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Identifying leading anti-inflammatory dietary determinants of depression and loneliness in older adults

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ABSTRACT

Objectives: The study aims to explore the association between anti-inflammatory dietary variables and prevalence of depression and loneliness in older adults.
Design: A cross-sectional secondary data analysis was performed using data from the English Longitudinal Study of Ageing (ELSA), targeting adults aged 50 and over.
Method: Data from wave 9 of ELSA were utilised. Binary logistic regression was employed to estimate the Odds ratios (ORs) and 95 % confidence intervals (CIs) for the association between participants' intake of fruits, vegetables, fish, nuts and seeds, legumes, and wholegrains, and the prevalence of depression and loneliness. Two sets of regressions were conducted: the first set examined each dietary component individually, while the second considered all variables simultaneously. Both models were tested with and without adjusting for covariates, including age, gender, ethnicity, self-rated weight, marital status, education, socio-economic status, and activity-limiting long-standing illnesses.
Results: Of 4254 participants included in the analysis, 355 participants (8 %) had depression, and 623 (15 %) reported experiencing loneliness. An association was observed between higher intakes of fruits and lower prevalence of depression (OR = 0.89, 95 % CI: 0.79–1.00, p = 0.05), and between higher intakes of vegetables and lower prevalence of loneliness (OR = 0.91, 95 % CI: 0.83–1.00, p = 0.05). However, these associations lost statistical significance after adjustment for confounders. Similarly, the second model, which included all anti-inflammatory dietary variables, failed to show a significant association with depression and loneliness.
Conclusions: The study does not support the hypothesis that anti-inflammatory variables are associated with prevalence of depression and loneliness in older adults.

1. Introduction

Depression and loneliness are significant global health issues, particularly amongst older adults. Their impact is substantial within this population, with estimated global prevalence rates of approximately 32 % for depression and 28.5 % for loneliness (Chawla et al., 2021; Zenebe et al., 2021). Both conditions are associated with adverse physical and mental health outcomes, leading to considerable healthcare expenditures (Fulton and Jupp, 2015; Ludvigsson et al., 2018; Luppa et al., 2008). For example, the direct healthcare cost for older adults suffering from depression surpasses that of their counterparts without depression by a ratio of 1.45 (Ludvigsson et al., 2018). Additionally, it is estimated that older adults experiencing loneliness generate a cost of £12,000 per person to the public sector over a 15-year period (Fulton and Jupp, 2015). Hence, effective prevention and management of depression and loneliness is vital for promoting healthy ageing and curbing healthcare expenses.

1.1. Depression and inflammation

Recent advancements in the field of immunology have showed robust associations between depressive symptoms and immune disfunction (A. H. Miller et al., 2009; A. H. Miller and Raison, 2016). Various meta-analyses show an increase in circulating inflammatory cytokines, including interleukin-6 (IL-6), tumour necrosis factor-alpha (TNF-α), and C-reactive protein (CRP), in depressed individuals compared with non-depressed (Dowlati et al., 2010; Goldsmith et al., 2016; Köhler et al., 2017). For instance, one meta-analysis of 24 studies

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indicates that major depressive disorder (MDD) is associated with an increase in IL-6 and TNF-α, even when excluding any medical comorbidity (Dowlati et al., 2010).

Other studies have proposed that immune dysregulation serves as a potential factor linking depression to health (Hughes et al., 2004; Surtees et al., 2008; Tubbs et al., 2020). One study comprising 19,649 subjects (aged 41 to 80), showed baseline depression associated with incident ischemic heart diseases, whilst CRP explained 15 % of the association (Surtees et al., 2008). Similarly, CRP also explained 7.3 % of the association between depressive symptoms and all-cause mortality in a study following 2389 older men over 18 years (Hughes et al., 2004).

In fact, recent research has underscored the potential of an anti-inflammatory intervention in mitigating depressive symptoms (Kappelmann et al., 2018; Köhler et al., 2014, 2016). For example, across 14 randomised clinical trials involving over 6000 participants, anti-inflammatory treatments exhibited positive effects on depressive symptoms without a heightened risk of side effects (Köhler et al., 2014). Likewise, similar effects have been noted amongst non-randomised controlled trials, indicating robust improvements in depressive symptoms following treatments with proinflammatory cytokine inhibitors (Kappelmann et al., 2018).

1.2. Loneliness and inflammation

Individuals experiencing heightened levels of loneliness have been found to exhibit greater inflammatory responses. Existing research has established an association between elevated inflammation levels and loneliness (Cole et al., 2007). Specifically, Cole et al. (2007) found that CRP levels were twice as high amongst those with pronounced loneliness compared to participants with low levels of loneliness. Similarly, other studies have yielded positive associations between loneliness and elevated fibrinogen, IL-6 levels, and CRP (Nersesian et al., 2018; Smith, 2021; Van Bogart et al., 2022). However, the findings linking loneliness to inflammation are less consistent. For instance, studies of middle-aged and older adults from the US and UK showed no relationship between loneliness and CRP or loneliness and fibrinogen (Mezuk et al., 2016; Shankar et al., 2011).

