Adherence to the Eatwell Guide and cardiometabolic, cognitive and neuroimaging parameters: An analysis from the PREVENT Dementia study

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Abstract

Healthy diet behaviours are important in a globally ageing population, particularly in relation to cardiometabolic and brain health. The Eatwell guide (EWG) reflects the UK government's recommendations for a healthy and balanced diet. Data from the PREVENT dementia cohort study baseline visit was used in this analysis. Binary and graded EWG scores (BEWG, GEWG) were created from a self-reported Food Frequency Questionnaire. The CAIDE score was included as the primary outcome measure to represent risk for future AD. Secondary outcome measures included cardiometabolic health measures, and brain health measures. Generalised additive models were run in R. A total of 517 participants were included in the analysis, with a mean BEWG score of 4.39 (±1.66) (out of a possible 12 points) and GEWG score of 39.88 (±6.19) (out of a possible 60 points). There was no significant association between either EWG score and the CAIDE (BEWG β: 0.07; p: 0.32; GEWG β: 0.02, p: 0.36) or any measures of brain health. There was a significant association between higher GEWG score and lower systolic and diastolic blood pressure and body mass index (BMI) (systolic β: -0.24, p: 0.03; diastolic β: -0.16, p: 0.01; BMI β: -0.09, p: 0.02). Although not directly associated with the CAIDE score, the EWG dietary pattern may be beneficial for dementia prevention efforts through modification of hypertension and obesity, which are both known risk factors for dementia. Future work could replicate these findings in other UK-based cohorts as well as further development of EWG scoring methodologies.

Introduction

Modification of dietary patterns has been considered as a potential strategy for the improvement of multiple health conditions. Healthy eating behaviours have been associated with reduced risk of all-cause mortality and many chronic age-related conditions [1, 2]. Indeed, one in seven UK deaths and one in five premature deaths in the UK is thought to be attributable to poor diet [3]. The role of healthier dietary behaviours is critical in the context of a globally aging population, particularly for cardiometabolic and brain health, with dementia and heart disease the leading causes of death in the UK [4].

There is substantial evidence supporting an association between adherence to a Mediterranean dietary pattern (MedDiet) and better cardiometabolic health [5-12]. The MedDiet is rich in whole plant foods such as fruit, nuts, vegetables and legumes, olive oil and fish [13]. Recent reviews have reported conflicting findings on the association between the MedDiet and brain health [14], with certain subgroups, such as those living in the Mediterranean region, potentially more likely to benefit from MedDiet adherence [15]. A recent analysis of the European Prevention of Alzheimer's Dementia Longitudinal Cohort Study (EPAD LCS) (n=1826, mean age 65.6 years) found that participants living in the Mediterranean had a stronger association with MedDiet adherence and brain health outcomes compared to those living in non-Mediterranean countries [16]. This may reflect the fact that high adherence to a MedDiet in non-Mediterranean regions differs from the pattern followed in the Mediterranean basin, where the consumption of olive oil, fish, vegetables and legumes is higher, differences or the fact the MedDiet scoring tools do not fully capture a high-quality diet in non-Mediterranean regions [17]. Scores such as the Dutch Dietary Guidelines and the Japanese Diet Index have been developed to better reflect the traditional healthy eating habits and national healthy eating guidelines [15], and are likely to be more considerate of national sustainability and sociocultural factors [18].

