slopes across low, medium and high adherence groups for HDI and MDS. However, for EEDS, high and medium adherence was associated with steeper slopes compared to low adherence. Depressive symptoms were not consistently associated with dietary patterns in men. **Conclusion** Our results suggest a relationship between adherence to healthy dietary patterns and lower depressive symptoms in Czech older women, while there was little evidence on an association in men. The Eastern European diet and its health impacts should be further evaluated.

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The association between dietary patterns and depressive symptoms in older adults: longitudinal evidence from the Czech Republic

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Abstract

Purpose

Late-life depression is more likely to be modified by external factors, such as diet. We aimed to longitudinally assess the relationship of three dietary scores with depressive symptoms in Czech older adults.

Methods

We used data on 3519 participants from the Czech part of the prospective Health, Alcohol and Psychosocial factors In Eastern Europe cohort. Participants reported their depressive symptoms using the Centre for Epidemiological Studies-Depression Scale. Healthy Diet Indicator (HDI), Mediterranean Diet Score (MDS), and Eastern European Diet Score (EEDS), were calculated from a Food Frequency Questionnaire collected at baseline. Growth curve model was used to investigate the longitudinal relationship between adherence to various dietary scores and depressive symptoms.

Results

At baseline, women with high adherence to any of the three dietary scores had significantly lower depressive symptoms compared with those with low adherence (HDI: B=-0.65, 95% CI [-1.18; -0.12], MDS: -0.56 [-1.01; -0.10], EEDS: -0.88 [-1.37; -0.39]). In terms of longitudinal trajectories among women, depressive symptoms increased over time with similar slopes across low, medium and high adherence groups for HDI and MDS. However, for EEDS, high and medium adherence was associated with steeper slopes compared to low adherence. Depressive symptoms were not consistently associated with dietary patterns in men.

Conclusion

Our results suggest a relationship between adherence to healthy dietary patterns and lower depressive symptoms in Czech older women, while there was little evidence on an association in men. The Eastern European diet and its health impacts should be further evaluated.

Key words: depression, depressive symptoms, ageing, Mediterranean diet, HAPIEE

INTRODUCTION

Late-life depression (LLD), referring to depression in adults aged 65 years and older, is becoming increasingly important as the global population continues to age. The World Health Organization (WHO) projects that by 2030, there will be up to 1.4 billion adults aged 65 years and older [1]. LLD substantially contributes to the broader burden of mental disorders, which in 2021 were the second leading cause of years lost due to disability (YLDs) in the European region, responsible for 16.9% of YLDs [2].

LLD is a multifactorial disorder determined by a complex system of modifiable and non-modifiable risk factors including sociodemographic, psychosocial, behavioral, and medical factors [3]. Manifestation of LLD may differ from the typical picture of depression in younger adults, presenting with somatization and neurocognitive symptoms [4]. The risk of depression in older adults is enhanced by the presence of medical comorbidities accumulated with age, leaving them at a higher risk of polypharmacy [5]. Moreover, older adults are less tolerant of antidepressant use due to changes in pharmacokinetics and pharmacodynamics, and their treatment options might be limited due to aforementioned polypharmacy [6]. Furthermore, LLD might complicate and prolong treatment of other somatic diseases and therefore contributes to greater health care costs [7].

Previous studies on the prevalence of LLD have revealed significant regional variations across Europe. The highest rate of LLD was observed in Southern Europe (35%) and Central and Eastern Europe (CEE) (32%), while the lowest rates were seen in Scandinavia (17%) [8]. Based on dominance analysis, these differences were attributed to somatic health and physical and cognitive functioning, which is in line with findings from a previously conducted cohort study among older women [3]. At the same time, the higher prevalence of LLD in CEE might be partially attributed to suboptimal health behaviors [4, 9]. LLD is also affected by a complex combination of poverty, comorbid health problems, and widowhood [10]. Across all age groups, the burden of depression is higher in women, including adults over 65 years of age [4].

Since health behaviors are more amenable to modifications than some other LLD risk factors, clarifying their role in preventing and reducing the burden of LLD is essential. Previous studies suggested diet as a modifiable environmental factor that could attenuate depressive symptoms (DS) or prevent the development of depression without the side effects of long-term antidepressant treatment [5]. Consuming a healthy diet is associated with a lower risk of cognitive decline in older adults; this is important since cognitive impairment is one of the core features of depression and persists even after remission [11].

Numerous dietary patterns (DP), as identified in the literature, have been shown to positively impact health. For instance, previous studies found an association between adherence to the WHO guidelines [12], represented by the Healthy Diet Indicator (HDI), and lower all-cause mortality [13, 14], as well as lower cardiovascular disease and coronary heart disease mortality [15] in older adults. In a Spanish study of adults aged 35–79 years, HDI was not associated with fewer DS, however, it was associated with lower risk of depression based on a clinical diagnosis [16]. Similarly, Mediterranean diet has been consistently recognized for its role in the prevention and lowering the burden of non-communicable chronic diseases, including depression [17, 18].

The major limitation of Mediterranean diet is the limited applicability to non-Mediterranean populations with largely different dietary habits due to cultural reasons. Given the higher burden of LLD in CEE, examining traditional DP can be particularly helpful in understanding the role of nutrition in LDD and health disparities between regions. To assess the traditional dietary habits in CEE, Stefler et al. developed the Eastern European diet score (EEDS), which reflects the consumption of nine food groups, commonly consumed by rural communities in several Eastern European countries during the 1950s and early 1960s. Their research explored the relationship between the EEDS and cardiovascular disease, cancer, and overall mortality rates in CEE, suggesting that these dietary habits may contribute to the poor health status of these populations [19].