1.3. Depression, loneliness, and anti-inflammatory diet amongst older adults

Over the past decade, nutrition has attracted heightened attention as a modifiable lifestyle factor to target in prevention and treatment programmes for depression and loneliness, particularly concerning foods influencing inflammation (Johnson et al., 2022; A. H. Miller and Raison, 2016; Sarris et al., 2015). Regular intake of anti-inflammatory foods, such as vegetables, fruits, and whole grains, has been found to have an inverse association with the risk of depression (Liu et al., 2016; Opie et al., 2017; Wu et al., 2021). Meanwhile, omega-3 supplements, recognised for their inflammation-reducing abilities, are found to alleviate cognitive difficulties related to loneliness (Jaremka et al., 2013).

Despite the growing interest in the health benefits of an anti-inflammatory diet, a universally accepted definition is still lacking. Recent studies have identified Mediterranean and Okinawan diets as dietary patterns that exhibit anti-inflammatory properties; thus, they are often regarded as subtypes of anti-inflammatory diet (Ricker and Haas, 2017). As such, an anti-inflammatory diet incorporates elements from both Mediterranean and Okinawan diets, which include consuming foods such as vegetables, fruit, fish, and plant-based proteins (Ricker and Haas, 2017). Conversely, a diet rich in inflammation-promoting foods such as sugar, refined flour, saturated fats, and red and processed meats is defined as a pro-inflammatory diet (Belliveau et al., 2022).

Numerous studies have examined the link between Mediterranean diets and symptoms of depression and loneliness, with some yielding relevant results (Ferrer-Cascales et al., 2018; Parletta et al., 2019; Yin et al., 2021). In this regard, a randomised controlled trial (RCT) conducted in Australia demonstrated that adherence to the Mediterranean diet significantly improves mental health in adults with depression (Parletta et al., 2019). By the end of the study, the intervention group had a marked increase in healthy food consumption and a 1.68-fold reduction in depressive symptoms which lasted through a six-month follow-up (Parletta et al., 2019). Similarly, a cross-sectional study involving Spanish adolescents finds that compare to participants with high levels of perceived loneliness, adolescents with low and medium levels of perceived loneliness showed greater adherence to the Mediterranean diet (Ferrer-Cascales et al., 2018). However, this relationship is influenced by high-stress levels.

In contrast to younger adults, older individuals are more prone to elevated inflammatory levels, as well as symptoms of depression and loneliness. As inflammation tends to increase with age, older adults face a heightened risk of developing inflammation-related health conditions (Graham et al., 2006). Moreover, older adults may experience diminished efficacy from medical treatments, amplifying their susceptibility to long-term side effects, including hepatic and renal dysfunction (Forbes et al., 2021; Haigh et al., 2017; Mitchell and Subramaniam, 2005). Consequently, embracing a healthy, anti-inflammatory dietary routine could serve as an effective intervention or preventive measure to reduce the risk of depression and loneliness.

A number of prospective cohort studies have investigated the association between dietary inflammation and depressive symptoms in older adults (Bizzozero-Peroni et al., 2022; Ma et al., 2021; Shivappa et al., 2018). One such study, involving two cohorts of community-dwelling older adults in Spain, indicates that individuals following pro-inflammatory diets are 2.76 times more likely to exhibit depressive symptoms compared to those adhering to anti-inflammatory diets (Bizzozero-Peroni et al., 2022). This finding held true across different variables, such as sex, age, physical activity, and morbidity. Supporting this conclusion, Ma et al. (2021) found a 31 % higher risk of developing depression in people consuming pro-inflammatory diets compared to those following anti-inflammatory ones amongst 1865 older Chinese adults. In a meta-analysis, Matison et al. (2021) discovered that older adults with higher consumption of pro-inflammatory foods had an increased incidence of depression, whilst a high intake of fruit and vegetables was linked to a decreased incidence.

The majority of existing studies have utilised the Dietary Inflammatory Index (DII) (Shivappa et al., 2018) to gauge the inflammatory potential of dietary choices, but the methods of application of this index vary. Participants in these studies are often categorised into four quartiles based on their DII scores. By comparing individuals on the most pro-inflammatory diets (highest DII score quartile) with those on the most anti-inflammatory diets (lowest DII score quartile), researchers can discern variations in dietary habits associated with the onset of depression. However, previous studies have included varying numbers of food parameters and adopted different DII score cut-off values. For example, Bizzozero-Peroni et al. (2022) included 32 of the 45 original DII food components, whilst Ma et al. (2021) only captured 22 food parameters. As a result, this inconsistency might lead to participants' inflammatory statuses being classified inconsistently, potentially resulting in under- or over-reporting. In addition, when converting individual's dietary consumptions into DII scores, the index cannot discern whether certain types of anti-inflammatory foods play a more significant role in the connection between anti-inflammatory diets and mental health than others. Consequently, the results may be limited in terms of offering specific dietary recommendations for participants.

However, findings concerning the diet-depression relationship remain mixed. In a study consisting of French individuals aged 60 or above, those consuming higher amounts of pro-inflammatory components did not display a significantly increased risk of developing depressive symptoms (Odds Ratio (OR): 1.22, 95 % confidence interval (CI): 0.91–1.63) over an approximate five-year follow-up period (Adjibade et al., 2019). Another study with Australian participants aged 65 and older found no significant association between dietary

inflammation and the risk of depressive symptoms during a five-year period (Shakya et al., 2021). Moreover, no longitudinal relationship between pro-inflammatory dietary patterns and depressive symptoms was identified in older Italian adults during a nine-year study (Vermeulen et al., 2018).