Public Health England (now The Office for Health Improvement and Disparities) produced the ‘Eatwell Guide’ (EWG) to communicate UK government recommendations for a healthy and balanced diet, with the ultimate aim of improving health and reducing non-communicable disease [19]. The EWG broadly aligns with key characteristics of the MedDiet, and promotes the consumption of fruit and vegetables, legumes and fish as sustainable protein sources, unsaturated oils, wholegrains and fibre rich carbohydrates sources, and adequate fluid intake, whilst limiting consumption of sugar-rich discretionary foods and processed meats [19, 20]. As the EWG is modelled around UK food and dietary habits, it may provide a more realistic dietary pattern goal than, for example, a MedDiet [21]. A number of the components of the EWG have been consistently associated with better health, including better cardiometabolic outcomes [22], reduced cancer incidence [23, 24] and cognitive health [25]. However, few studies have explored associations between overall adherence to the EWG and health. In one cross-cohort analysis of data from EPIC-Oxford, One Million Women study and UK Biobank, higher adherence to the EWG was associated with a reduced risk of mortality [26]. This study by Scheelbeck *et al* is the first to create an empirical score from the EWG and investigate associations with health outcomes. Analyses applying the same EWG scoring methodology in post-menopausal women in the UK Women's Cohort Study (UKWCS) reported that higher adherence to the EWG was associated with lower weight, waist circumference and BMI [27]. Further, greater adherence to the EWG at baseline was associated with smaller increases in waist circumference and lower risk of abdominal obesity over 4 years [27]. Whilst these provisional findings are promising, they are restricted to a limited number of health outcomes. Moreover, Scheelbeek *et al* did not incorporate all EWG components into their score due to availability of data across datasets and scored each EWG component on a binary basis (i.e., points awarded for achieving a dietary goal), which may fail to capture more nuanced differences in diet quality between individuals (e.g., by partially meeting an EWG recommendation).

Associations between EWG adherence and risk of dementia are currently unknown. Indeed, the SACN (2018) review on *Diet, Cognitive Impairment and Dementia* identified a gap in the research about UK healthy eating recommendations and dementia risk [28]. The aim of this current study was to develop a new binary and graded scoring methodologies for EWG adherence, building on the initial methodology developed by Scheelbeek *et al*, in order to explore associations between adherence to the EWG and risk for dementia, cardiometabolic and brain health in a cohort of midlife adults in the UK and Ireland. Furthermore, a comparison was made between the EWG scores and MedDiet scores within the cohort, to explore the comparability of these two models to capture healthy eating.

Methods

PREVENT Dementia Programme

The data used in this study is drawn from the baseline visit of the PREVENT dementia programme (PREVENT) [29, 30]. PREVENT is a prospective cohort study of 700 participants aged 40 to 59 years of age at baseline, at least half of whom have a parental history of dementia. Participants were recruited from five centres in the UK and Ireland (Cambridge, Dublin, Edinburgh, London, and Oxford). Participants completed physical health and cognitive assessments at the baseline visit as well as providing information on risk factors for future neurodegeneration through a series of self-report questionnaires.

Ethical Approval and Consent

The study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human participants were approved by the London-Camberwell St Giles National Health Service Research Ethics Committee (REC reference 12/LO/1023). Written informed consent was provided by all participants prior to any protocol procedures.

Calculation of Eatwell Guide scores

Dietary data were collected with the Scottish Collaborative Group Food Frequency Questionnaire (SCG-FFQ) [31, 32]. The SCG-FFQ was self-administered by each participant. It begins with clear instructions on the first page of the questionnaire including pictures of portion sizes, which all participants were instructed to read before self-reporting their diet. Study staff were on hand to answer any questions that participants had and to check for missing data prior to the participant leaving the site. The SCG-FFQ has been validated in several populations in the UK as a self-report tool [31, 32]. The SCQ-FFQ asks participants to report their consumption of 175 foods and drinks over the previous two to three months. The SCG-FFQ was completed at the baseline visit, with repeated dietary data collection currently ongoing in follow up visits (Visit 2; 2-4 years post-baseline; Visit 3: 5-8 years post baseline). A comprehensive nutritional breakdown is available for each participant in addition to food level responses. Daily nutrient intake was calculated from the food intake data using the McCance and Widdowson 2021 dataset [33]. Intakes of carbohydrates, proteins, total fats and saturated fatty acids (SFA) were converted into calorie values to calculate the percentage of calories from each food group included in the diet.