The aim of this study was firstly to assess the relationship of three different dietary scores with LLD using prospective data from the Health, Alcohol and Psychosocial factors in Eastern Europe (HAPIEE) study, and secondly to investigate potential sex disparities in this relationship.

METHODS

Data from the Czech arm of the HAPIEE study were used for the purpose of this analysis. The design and baseline characteristics have been previously reported [20]. Briefly, the HAPIEE study is an ongoing prospective cohort study consisting of four urban cohorts established between 2002 and 2005 in Russia, Poland, Czech Republic, and Lithuania. A random sample of men and women aged 45–69 years old at baseline, stratified by sex and 5-year age groups, was selected from population registers. Only the Czech data are used in this report. The subjects were recruited from seven cities – Havířov, Karviná, Hradec Králové, Liberec, Jihlava, Kroměříž and Ústí and Labem. The subjects completed the questionnaire upon a visit at home, and subsequently attended a short examination at the clinic. Further waves of data collection were administered through postal questionnaires 4, 5, 8, 10, and 12 years after baseline.

From 4,910 individuals who reported DS at baseline and at least one further wave of data collection, persons with DS score over 10 at baseline (N=598), persons without valid food frequency questionnaire data (N=701), and persons with missing data on remaining covariates (N=92) were excluded. This resulted in an analytical sample of 3,519 participants. Dataset was transformed into a long format with 2 to 6 measurements of DS per respondent (average number of measurements 4.6). The total number of observations in the analysis was 16,295. All participants signed an informed consent form, and the study was approved by ethical committees at University College London, UK, and ethical committees at the participating centers.

Measurements

Depressive symptoms

Participants reported their DS using the Centre for Epidemiological Studies-Depression Scale including a battery of 10 statements (CES-D-10) regarding the respondent's feelings within the past week. The frequency was rated from 0=rarely/never to 3=most/all of the time and included statements were as follows: 'I felt depressed'; 'I felt all was an effort'; 'My sleep was restless'; 'I was happy' 'I felt lonely' 'People were unfriendly'; 'I enjoyed life' 'I felt sad'; 'I felt people disliked me'; 'I could not get going'. Positive items had reversed scoring. For each data collection wave, a score was calculated as the sum of all responses as long as at least 9 questions were answered; if one item was missing, the mean of the 9 completed items was multiplied by 10. The score thus ranged from 0 to 30 [21]. Cut-off score of 10 has been used to define DS as previously validated in nonclinical older adult samples [22]. In regression analysis, the DS score was kept continuous; however, the cut-off score was used as an exclusion criterion at baseline. CES-D-10 was collected at six time points.

Dietary assessment

The variables needed for constructing the dietary scores were obtained from food frequency questionnaire (FFQ) data collected at baseline. Using a 9-point scale with a range of choices from "never or less than once per month" to "six or more times per day", Czech participants were asked about consumption of 136 dietary items in the preceding three months [19]. Daily intakes of the different food groups were calculated using the EFSA food classification system and country-specific portion sizes. To assess the validity of the FFQ regarding fruit, vegetable and micronutrient intake data, correlation with plasma biomarkers was measured in a central laboratory (Clinical Trial Service Unit Oxford, UK) in a random subsample of study participants, and correlation coefficients indicated mostly adequate validity [15].

Healthy Diet Indicator

HDI is a diet score based on the adherence to 2003 WHO dietary recommendations for prevention of non-communicable diseases and designed for worldwide use [12]. The nine components and the daily recommendations are included in Supplementary table 1. Using the constructed daily intake of nutrients, a dichotomous yes=1/no=0 variable was generated for each nutrient group included in the WHO recommendations for the prevention of chronic diseases depending on whether the participant has reached the recommended dietary goal or not. The HDI score is a sum of these nine variables with a value range from 0 to 9 [15]. The cut-off values were divided into three categories, with <2 classified as low adherence, 2 as medium, and >2 as high[13], given that the median value was 2.

Mediterranean Diet Score

For MDS, the components and cut-off values were based on the recommendations of Sofi et al [23]. The score employs a three-tier scoring system which assigns zero, one or two points given to participants for each component. The components and scoring criteria are included in Supplementary table 2. The olive oil component had to be modified to one point for the participants who stated olive oil use for cooking, and zero point to respondents cooking with any other type of oil. The maximum MDS score was 17 and divided into three categories: low (0-7), moderate (8-10), and high (11-17) adherence.

Eastern European Diet Score

The Eastern European diet score (EEDS) was originally defined by Stefler at al. [19] to examine the relationship between the traditional DP and cardiovascular disease, cancer, and overall mortality rates in CEE, and found that said dietary habits may contribute to the poor health status of these populations. The components and scoring criteria are included in Supplementary table 3. The FFQ was used to calculate energy-adjusted intakes for all components except lard. Lard consumption was modified to one point for participants who stated lard use for cooking, and zero points for respondents cooking with any other type of fat. The maximum EEDS score was 17 and divided into three categories using the Stefler et al. cut off values: low (0-6), medium (7-10), and high (11-17) adherence.

Covariates

Age at baseline and energy intake in kcal were used as continuous measures, sex was used as binary for men and women. All other variables were categorical. Marital status had five categories (single, married, cohabiting, divorced/separated, widowed). Economic activity was assessed by employment status - employed, retired, or unemployed. The highest achieved level of education was grouped into three categories: primary/vocational, secondary and university. Smoking status was defined as smokers, ex-smokers, and non-smokers.