On the other hand, empirical evidence for the link between dietary patterns and loneliness in older adults is scarcer than that for depression. A study in 1997 revealed that marital status plays a pivotal role in the dietary quality of older adults (Charlton, 1999). Specifically, older single men tend to consume fewer fruits and opt for easily prepared foods compared to their married counterparts (Charlton, 1999). Similarly, a review exploring the association between living alone and nutrient intake found that older single men who live alone are more likely to have a low intake of some core foods, especially fruits, vegetables, and fish (Hanna and Collins, 2015). However, these studies lacked a systematic examination of loneliness and its association with participants' dietary habits. Conversely, a longitudinal study of English adults aged 52 and older over a 10-year period found no association between loneliness and the dietary habit of consuming fruits and vegetables (Kobayashi and Steptoe, 2018).

1.4. Aim and hypothesis

Despite the high prevalence of depression and loneliness amongst older adults, this demographic group remains underrepresented in existing research. The consequences of late-life depression and loneliness are diverse, having found several relationships between depression and loneliness with increased morbidity, more functional and cognitive impairment, and other health outcomes involving sleep quality and stress responses (Cohen-Mansfield et al., 2016; Fiske et al., 2009; Wu et al., 2012). With a growing elderly population, dietary interventions designed to reduce the risk of depression and loneliness have the potential to reduce the global burden of these conditions.

Accordingly, this study aims to investigate the role of anti-inflammatory dietary patterns in depression and loneliness amongst the elderly population. No previous research has studied depression and loneliness individually within the same dataset and examined both individual and combined effects of distinct types of anti-inflammatory foods. It is hypothesised that anti-inflammatory dietary components are associated with a reduced risk of depressive symptoms and loneliness in older adults. Thus, this study will further examine the relationships between the prevalence of depression and loneliness, and the individual and combined effects of anti-inflammatory dietary components.

2. Materials & methods

2.1. Study design

This study uses data from the English Longitudinal Study of Ageing (ELSA) to analyse the association between diet and depression or loneliness symptoms. ELSA is a population-based longitudinal cohort study of people aged 50 or older in England. It is designed to offer insights into the economic, social, and health-related dimensions affecting this aging population. The present study used data on diet, depression, and loneliness from the ninth wave of ELSA collected between 2018 and 2019.

The cohort's ethical approval was obtained from South Central – Berkshire Research Ethics Committee on May 10, 2018 (17/SC/0588). Informed consent was obtained from all participants. Further details on the ELSA survey are available at: http://www.elsa-project.ac.uk.

2.2. Population

Participants who completed questionnaires on diet, depression, and loneliness in wave 9 were included in the present study. In wave 9, every ELSA participant who completed the primary in-person interview was invited to complete an Online Dietary Questionnaire. They were prompted to do so on two distinct days in the week following their interview. Detailed information about the process can be found in the leaflet available at https://www.elsa-project.ac.uk/study-documentation.

Out of all eligible individuals, 5068 (approximately 61 %) participants completed at least one diary day during the fieldwork period. Of these, the vast majority (n = 4403) completed both days. After accounting for missing data in the dietary components, 4254 participants remained in the final dataset ready for analysis.

A power analysis was conducted using the G*Power software to determine the required sample size for logistic regression analysis. As previous reviews of cross-sectional studies have shown a small effect size between diet quality scores and mental health conditions (Lassale et al., 2019; Solomou et al., 2023), an effect size of 0.3 was assumed. The significance level (α) was set at 0.05, with the analysis designed to achieve a power of 0.90. The predictor was assumed to follow a binomial distribution. The probabilities of the outcome, given predictor values of 0 and 1, were estimated to be 0.2 and 0.5, respectively. The calculated necessary sample size was 2890 considering these assumptions. Therefore, the current sample size of 4254 should be sufficient to detect an effect size of 0.3.

2.3. Measures

2.3.1. Anti-inflammatory dietary patterns

On the designated days, participants were required to log in to the questionnaire and document their food and drink consumption from the previous day. This data was then processed in NatCen's Brentwood data processing unit, where each dietary variable was coded to reflect the actual quantity of portions consumed per day. Participants' intake of fruits, nuts and seeds, fish, wholegrains, legumes, and vegetables were included in the current study.

2.3.2. Loneliness

Loneliness was assessed using the revised version of the three-item short-form scale developed at the University of California, Los Angeles (R-UCLA) (Hughes et al., 2004). It consists of three indirect questions related to loneliness that do not use the word 'lonely' including: 'How often do you feel that you lack companionship?'; 'How often do you feel left out'; and 'How often do you feel isolated from others?' (Hughes et al., 2004).

Responses were given on a three-point Likert scale with the following options: 1 = 'Hardly ever or never,' 2 = 'Some of the time,' and 3 = 'Often'. Consistent with existing studies, participants with scores of 6 or above were classified as experiencing loneliness (Kobayashi and Steptoe, 2018). The reliability of the three-item R-UCLA loneliness scale is demonstrated by a Cronbach's alpha of 0.71 (Hughes et al., 2004).