Statistical analysis

Descriptive statistics for categorical variables are presented as percentages, and for men and women separately. Furthermore, the mean CES-D-10 score, and standard deviation are reported for each category of dietary adherence in the full sample and by sex.

The differences in DS at baseline were examined in a crude unadjusted analysis using Welch's test and Brown-Forsythe test as all entered variables violated the assumption of normality. These analyses were done using IBM SPSS Statistics 29.

Growth curve modelling, using Stata BE 17, was performed to investigate the longitudinal relationship between adherence to a specific dietary score and DS. Within-subject variance presents level 1 and between-subject variance is level 2 in longitudinal multilevel modelling. In the final model, the slope of CES-D score over time by adherence to DP was adjusted for age at baseline, sociodemographic factors, energy intake, and smoking. We also included quadratic term for wave to account for potential non-linear trends, and an interaction between wave and dietary scores to allow for effect modification over time. Furthermore, due to statistically significant effect modification by sex in models using HDI and EEDS ($p<0.001$ and $p <0.001$), we separately constructed the models for men and women.

RESULTS

Descriptive characteristics of the sample

The analytical sample consisted of 3519 participants, among whom 1892 (53.8%) were women and 1627 (46.2%) were men. At baseline, the mean age of participants was 57.7 years. Descriptive characteristics of the study subjects are shown in Table 1. Most participants (41.8%) completed secondary education, followed by those who completed primary or vocational education (40.0%) and those who had obtained a university degree

(18.2%). Overall, 59.5% of respondents were employed at baseline, meanwhile 38.3% were non-working pensioners. Only 2.2% of participants were unemployed. Married respondents or respondents in a partnership represented 79.9% of the sample.

Dietary score and baseline depressive symptoms

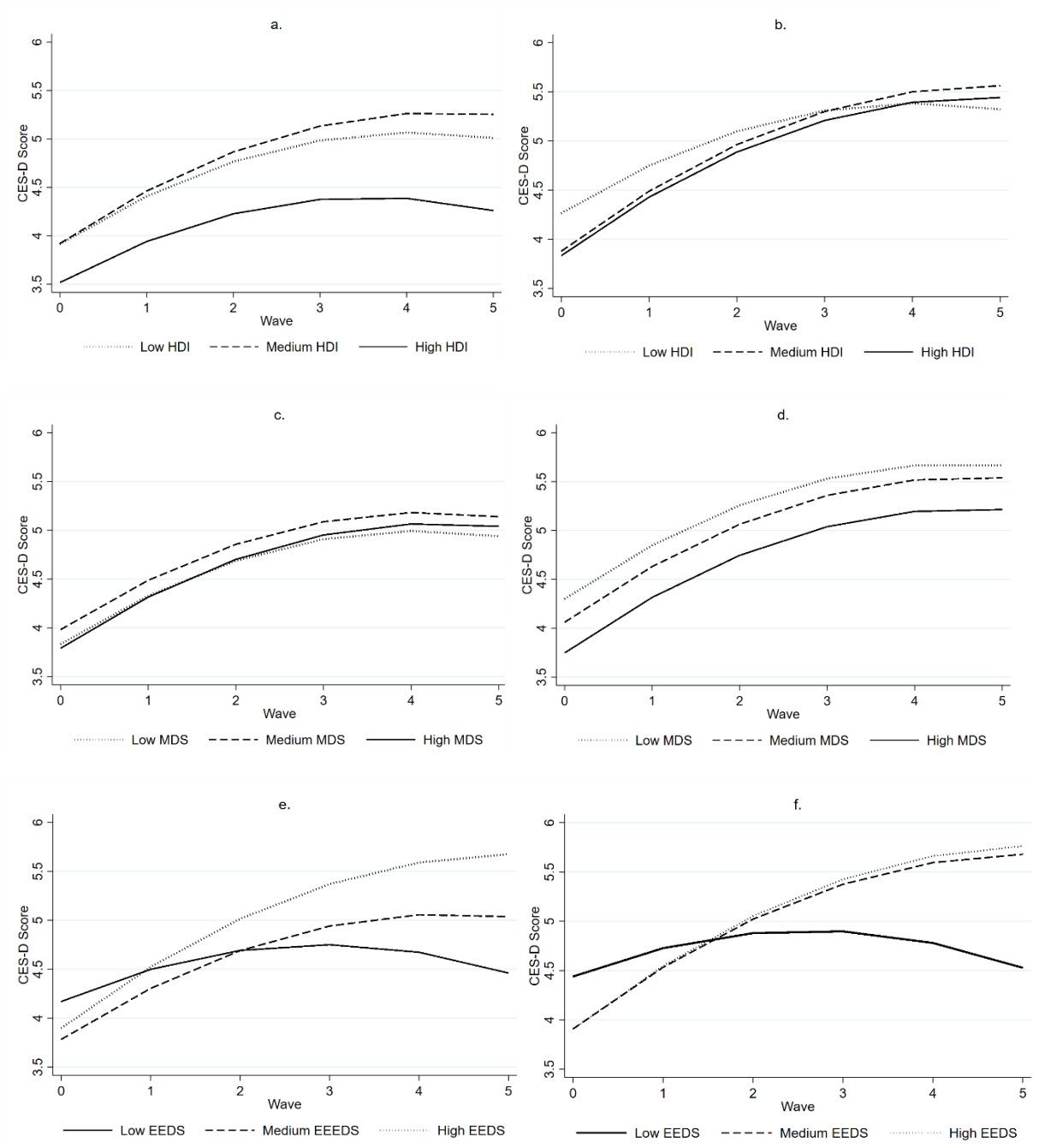
The most commonly observed adherence level to HDI, MDS, and EEDS was medium, with proportions of 45.3%, 44.9%, and 55.2%, respectively. However, there were statistically significant differences in HDI adherence between men and women (p=0.001), with 55% men with low adherence compared to 51% women in medium adherence level. Medium adherence was the most prevalent in both sexes in both MDS and EEDS. In total, 44.1% men and 45.7% women showed a medium adherence to MDS. For EEDS, medium adherence was observed in 56.5% men and 54.0% women (Table 1).