2.3.3. Depression

Self-reported depressive symptoms were measured using the eight-item Centre for Epidemiologic Studies Depression Scale (CES-D), a shortened version of the original 20-item CES-D scale (Radloff, 1977). This short version boasts high internal consistency (Cronbach alpha = 0.81) and has psychometric properties comparable to the full 20-item CES-D (Briggs et al., 2018). The scale consists of eight yes/no questions, asking respondents whether they experienced depressive symptoms, such as feeling down or having restless sleep, in the week prior to the interview. Participants who responded positively to four or more questions were categorised as displaying significant depressive symptoms (Zaninotto et al., 2022).

2.3.4. Covariates

Participants' age (participant's self-reported age), gender (participant's self-identification as a man or a women), and ethnicity (categorised as white or non-white) were regarded as covariates. Self-rated

weight was divided into three levels: 1 = About the right weight, 2 = Too heavy, 3 = Too light. Marital status was categorised into four groups: 1 = Single, 2 = Married/Remarried, 3 = Separated/Divorced, and 4 = Widowed. Education was grouped into two categories: 1 = higher education, 2 = below university degree. Socio-economic status was gauged using non-housing wealth and was divided into three tertiles: 1 = lowest tertile, 2 = medium tertile, and 3 = highest tertile. Lifestyle factors, such as the presence or absence of an activity-limiting long-standing illness, were also included as covariates.

2.4. Statistical analysis

Differences in the prevalence of depression and loneliness based on demographic variables have been described. Moreover, to explore differences in anti-inflammatory dietary habits amongst participants with or without depression and loneliness, anti-inflammatory variables were categorised as low intake group (0–90th percentile) and high intake group (90–100th percentile) for the descriptive analysis.

Two sets of binary logistic regressions were conducted to estimate the OR and the 95 % CI for the association between anti-inflammatory dietary variables and the prevalence of depression and loneliness. In the first set, each anti-inflammatory dietary component – fish, fruit, nuts and seeds, legumes, vegetables, and wholegrains – was viewed as a single independent predictor of depression and loneliness. By contrast, the second set of logistic models included all anti-inflammatory dietary variables simultaneously. Both models were built with and without adjusting for relevant covariates including participant's age, gender, ethnicity, self-rated weight, marital status, education, socio-economic status, and activity-limiting long-standing illness.

To assess the performance of these models, McFadden's R^2 was used to evaluate model fit. McFadden's R^2 is a pseudo R^2 measure that assesses the explanatory power of binary logistic regression models. Unlike traditional R^2 in linear regression, which represents the proportion of variance explained, McFadden's R^2 is based on the ratio of the log-likelihood of the fitted model to the null model (McFadden, 1987). In this context, McFadden's R^2 values indicate the extent to which dietary variables and covariates improve model fit when predicting depression or loneliness outcomes, rather than the absolute proportion of variance explained. However, model fit alone does not guarantee statistical validity.

To ensure the reliability and validity of the logistic regression models, assumption checks were performed before summarising the models. Specifically, the model's goodness-of-fit was tested using the Hosmer & Lemeshow tests, and multicollinearity was assessed with the variance inflation factor (VIF). All models passed both tests: they had a significant p-value in the Hosmer and Lemeshow test, and the mean VIF was less than 5 (meaning no evidence of high multi-collinearity). This indicates there was no multicollinearity amongst the included independent variables, whilst there is no significant difference between the observed and predicted values.

Overall, this comprehensive approach facilitated a robust evaluation of both individual and combined dietary effects on mental well-being while ensuring the statistical integrity of the results. All statistical analyses were conducted in RStudio (version 4.1.3), with the significance level set at a p-value of 0.05.

3. Results

3.1. Sample characteristics

The baseline characteristics of the analytical sample are presented in Table 1. The core population contains 4254 participants (46 % male, 54 % female). The average age of the sample is 68.24 (standard deviation (sd) = 7.61). The sample is predominately white (n = 4,143, 97 %), and well-educated (n = 3,883, 91 %).

Overall, 355 participants (8 %) had depression, and 623 participants (15 %) reported having loneliness. Depressed participants are generally younger (mean age = 67.58), while lonely participants are older (mean age = 69.79). Socio-economic position varies with depression status; notably, half of the depressed participants (n = 177) have low non-

Table 1
Characteristics of the participants classified according to their depression and loneliness status.