Baseline CES-D score did not statistically differ between men (3.8) and women (3.9) (Table 1). In the full sample, baseline CES-D score was higher in respondents without partner compared to respondents with a partner. Negative impact of unemployment was pronounced in men, while low education was associated with higher CES-D score in women (Supplementary table 4). At baseline, the difference in CES-D score according to diet adherence was only statistically significant in EEDS (Table 2), even upon stratifying by sex (Supplementary table 5, 6).

Longitudinal changes in depressive symptoms scores by sex

All growth curve models were first adjusted for age at baseline, quadratic wave, sociodemographic factors (marital status, employment status, education), energy intake, and smoking. Based on existing research [24], we tested for an interaction between dietary scores and sex. Significant likelihood ratio test for HDI and EEDS provided statistical support for estimating the models for men and women separately ($p<0.001$ and $p<0.001$). The results of sex-stratified growth curve models are presented in Table 3 and the longitudinal trajectories of DS by sex are shown in Figure 1.

Fig 1. Sex differences in longitudinal trajectories of depressive symptoms by dietary adherence
(a) HDI – men; (b) HDI – women; (c) MDS – men; (d) MDS – women; (e) EEDS – men; (f) EEDS – women
Men Women



In models with HDI, men with medium (B = −0.68, 95% CI [−0.43; 0.29]) and high adherence (B = −0.55, [−1.24; 0.13]) exhibited lower baseline DS compared with those with low adherence, although these associations were not statistically significant. In women, both medium (B = −0.54, [−0.90; −0.19]) and high adherence (B = −0.65, [−1.18; −0.12]) were significantly associated with lower baseline DS scores. The slope coefficients indicated an overall increase in DS over time for all adherence groups (men: B range 0.49–0.61; women: B range 0.55–0.68), with no clear pattern suggesting differential trajectories by adherence category.

When using MDS as the dietary exposure, no clear association with baseline DS was observed among men (medium: B = 0.12, [−0.26; 0.51]; high: B = −0.14, [−0.61; 0.33]). In contrast, women with high adherence reported lower baseline DS, compared to those with low adherence (B = −0.56, [−1.01; −0.10]). For both sexes, DS significantly increased over time, however, the difference in slope estimates across adherence categories were small (slope range: men 0.56–0.59; women 0.62–0.64), indicating broadly parallel trajectories irrespective of dietary adherence

For EEDS, higher adherence was consistently associated with lower baseline DS in both sexes. Among men, medium adherence was associated with lower baseline DS (B = −0.44, [−0.87; −0.01]) whereas high adherence showed a similar trend but did not reach statistical significance (B = −0.38, [−0.91; 0.12]). In women, both medium and high adherence were significantly associated with lower baseline DS, with a stronger effect observed for high adherence (medium: B = −0.76, [−1.19; −0.33]; high: B = −0.88, [−1.37; −0.39]). Slope estimates indicated a clear, progressive gradient across EEDS adherence levels. In men, slopes were progressively higher from low (B = 0.40, [0.22; 0.57]) to medium (B = 0.59, [0.43; 0.74]) and high adherence (B = 0.69, [0.52; 0.86]). A similar pattern was observed in women, with slopes higher from low (B = 0.35, [0.19; 0.51] to medium (B = 0.69, [0.55 to 0.83]), and high (B = 0.71, [0.56; 0.86]). These findings suggest that although participants with higher EEDS adherence started with lower DS, their trajectories of DS over time were steeper.

DISCUSSION

This study investigated the relationship of three different dietary scores with DS in Czech older adults over time. Several results are noteworthy. First, we found an inverse association of HDI with the intensity of DS at baseline after controlling for covariates in women. Secondly, women with high adherence to MDS showed lower baseline DS compared to women with low adherence to MDS. Finally, medium and high adherence to EEDS was inversely associated with baseline DS in women, and men with medium adherence to EEDS had lower baseline DS compared to men with low adherence. There were no other statistically significant results in men, possibly due to smaller proportion of men in high adherence groups, however, the direction of the effect was similar to the one in women, although the associations were weaker. Regarding the longitudinal trends, DS increased over time for all participants. Importantly, trajectories were largely parallel across HDI and MDS adherence levels, indicating differences at baseline (intercept) but not in the rate of change over time (slope). This pattern likely reflects the stability of general healthy eating habits captured by HDI and MDS. These diets, particularly in older

adults, tend to remain relatively constant over time. As a result, adherence primarily influences the starting level of depressive symptoms but does not substantially alter their trajectory. In contrast, for EEDS, DS trajectories followed a progressive gradient, with higher adherence linked to slightly steeper long-term changes. This suggests that although participants with better adherence to EEDS started off with lower DS, their symptoms increased faster over time.

WHO dietary guidelines for the prevention of chronic diseases are globally applicable, allowing HDI to be compared internationally [25]. Previous Spanish study did not find an association between HDI and fewer DS, however, based on a clinical diagnosis, it was associated with a lower risk of depression [16]. Furthermore, several other studies have suggested that healthy DP may be associated with a reduced risk of depression and DS [26–29]. Additionally, HDI has been associated with lower all-cause mortality [25] and partially with cardiovascular disease [15, 30].

Despite being regionally limited, Mediterranean diet is a diet with the most evidence for potentially attenuating DS. In a large, biracial study of older adults, higher adherence to Mediterranean diet was associated with decreased likelihood of developing DS during 7.2 years of follow-up [31]. Similarly, a Spanish cohort of young and middle-aged adults found an inverse association between adherence to the Mediterranean diet and the risk of self-reported clinical depression [32]. Lastly, a 2025 systematic review and meta-analysis suggested that Mediterranean diet interventions could alleviate DS in already depressed young and middle-aged adults [33]. Curiously, we found limited associations with MDS in the HAPIEE study. Due to varied composition of food groups and differences in aspects of food production and preparation, such as vegetable preferences and lack of raw olive oil usage, MDS might be restricted in assessing the adherence to Mediterranean diet in non-Mediterranean populations [34].

Eating habits and DP tend to remain stable over time [35]. We hypothesize that similar trajectories of DS across HDI and MDS adherence levels reflect this stability, with adherence primarily influencing baseline symptom levels, rather than their progression. On the contrary, EEDS is not inherently a healthy or an unhealthy score, as it has components that overlap with categories predefined both in healthy and unhealthy DP. For example, legumes are included in MDS, meanwhile lard and processed meat products would be typically included in more "unhealthy" DP [36]. The original study that established EEDS found results suggesting a positive association of higher adherence to EEDS with increased mortality in the HAPIEE cohort [19], which makes the negative association with DS at baseline surprising. EEDS lacks anti-inflammatory nutrients that are commonly proposed

to play a role in improving DS [36]. Interestingly, our study revealed steeper increase in DS in those with high adherence to the EEDS, despite having lower DS at baseline. This may reflect the mixed nature of the EEDS, leading to a delayed or cumulative impact on mental health. Unlike HDI and MDS, whose effect appeared consistent and primarily influenced baseline symptom levels, EEDS showed a dose-response trajectory, with symptom changes becoming more pronounced over time. Alternatively, this finding might indicate reverse causation at baseline. Participants with higher level of DS are potentially more likely to follow traditional dietary habits, while the actual negative effect of this DP on DS is reflected by the longitudinal association. Further investigation of this finding is clearly needed in order to provide adequate explanation. Our findings suggest that DP can shape both the baseline severity and the trajectory of DS, underscoring the importance of overall diet quality as a modifiable determinant of mental health.

Current research focuses on DP over singular nutrients due to the synergistic effect of various components [5]. Healthy DP, associated with reducing the risk of depression in general population [26–28] share common elements, such as higher fruits, vegetables and nuts intake, lower intake of pro-inflammatory food items such as processed meats and trans fats, and a moderate alcohol consumption [26]. There are several proposed pathways for the relationship between DP and DS that commonly overlap and act synergistically. For instance, good diet quality may partially attenuate chronic low-grade inflammation, oxidative stress, and decreased neurogenesis, which are all factors that play a role in major depressive disorder [37].

An important, if expected, finding were the sex differences. According to previous research, older women have approximately 1.5 times higher risk of incident and recurrent depression in later life than men [4]. Our results also highlighted further differences, both in adherence and with healthy eating appearing more beneficial in relation to DS in women. This is similar to findings from a Whitehall II study reporting that adherence to healthy dietary recommendations reduced the likelihood of developing DS later in life in women but not in men even after adjusting for other covariates [24]. It is unclear whether that is due to differences between sex, reporting differences in diet, low sensitivity of used DS scale to male depression, or an outsider factor, however, it accentuates another gap in research.

Nutritional psychiatry is a relatively new field that tends to focus mostly on younger adults in Western Europe and in the United States. CEE region shows one of the largest prevalence of LLD [8], however, findings from other regions cannot be extended to the CEE population due to sociopolitical changes and cultural differences. Dietary intake naturally varies between countries and within countries, commonly varied by socioeconomic

factors [38]. Therefore, it is important to take such variation into account while proposing potential policies. Evidence on sex differences in LLD and DP also remains scarce, though results suggest an important interaction.

Our study has several strengths. Firstly, it uses unique longitudinal data from a well-established cohort study of Czech older adults. That is important for multiple reasons. The CEE region is understudied in many fields of epidemiology [39], while the East-West health gap prevails. Furthermore, risk factors of LLD differ from depression in younger adult age, however, nutritional psychiatry research mainly focuses on younger adults, and available data on older adults is scarce. Secondly, it uses three dietary scores to establish the best fit for assessing the relationship between diet and DS in a specific region. Thirdly, the use of longitudinal data may at least partly help to reduce the risk of reverse causality. Lastly, our study stratifies the models by sex which is a major shortcoming of many previous studies, as women are at a higher risk of depression across all age groups [4] and the impact of risk factors on DS seems to differ between sexes.

Nonetheless, this study also has several limitations. The HAPIEE study has been conducted in urban settings and has moderate response rate, although relatively high compared to most other European studies. The findings therefore may not be generalizable for the entire Czech older adult population. Furthermore, only 46% of participants provided sufficient data to enter the analysis. FFQ itself has many limitations; it is a semi-quantitative method and it commonly over- or underestimates an individual's intake. There is also a risk of reporting error, wrong estimation of frequency or quantity of food consumption [40]. In addition, there might be sex disparities in reporting [41], though a 2021 meta-analysis showed both men and women significantly underestimate their energy intake [42]. Self-reporting bias is also possible for DS [43], together with underreporting of DS in general [44]. CES-D is also speculated to be less sensitive to male depression [24].