	Total (n = 4254)	Participants without depression (n = 3774)	Participants with depression (n = 355)	Participants without Loneliness (n = 3506)	Participants with Loneliness (n = 623)
Age (years)	68.24 (7.61)	68.33 (7.48)	67.58 (8.34)	68.35 (7.52)	69.79 (7.77)
Gender (n,%)	4254				
Male	1946 (46 %)	1772 (47 %)	112 (41 %)	1631 (47 %)	253 (41 %)
Female	2308 (54 %)	2002 (53 %)	243 (59 %)	1875 (53 %)	370 (59 %)
Ethnicity (n,%)	4254				
White	4143 (97 %)	3687 (98 %)	340 (96 %)	3431 (98 %)	596 (96 %)
Non-white	111 (3 %)	87 (2 %)	15 (4 %)	75 (2 %)	27 (4 %)
Weight (n,%)	4251				
Too light	133 (3 %)	101 (3 %)	28 (8 %)	94 (3 %)	35 (6 %)
About the right	1873 (44 %)	1711 (45 %)	112 (32 %)	1599 (46 %)	224 (36 %)
Too heavy	2245 (53 %)	1960 (52 %)	215 (61 %)	1811 (52 %)	364 (58 %)
Marital status (n,%)	4254				
Single	246 (6 %)	204 (5 %)	28 (8 %)	172 (5 %)	60 (10 %)
Married	3126 (73 %)	2841 (75 %)	201 (57 %)	2718 (78 %)	324 (52 %)
Divorced or separated	500 (12 %)	412 (11 %)	73 (21 %)	356 (10 %)	129 (21 %)
Widowed	382 (9 %)	317 (8 %)	53 (15 %)	260 (7 %)	110 (18 %)
Education (n,%)	4163				
Higher education	3883 (93 %)	3451 (93 %)	324 (94 %)	3205 (93 %)	570 (93 %)
Below university degree	280 (7 %)	248 (7 %)	21 (6 %)	226 (7 %)	43 (7 %)
Non-housing wealth	4214				
Low	1405 (33 %)	1179 (32 %)	177 (50 %)	1081 (31 %)	275 (44 %)
Medium	1404 (33 %)	1282 (34 %)	92 (26 %)	1181 (34 %)	193 (31 %)
High	1405 (33 %)	1279 (34 %)	85 (24 %)	1212 (35 %)	152 (25 %)
Long-standing illness (n,%)	4254				
No	2997 (70 %)	2765 (73 %)	142 (40 %)	2558 (73 %)	349 (56 %)
Yes	1257 (30 %)	1009 (27 %)	213 (60 %)	948 (27 %)	274 (44 %)

Values are means (standard deviations) or number of participants (proportions).

housing wealth, compared to 32 % of non-depressed individuals (n = 1777) who also have low non-housing wealth.

Compared to married individuals, those who are divorced, separated, or widowed showed heightened prevalence of depression and loneliness. Furthermore, depression and loneliness are more prevalent amongst women, non-whites, those perceiving themselves to be 'too heavy,' individuals with lower non-housing wealth, and those with activity-limiting long-standing illnesses.

3.2. Prevalence of depression and loneliness according to eating habits

The proportion of participants with or without depression remains relatively consistent across various anti-inflammatory dietary intakes, as depicted in Table 2. Amongst those with a low intake of anti-inflammatory foods, around 3374 participants (91 %) did not report depression, whereas 326 participants (9 %) did. Similarly, amongst those with a high intake of anti-inflammatory foods, around 400 participants (93 %) did not report depression, whilst 29 participants (7 %) did.

For each dietary variable, those in the high intake percentile generally reported a slightly lower rate of depression than those in the low intake percentile. However, the wholegrain category was an exception, with the high intake group reporting a slightly higher depression rate (10 %) compared to the low intake group (8 %).

Overall, the prevalence of depression appears to be marginally lower in the high-intake group for most of the anti-inflammatory dietary variables.

For most dietary variables (specifically fruits, nuts and seeds, fish, and vegetables), higher consumption had a lower prevalence of loneliness compared to their lower consumption counterparts (Table 3). Amongst those with a low intake of these anti-inflammatory foods, 3136 participants (89 %) did not report loneliness, whereas 370 participants (11 %) did. Meanwhile, amongst those with a high intake, 564 participants (91 %) did not report feelings of loneliness, whereas 59 participants (9 %) indicated they did.

However, other food parameters, including legumes and wholegrains, exhibit an increased prevalence of loneliness with higher intake (Table 3).

3.3. The association between individual anti-inflammatory dietary components and the prevalence of depression and loneliness

The results from the binary logistic regression, with each anti-inflammatory variable treated as an independent variable, are presented in Table 4.

In the non-adjusted models, most of the dietary components appear to demonstrate a protective trend against both depression and loneliness, as indicated by a positive OR. The odds ratio associated with fruit consumption and depression is 0.89 (95 % CI: 0.79, 1.00, p = 0.05). The odds ratio associated with fruit consumption and depression is 0.89 (95 % CI: 0.79, 1.00, p = 0.05). This suggests that, for every unit increase in fruit consumption, the odds of experiencing depression decrease by approximately 11 %. Similarly, a 9 % reduction in the odds of experiencing loneliness is associated with every unit increase in vegetable consumption (OR = 0.91, 95 % CI: 0.83, 1.00, p = 0.05). However, the other anti-inflammatory dietary components, namely, nuts and seeds, fish, wholegrains, and legumes, showed only a weak or negligible association with the odds of depression and loneliness, as evidenced by the odds ratio values being close to 1 and the p-values not being particularly low.

Despite observing certain associations, the p-values for most of these predictors exceed the conventional significance level of 0.05 after adjusting for covariates (Table 4). This means there is no strong statistical evidence to assert that these dietary elements are associated with depression or loneliness. Furthermore, the R^2 values are all relatively low (R^2 = 0.00), suggesting that the dietary variables alone do not account for much of the variability in depression or loneliness.

Table 2
Observations on the anti-inflammatory dietary variables and the prevalence of depression in ELSA (n = 4254).

	Low intake (0–90 % percentile)		High intake (90–100 % percentile)	
	Without depression	With depression	Without depression	With depression
Fruit	3374 (91 %)	326 (9 %)	400 (93 %)	29 (7 %)
Nuts and seeds	3374 (91 %)	325 (9 %)	400 (93 %)	30 (7 %)
Fish	3631 (91 %)	342 (9 %)	143 (92 %)	13 (8 %)
Wholegrain	3496 (92 %)	323 (8 %)	278 (90 %)	32 (10 %)
Legume	3553 (91 %)	332 (9 %)	221 (91 %)	23 (9 %)
Vegetables	3343 (91 %)	325 (9 %)	331 (92 %)	30 (8 %)

Table 3
Observations on the anti-inflammatory dietary variables and the prevalence of loneliness in ELSA (n = 4254).

	Low intake (0–90 % percentile)		High intake (90–100 % percentile)	
	Without loneliness	With loneliness	Without loneliness	With loneliness
Fruit	3136 (89 %)	370 (11 %)	564 (91 %)	59 (9 %)
Nuts and seeds	3130 (89 %)	376 (11 %)	569 (91 %)	54 (9 %)
Fish	3372 (96 %)	134 (4 %)	601 (96 %)	22 (4 %)
Wholegrain	3240 (87 %)	579 (13 %)	266 (86 %)	44 (14 %)
Legume	3307 (85 %)	578 (15 %)	199 (82 %)	45 (18 %)
Vegetables	3192 (91 %)	314 (9 %)	576 (92 %)	47 (8 %)

Table 4
Binary logistic regression analyses predicting prevalence of depression and loneliness using single dietary variables with and without covariates.

Predictors	Odds ratio (95 % confidence interval)					
	With depression	p-value	R^2	With Loneliness	p-value	R^2
Fruit	**0.89 (0.79, 1.00)**	**0.05**	**0.00**	0.93 (0.85, 1.02)	0.11	0.00
	0.88 (0.79, 1.00)	0.06	0.11	0.93 (0.85, 1.02)	0.12	0.08
Nuts and seeds	0.93 (0.83, 1.05)	0.26	0.00	0.91 (0.83, 1.00)	0.06	0.00
	0.96 (0.85, 1.08)	0.49	0.11	0.93 (0.84, 1.01)	0.10	0.08
Fish	0.90 (0.80, 1.02)	0.11	0.00	0.10 (0.91, 1.09)	0.93	0.00
	0.93 (0.82, 1.05)	0.24	0.11	1.00 (0.91, 1.10)	0.94	0.07
Wholegrain	0.98 (0.88, 1.09)	0.71	0.00	0.94 (0.86, 1,02)	0.16	0.00
	1.04 (0.93, 1,17)	0.53	0.11	0.94 (0.86, 1.03)	0.16	0.08
Legume	0.98 (0.87, 1.10)	0.70	0.00	0.99 (0.90, 1.08)	0.80	0.00
	1.01 (0.90, 1.14)	0.81	0.11	1.00 (0.92, 1.10)	0.92	0.08
Vegetables	0.89 (0.79, 1.01)	0.06	0.00	**0.91 (0.83, 1.00)**	**0.05**	**0.00**
	0.92 (0.81, 1.03)	0.15	0.11	0.94 (0.85, 1.03)	0.12	0.08

*Each predictor has two rows of results: the first row presents the odds ratio and associated statistics without any covariates, while the second row includes the odds ratio with covariates.
* Covariates including participant's: age, gender, ethnicity, self-rated weight, marital status, education, socio-economic status, and limiting long-standing illness.
*Significant results were bolded.

However, amongst the dietary variables considered, fruit intake appears to have the most pronounced potential protective association against depression after adjusting for covariates. This association is on the verge of reaching statistical significance with a p-value of 0.06.

3.4. The association between combined dietary components and the prevalence of depression and loneliness

Table 5 presents the analytical results incorporating all dietary components as independent variables.

Similar to individual effects observed earlier, anti-inflammatory dietary components appear to exert only a minor influence on the prevalence of depression and loneliness. None of the dietary factors have a precise association. Notably, the odds ratios for wholegrains and legumes are close to 1. This indicates that there is almost no change in odds for depression or loneliness with an increase in these dietary intakes.

By contrast, the incorporated covariates stand out as significant predictors for the outcomes. When these covariates are taken into consideration, the effect size between diet and mental well-being becomes minimal.

The particularly low R^2 values (0.004 and 0.003 for depression and loneliness without covariates, respectively) show that these dietary factors only make a minimal contribution to the variability in depression and loneliness. Furthermore, even with the inclusion of covariates, the R^2 values remain relatively low (0.115 and 0.078 for depression and loneliness, respectively), indicating that a large portion of the variability remains unexplained.

4. Discussion

This study analysed the association between anti-inflammatory dietary components and the prevalence of depression and loneliness in a nationally representative sample of English older adults. Contrary to the hypothesis, anti-inflammatory dietary patterns were not consistently associated with a reduced risk of depressive symptoms or loneliness in older adults, except for some borderline unadjusted associations between single dietary components (such as fruit and vegetable intake) and depression or loneliness.

Table 5
Binary logistic regression analyses predicting prevalence of depression and loneliness using all anti-inflammatory dietary variables with and without covariates.