Lastly, despite using longitudinal data, the study had limited ability to determine causality. As LLD is a multietiological disorder, it is highly unlikely that only nutrition impacts the presence and intensity of DS. Furthermore, the relationship between DS and DP is thought to be bi-directional. Poor mental health may lead to unhealthy eating habits and changes in appetite, and might influence nutrient levels during depressive episodes [45]. In addition, comorbidity and polypharmacy tend to be common amongst older adults and this further complicates efforts to investigate relationships between DP and DS [33].

CONCLUSION

This is the first study which attempted to longitudinally assess the relationship between depressive symptoms and adherence to various dietary scores in older adults in Central and Eastern Europe. In women, higher adherence to Healthy Diet Indicator and Mediterranean Diet Score was associated with lower, albeit still increasing depressive symptoms over time. Women with higher adherence to Eastern European Diet Score showed lower depressive symptoms at baseline but a steeper increase in time. Similar pattern was seen in men. These results underline the need for more research on the association between diet and mental health, with particular attention to differences between men and women.

DECLARATIONS

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Competing interests

The authors declare that they have no competing interests.

Consent

Consent obtained directly from patients.

Ethics approval

The HAPIEE study was approved by the University College London ethics committee, the University College Hospital ethics committee (99/0081) and local ethics committees in each participating centre. All methods were

performed in accordance with the relevant guidelines and regulations. Participants gave informed consent to participate in the study before taking part.

Data availability

Files with syntax enabling replication of the results are available at: https://doi.org/10.5281/zenodo.17790928.

Authors' contribution statement

KV and HP conceived and designed the study. KV, HP and AB analyzed the data. KV wrote the first draft of the manuscript with the support of AB, DS and HP. HP, MB and NC provided critical revisions. All authors read and approved the submitted manuscript.

Table 1. Descriptive characteristics of the study sample at baseline (N=3519)

	Sample	Men	Women	p*
	Total	Total	Total	
n (%)	3519	1627 (46.2)	1892 (53.8)	
Age, mean (SD)	57.7 (6.8)	58.1 (6.9)	57.3 (6.7)	<0.001
Education				0.014
Primary, vocational (%)	40.0	41.9	38.5	
Secondary (%)	41.8	34.8	47.7	
University (%)	18.2	23.3	13.8	
Marital status				<0.001
Married/partnership (%)	79.9	87.5	73.3	
Without partner (%)	20.1	12.5	26.7	
Employment status				<0.001
Working (%)	59.5	66.2	53.8	
Retired (%)	38.3	31.7	44.1	
Unemployed (%)	2.2	2.2	2.2	
Smoking				<0.001
Smokers (%)	23.1	26.1	20.6	
Ex-smokers (%)	30.0	38.2	22.9	
Non-smokers (%)	46.9	35.6	56.5	
HDI				<0.001
Low (%)	44.3	54.8	35.4	
Medium (%)	45.3	38.4	51.3	
High (%)	10.3	6.9	13.3	
MDS				<0.001
Low (%)	27.1	33.5	21.7	
Medium (%)	44.9	44.1	45.7	
High (%)	27.9	22.4	32.7	
EEDS				0.014
Low (%)	19.9	20.8	19.2	
Medium (%)	55.2	56.5	54.0	
High (%)	24.9	22.7	26.7	

Energy intake in kcal, mean, SD	2031.1 (677.9)	2092.1 (677.6)	1978.6 (673.9)	<0.001
CES-D Score, mean, (SD)	3.8 (2.7)	3.8 (2.6)	3.9 (2.7)	0.432

* test for difference between men and women

Table 2: Means (SD) of depressive symptoms scores at each data collection wave by dietary adherence at baseline N=3519), unadjusted

	Wave 1		Wave 2		Wave 3		Wave 4		Wave 5		Wave 6	
	CES-D score Mean (SD)	*p	CES-D score Mean (SD)	*p	CES-D score Mean (SD)	*p	CES-D score Mean (SD)	*p	CES-D score Mean (SD)	*p	CES-D score Mean (SD)	*p
HDI		0.039		0.239		0.703		0.231		0.893		0.943
Low (%)	3.94 (2.65)		4.66 (4.24)		4.98 (4.43)		4.85 (4.46)		4.84 (4.67)		5.06 (4.54)	
Medium (%)	3.74 (2.65)		4.70 (4.29)		4.94 (4.51)		4.89 (4.14)		4.94 (4.55)		5.31 (4.50)	
High (%)	3.72 (2.81)		4.17 (4.37)		4.86 (4.70)		4.33 (4.11)		4.80 (5.08)		4.83 (4.07)	
MDS		0.251		0.058		0.300		0.814		0.198		0.974
Low (%)	3.84 (2.62)		4.79 (4.41)		4.93 (4.36)		4.86 (4.40)		4.93 (4.96)		5.09 (4.56)	
Medium (%)	3.90 (2.67)		4.68 (4.23)		5.12 (4.54)		4.79 (4.22)		5.02 (4.64)		5.22 (4.34)	
High (%)	3.70 (2.70)		4.39 (4.22)		4.69 (4.53)		4.80 (4.29)		4.62 (4.41)		5.1 (4.62)	
EEDS		0.001		0.759		0.153		0.019		0.002		0.001
Low (%)	4.18 (2.71)		4.80 (4.47)		4.82 (4.37)		4.61 (4.01)		4.38 (4.37)		4.41 (3.87)	
Medium (%)	3.76 (2.64)		4.51 (4.19)		4.91 (4.50)		4.73 (4.31)		4.89 (4.67)		5.33 (4.62)	
High (%)	3.71 (2.67)		4.74 (4.31)		5.14 (4.57)		5.16 (4.43)		5.27 (4.83)		4.414.60)	