Predictors	Odds ratio (95 % confidence interval)			
	With depression	p-value	With Loneliness	p-value
Fruit	0.92 (0.81, 1.05)	0.21	0.97 (0.88, 1.06)	0.50
	0.91 (0.79, 1.03)	0.14	0.96 (0.87, 1.06)	0.43
Nuts and seeds	0.95 (0.84, 1.08)	0.43	0.92 (0.84, 1.01)	0.11
	0.98 (0.87, 1.10)	0.69	0.93 (0.85, 1.03)	0.17
Fish	0.92 (0.81, 1.04)	0.16	1.01 (0.92, 1.10)	0.87
	0.93 (0.82, 1.06)	0.29	1.02 (0.86, 1.00)	0.75
Wholegrain	1.00 (0.78, 1.11)	0.95	0.95 (0.87, 1.03)	0.22
	1.05 (0.94, 1.19)	0.36	0.94 (0.93, 1.12)	0.22
Legume	1.00 (0.89, 1.12)	0.96	1.01 (0.92, 1.10)	0.91
	1.03 (0.92, 1.16)	0.61	1.02 (0.93, 1.12)	0.65
Vegetables	0.93 (0.81, 1.05)	0.25	0.93 (0.84, 1.03)	0.16
	0.95 (0.83, 1.08)	0.39	0.95 (0.86, 1.05)	0.28

R^2 (depression without covariates) = 0.004; R^2 (depression with covariates) = 0.115.
R^2 (loneliness without covariates) = 0.003, R^2 (loneliness with covariates) = 0.078.
*Each predictor has two rows of results: the first row presents the odds ratio and associated statistics without any covariates, while the second row includes the odds ratio with covariates.
* Covariates including participant's: age, gender, ethnicity, self-rated weight, marital status, education, socio-economic status, and limiting long-standing illness.

Fruit and vegetable consumption is universally recognised as being integral to a healthy way of life. The World Health Organisation (WHO) recommends eating at least 400 g or five servings of fruit and vegetables daily (WHO, 2003). The exact mechanisms by which fruits and vegetables are thought to lead to a decreased risk of depression are yet to be clearly identified. However, some evidence suggests that consumption of flavonoids, vitamin C, and vitamin E found in fruits and vegetables, are associated with reduced risk of developing depression (Ali et al., 2021; Mikkelsen et al., 2016; Sahraian et al., 2015). One possible pathway involves the oxidative stress, which has been implicated in the pathophysiology of depression and loneliness (Bajpai et al., 2014; Li and Xia, 2020; Payne et al., 2012). As fruits and vegetables are micronutrient and anti-oxidant rich, they could help combat oxidative stress and, therefore, impact on participants' mood. In a study investigating children aged between 7 and 10 (n = 50) and young adults ranging from 18 to 21 years (n = 21), the consumption of a blueberry beverage enriched with flavonoids was associated with alleviated depressive symptoms and improved positive mood (Khalid et al., 2017).

The current findings are consistent with two other cohort studies conducted amongst the English population, which found no association between anti-inflammatory dietary patterns and depression or loneliness (Kobayashi and Steptoe, 2018; Luciano et al., 2012). Specifically, there was a borderline statistically significant association found between consuming five daily servings of fruits and vegetables and loneliness in older English adults. However, this association weakened after a complete adjustment for covariates (Kobayashi and Steptoe, 2018). Similarly, Luciano et al. (2012) found no mediation effect of the Mediterranean diet on the relationship between depressive symptoms and inflammation.

In contrast, other studies in different populations, such as Chicago and Greece, support the hypothesis that adherence to a Mediterranean diet—characterised by high intake of vegetables, fruits, wholegrains, fish, and legumes—may protect against depressive symptoms (Skarupski et al., 2013; Mamalaki et al., 2023). The inconsistencies between findings may be partly explained by geographical and cultural variations in dietary patterns (Lassale et al., 2019). According to Lassale et al. (2019), dietary patterns reflect the habitual food environment of a given population, which may differ from the idealised Mediterranean or anti-inflammatory diet assessed in research. This suggests that discrepancies between studies could arise from differences in food accessibility, preparation methods, or broader lifestyle factors associated with dietary habits.

Another possible explanation for the weaker associations found in this study is the differential effects of pro- and anti-inflammatory foods. As discussed in the literature review, studies such as Adjibade et al. (2019) have demonstrated that pro-inflammatory diets are strongly associated with an increased risk of depression, suggesting that these foods may exert more immediate effects on systemic inflammation, thereby exacerbating mood disorders. In contrast, anti-inflammatory dietary components may require long-term adherence or interaction with other lifestyle factors to exert meaningful effects (Mamalaki et al., 2023). Given these findings, both reducing pro-inflammatory dietary intake and increasing anti-inflammatory foods should be considered complementary approaches rather than mutually exclusive strategies for promoting mental well-being.

Traditional analyses in nutrition that focus on a single food or a small number of foods have been criticised for their conceptual and methodological limitations (Hu, 2002; Kant, 1996). In this context, dietary pattern analysis, which reflects various combinations of food intake, enhances researchers' ability to comprehensively assess and understand the complex interplay between diet and disease risk (Hu, 2002). However, the present study only examined anti-inflammatory food groups, including fruit, nuts and seeds, fish, wholegrains, legumes, and vegetables, yet did not consider other dietary patterns investigated with ELSA, such as dairy intake, or sugar, alcohol, or meat consumption. The

excluded food parameters could play a pivotal role in the relationship between diet and participants' mental well-being. Thus, it is possible that non-anti-inflammatory or overall dietary patterns might have a more pronounced effect on mental well-being than anti-inflammatory components.

However, the absence of a universal definition for an anti-inflammatory diet has resulted in diverse methods used to characterise these diets, making the results incomparable. This incomparability could impede the ability to combine data from multiple studies in meta-analyses, which are critical for providing evidence-based recommendations. Furthermore, it restricts the reproducibility of studies, raising concerns about the reliability of the research.