* p = test for trend

Table 3. Sex-stratified growth curve models for longitudinal changes in depressive symptoms according to adherence to a dietary score (N=3519)

	Healthy diet indicator		**Mediterranean Diet Score**		**Eastern European Diet Score**	
	Men	**Women**	**Men**	**Women**	**Men**	**Women**
Fixed effects						
Adherence categories	B (95% CI)	B (95% CI)	B (95% CI)	B (95% CI)	B (95% CI)	B (95% CI)
Intercept						
Low	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Medium	-0.68 (-0.43; 0.29)	**-0.54 (-0.90; -0.19)**	0.12 (-0.26; 0.51)	-0.30 (-0.73; 0.12)	**-0.44 (-0.87; -0.01)**	**-0.76 (-1.19; -0.33)**
High	-0.55 (-1.24; 0.13)	**-0.65 (-1.18; -0.12)**	-0.14 (-0.61; 0.33)	**-0.56 (-1.01; -0.10)**	-0.38 (-0.91; 0.12)	**-0.88 (-1.37; -0.39)**
Slope						
Low	0.56 (0.41; 0.72)	0.55 (0.41; 0.70)	0.56 (0.40; 0.72)	0.62 (0.46; 0.77)	0.40 (0.22; 0.57)	0.35 (0.19; 0.51)
Medium	0.61 (0.45; 0.77)	0.68 (0.54; 0.82)	0.57 (0.42; 0.73)	0.64 (0.49; 0.78)	0.59 (0.43; 0.74)	0.69 (0.55; 0.83)
High	0.49 (0.27; 0.71)	0.66 (0.49; 0.83)	0.59 (0.42; 0.76)	0.64 (0.49; 0.78)	0.69 (0.52; 0.86)	0.71 (0.56; 0.86)
Quadratic slope	-0.07 (-0.10; -0.04)	-0.07 (-0.09; -0.04)	-0.07 (-0.10; -0.04)	-0.07 (-0.09; -0.04)	-0.07 (-0.10; -0.04)	-0.07 (-0.09; -0.04)
Random effects						
Intercept variance	5.68 (5.14; 6.28)	6.59 (6.04; 7.19)	5.71 (5.17; 6.31)	6.56 (6.01; 7.17)	5.71 (5.17; 6.31)	6.62 (6.06; 7.22)
Residual variance	10.25 (9.88; 10.63)	10.39 (10.05; 10.73)	10.25 (9.89; 10.64)	10.40 (10.06; 10.75)	10.22 (9.85; 10.60)	10.33 (9.99; 10.68)
ICC	0.36 (0.33; 0.38)	0.39 (0.36; 0.41)	0.36 (0.33; 0.38)	0.39 (0.36; 0.41)	0.36 (0.33; 0.38)	0.39 (0.36; 0.41)

* all models were adjusted for age, quadratic wave, sociodemographic factors (marital status, employment status, education), health behaviors (smoking), and energy intake in kcal

bold values represent statistically significant effects ($p<0.05$).

B= unstandardized results

Supplementary tables

Supplementary table 1. Components of HDI

Component	Recommendations
SFAs, energy %	0-10
n3-PUFAs, energy %	1-2
n6-PUFAs, energy %	5-8
Trans fatty acids, energy %	<1
Mono- and disaccharides, energy %	0-10
Protein, energy %	10-15
Cholesterol, mg/day	0-300
Fruits/vegetables, g/day	>400
Non-starch polysaccharides, g/day	>20

Supplementary table 2. Components and scoring of MDS

Component	Scoring criteria of MDS components		
	0 points	**1 point**	**2 points**
Vegetables, g/day	<100	100–250	>250
Fruits and nuts, g/day	<150	150–300	>300
Legumes, g/week	<70	70–140	>140
Cereals, g/day	<130	130–195	>195
Fish, g/week	<100	100–250	>250
Meat and meat products, g/day	>120	80–120	<80
Dairy products, g/day	>270	180–270	<180
Alcohol, g/day	>24	<12	12–24
Olive oil usage	Not used for cooking	Used for cooking	–

Supplementary table 3. Components of EEDS

Component	Energy-adjusted intake (g/day/1000 kcal) percentiles		
	33.3rd	**50th**	**66.6th**
Bread and other grain products	15.0	26.3	40.0
Potato	33.7	41.5	51.6
Legumes	3.4	5.4	7.6
Preserved fruits and vegetables	5.0	7.4	10.6
Storable vegetables	44.7	60.0	76.0
Dairy products and egg	19.4	25.2	31.7
Poultry meat	10.4	17.4	22.4
Processed meat products	17.0	23.6	30.9
Lard (%)	–	–	–

Supplementary table 4. Depressive symptoms scores in covariates at baseline (N=3519)

	Total		Men		Women	
	CES-D score Mean (SD)	p	CES-D score Mean (SD)	p	CES-D score Mean (SD)	p
Education		0.163		0.956		0.021
Primary, vocational (%)	3.93 (2.69)		3.77 (2.56)		4.08 (2.79)	
Secondary (%)	3.76 (2.66)		3.82 (2.62)		3.73 (2.69)	
University (%)	3.75 (2.63)		3.78 (2.61)		3.71 (2.68)	
Marital status		<0.001		0.010		0.003
Married/partnership (%)	3.74 (2.67)		3.73 (2.60)		3.75 (2.74)	
Without partner (%)	4.18 (2.65)		4.22 (2.50)		4.17 (2.71)	
Employment status		0.068		0.003		0.545
Working (%)	3.88 (2.61)		3.92 (2.53)		3.83 (2.70)	
Retired (%)	3.72 (2.73)		3.47 (2.66)		3.88 (2.76)	
Unemployed (%)	4.37 (2.89)		4.43 (2.94)		4.32 (2.88)	
Smoking		0.380		0.051		0.962
Smokers (%)	4.08 (2.56)		4.28 (2.49)		3.81 (2.61)	
Ex-smokers (%)	3.77 (2.68)		3.69 (2.65)		3.89 (2.73)	
Non-smokers (%)	3.83 (2.70)		3.75 (2.59)		3.87 (2.76)	

Supplementary table 5. Depressive symptoms scores according to dietary adherence in men (N=1627)

	Wave 1		Wave 2		Wave 3		Wave 4		Wave 5		Wave 6	
Baseline diet	CES-D score Mean (SD)	p*	CES-D score Mean (SD)	p*	CES-D score Mean (SD)	p*	CES-D score Mean (SD)	p*	CES-D score Mean (SD)	p*	CES-D score Mean (SD)	p*
HDI												
Low (%)	3.86 (2.60)	0.135	4.45 (4.01)	0.719	4.79 (4.20)	0.773	4.70 (4.48)	0.443	4.80 (4.87)	0.243	4.96 (4.60)	0.315
Medium (%)	3.75 (2.57)		4.76 (4.14)		4.83 (4.23)		4.91 (4.16)		4.87 (4.38)		4.86 (4.41)	
High (%)	3.47 (2.58)		3.59 (3.81)		4.50 (5.46)		3.74 (3.77)		3.70 (4.40)		4.24 (3.49)	
MDS		0.679		0.897		0.356		0.794		0.978		0.921
Low (%)	3.73 (2.56)		4.52 (4.23)		4.51 (3.85)		4.77 (4.54)		4.69 (4.18)		4.77 (4.53)	
Medium (%)	3.93 (2.62)		4.54 (3.95)		5.01 (4.51)		4.65 (4.23)		4.85 (4.47)		5.01 (4.35)	
High (%)	3.61 (2.56)		4.47 (3.98)		4.75 (4.58)		4.70 (4.32)		4.65 (4.24)		4.76 (4.46)	
EEDS		0.029		0.439		0.095		0.121		0.014		0.028
Low (%)	4.10 (2.62)		4.62 (4.26)		4.52 (4.20)		4.57 (3.94)		4.49 (4.75)		4.26 (3.99)	
Medium (%)	3.71 (2.57)		4.36 (3.89)		4.76 (4.32)		4.59 (4.37)		4.54 (4.50)		4.99 (4.63)	
High (%)	3.71 (2.60)		4.80 (4.23)		5.11 (4.40)		5.13 (4.52)		5.56 (4.96)		5.19 (4.43)	

p* = test for trend

Supplementary table 6. Depressive symptoms scores according to dietary adherence in women (N=1892)

	Wave 1		Wave 2		Wave 3		Wave 4		Wave 5		Wave 6	
	CES-D score Mean (SD)	p*	CES-D score Mean (SD)	p*	CES-D score Mean (SD)	p*	CES-D score Mean (SD)	p*	CES-D score Mean (SD)	p*	CES-D score Mean (SD)	p*
Baseline diet												
HDI												
Low (%)	4.05 (2.71)	0.090	4.93 (4.51)	0.120	5.22 (4.71)	0.488	5.04 (4.45)	0.213	4.89 (4.43)	0.397	5.18 (4.47)	0.786
Medium (%)	3.74 (2.70)		4.66 (4.38)		5.00 (4.66)		4.87 (4.14)		4.97 (4.65)		5.57 (4.54)	
High (%)	3.83 (2.91)		4.41 (4.58)		5.03 (4.30)		4.59 (4.24)		5.29 (5.30)		5.06 (4.26)	
MDS		0.178		0.007		0.011		0.750		0.046		0.553
Low (%)	4.00 (2.70)		5.15 (4.61)		5.47 (4.91)		4.96 (4.22)		5.24 (4.66)		5.49 (4.57)	
Medium (%)	3.87 (2.72)		4.80 (4.44)		4.57 (4.22)		4.90 (4.22)		5.16 (4.76)		5.37 (4.33)	
High (%)	3.76 (2.78)		4.34 (4.35)		4.66 (4.51)		4.86 (4.37)		4.60 (4.50)		5.27 (4.64)	
EEDS		0.006		0.270		0.698		0.089		0.062		0.021
Low (%)	4.24 (2.81)		4.96 (4.66)		5.08 (4.50)		4.65 (4.06)		4.29 (4.05)		4.54 (3.77)	
Medium (%)	3.80 (2.71)		4.65 (4.43)		5.05 (4.68)		4.85 (4.26)		5.20 (4.80)		5.60 (4.60)	
High (%)	3.71 (2.72)		4.70 (4.46)		5.15 (4.68)		5.18 (4.43)		5.08 (4.75)		5.55 (4.71)	

p* = test for trend

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