While a large number of studies have primarily focused on pro-inflammatory dietary patterns and their association with elevated depressive symptoms (Bizzozero-Peroni et al., 2022; Ma et al., 2021), the present study highlights the need for more nuanced research on anti-inflammatory diets. The borderline significance of specific anti-inflammatory dietary components in this study—such as fruit intake for depression and vegetable intake for loneliness—suggests that further exploration of these dietary factors is warranted. Rather than viewing anti-inflammatory diets merely as the inverse of pro-inflammatory diets, future research should investigate their independent effects and optimal dietary compositions for mental health benefits.

To address these gaps, future studies should develop or adopt a standardised definition of what constitutes an 'anti-inflammatory diet' to ensure consistency in research and to make study results more comparable. Additionally, the cross-sectional nature of the current study only allows the researcher to determine the prevalence of depression and loneliness. However, the single measurement of dietary intake fails to capture the dynamic nature of dietary habits and their potential shifts over time, which could be intrinsically linked to the incidence rates of depression and loneliness. Anti-inflammatory dietary components might serve as a protective factor against the development of depression and loneliness (e.g., Tolkien et al., 2019). Longitudinal studies should be conducted, involving multiple assessments over time, to examine whether there is a relationship between anti-inflammatory diets and the incidence of depression or loneliness. Employing longitudinal studies could address numerous shortcomings found in cross-sectional research (Caruana et al., 2015), by allowing for causal inferences between an anti-inflammatory diet and mental health. This approach could also explore the clinical applications of adjusting the inflammatory characteristics of dietary patterns to enhance mood and reduce both depressive and loneliness symptoms.

Whilst diet might be a key factor, it represents just one aspect of understanding and managing mental health. It is apparent from the varied results that the relationship between diet and mental health is multifaceted. Consistent with the low R-squared result from the current study, Vermeulen et al. (2018) found that the explained variation in food groups related to older adults' depressive symptoms was a mere 4.9 %. Other lifestyle factors, such as genetics, environment, physical activity, and social relationships, undoubtedly play pivotal roles in older adult's mental well-being (Firdaus, 2017; Forsman et al., 2013; Langhammer et al., 2018). Hence, a comprehensive approach to mental well-being is paramount. Future research should also explore the synergistic effects of anti-inflammatory diets in conjunction with other interventions, such as exercise, cognitive-behavioural therapy (CBT), and medication.

To the best of the author's knowledge, this is the first study to examine the relationship between an anti-inflammatory diet and loneliness, particularly in the older population. This age group warrants special attention because older individuals generally have an elevated susceptibility to inflammation, depression, and loneliness in comparison with younger adults. Of the foods investigated in the present study, increasing fruit intake might offer the most pronounced potential benefit in terms of reducing the odds of experiencing depression.

This study has several strengths, especially its utilisation of secondary data sourced from ELSA. One of its primary advantages is the inclusion of a large and comprehensive elderly sample which captures the dynamics of ageing and offers representative insights into the elderly population in England. Both loneliness and depression scales are well-established with demonstrated reliability, thus enhancing the robustness of the findings.

However, the present study also has certain limitations which should be acknowledged. Firstly, the ELSA sample predominantly consisted of white participants (97 %), with a considerable majority being affluent and highly educated (93 % holding a university degree). In wave 9, 8736 participants have participated in the interview. The current sample size only includes 48 % of the respondents, with the rest of the ELSA participants not completing the dietary assessment of the study. Consequently, they were not included in the present study. These drawbacks raise concerns regarding the generalisability of the findings to the broader elderly population in the UK.

Secondly, the study focused on five dietary components with anti-inflammatory properties—fruits, nuts and seeds, fish, wholegrains, legumes, and vegetables—while excluding pro-inflammatory dietary factors such as sugar, alcohol, and meat, despite their availability in the dataset. These components were not included because the study aimed to examine foods that have been associated with anti-inflammatory effects. However, we acknowledge that pro-inflammatory foods may also play a role in the relationship between diet and mental health outcomes. Future research could explore the combined effects of both anti-inflammatory and pro-inflammatory dietary patterns to provide a more comprehensive understanding of their role in depression and loneliness.

Additionally, another potential limitation is the study's omission of data regarding the use of medications or a clinical diagnosis related to depression. This leaves a gap in the evidence supporting clinical manifestations of these conditions. Moreover, the researcher did not account for the presence of other pertinent chronic illnesses, such as diabetes. Considering the known correlation between the dietary restrictions often faced by diabetic patients (such as limited food choices, food insecurity) and heightened depression severity (Silverman et al., 2015), overlooking these variables might lead to a potentially skewed interpretation of the results.

5. Conclusion

In conclusion, this study adds to the growing body of research indicating a role for an anti-inflammatory diet in older adults' health and well-being. Whilst individual dietary components showed borderline significance, a holistic approach to dietary patterns may offer more insights into older adults' mental well-being. Ultimately, implementing dietary interventions with other therapeutic strategies could be an avenue for holistic treatment approaches. Future research is required to investigate these associations and to develop comprehensive mental health strategies for the ageing population.

CRediT authorship contribution statement

Yujia Zhang: Writing – original draft. **Eleonora Iob:** Writing – review & editing, Supervision. **Thamara Tapia Munoz:** Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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