Two EWG scores were created, one applying a binary scoring methodology, and one a graded score (hereafter referred to as the binary EWG and graded EWG respectively). Full details of scoring methodologies are available in the supplementary materials (Supplementary Table S1). Each score awarded points for adherence to EWG criteria for the following food and nutrient groups; carbohydrates, proteins, fats, SFA, fibre, sugars, salt, total kilocalories, fruit and vegetables, fish, red and processed meats, and water. For the binary scoring, the method was modelled on a traditional MEDAS score [34]; participants were awarded 1 point if they met criteria for the nutritional or food component, else 0 points were awarded, with a total possible score of 12. Intake values were not rounded up for any of the components. The graded score was modelled on the Panagiotakos Pyramid MedDiet score [35], with 0 to 5 points allocated according to level of compliance with the EWG recommendations, with a total possible score of 60. 5 points was awarded if a participant met the EWG recommendations for a food or macronutrient group. 0 points were awarded for achieving less than half of the recommended intake for healthy foods (carbohydrates, proteins, fibre, fruit and vegetables, fish and water) and for consuming 1.5 times the recommended limit for unhealthy foods (fats, SFA, sugars, salts, red and processed meats). Taking carbohydrates as an example for the binary EWG score 1 point was awarded if ≥50% of calories reported in the diet were from carbohydrates and 0 points for <50% of calories from carbohydrates; for the graded EWG score 5 points were awarded for ≥50% of calories reported in the diet were from carbohydrates, 4 points for

≥43.75% and <50% of calories from carbohydrates, 3 points for ≥37.5% and <43.75% of calories from carbohydrates, 2 points for ≥31.25% and <37.5% of calories from carbohydrates, 1 point for ≥25% and <31.5% of calories from carbohydrates and 0 points for <25% of calories from carbohydrates.

Calculation of Mediterranean diet scores

Three MedDiet scores (the Mediterranean Diet Adherence Screener (MEDAS) score, the MEDAS continuous and the MedDiet Pyramid (Pyramid) score) were calculated using previously published scoring methods. Briefly, the MEDAS score was calculated using a binary scoring method, whereby participants were allocated 0 or 1 points for each of 14 food groups depending on whether they met consumption criteria [36]. The MEDAS continuous was developed by Shannon *et al* with points allocated for the same consumption criteria as MEDAS but on a continuous scale from 0 to 1, depending upon proximity to the dietary target, as opposed to binary allocations [37]. Similarly, the Pyramid score was also coded on a continuous scale of 0 to 1 with a total possible score of 15 points [38]. Continuous scores have been shown to have more sensitivity to detecting differences in diet quality, particularly in a UK population, where they have shown stronger associations with better cognition [37] and reduced dementia risk [39] compared with binary scores.

CAIDE score

The Cardiovascular Risk Factors, Ageing and Dementia (CAIDE) risk score was calculated for all participants. The CAIDE score was originally developed in the FINGER study, and ranges from 0 to 18 points with higher scores representing greater dementia risk [40]. The CAIDE score was calculated using self-reported age, education and sex, systolic blood pressure (SBP) (mean of triplicate blood pressure readings in supine or seated position recorded at baseline visit), body mass index (BMI) (height and weight recorded at baseline visit, used for BMI calculation), fasting plasma total cholesterol, (analysed in local laboratories at the baseline visit), physical activity (self-reported non-validated questionnaire asking participants how often they complete light, moderate and vigorous exercise; 0 points awarded for never up to 5 points for daily, scores summed across all three categories with higher points reflecting more physical activity) and *APOEε4* carrier status (DNA analysed from blood collected at baseline). The score weighting is presented in TableS2

Cardiometabolic outcome variables

Data on blood pressure (systolic and diastolic (SBP, DBP)), BMI, and waist-to-hip ratio (WHR) values (recorded at baseline visit) were extracted from the database. Each of these cardiometabolic measures were collected by trained study staff at the baseline visit. A Framingham Risk Score (FRS) was calculated for each participant using the 'CVrisk' package in R [41] and a QRisk3 score was calculated using the 'QRISK3' R package [42]. The variables used to create these cardiovascular risk scores are detailed in Supplementary Table S3.

Cognitive outcome measures

For the purposes of this analysis, the score for the Four Mountains Task (4MT) was selected as the primary cognitive outcome. The 4MT is a novel tablet-administered task designed to assess allocentric processing. Participants are shown an image of four mountains for approximately 10 seconds and after a short interval (~ 1 second) asked to select which scene they were previously shown from a choice of four image options [43]. The 4MT has been shown to be sensitive to early neurodegenerative disease [44] and has also previously been associated with the MedDiet in a European cohort study [16].

Magnetic resonance imaging (*MRI) variables*

Magnetic resonance imaging (MRI) scans were collected using 3T Siemens scanners (Verio, PRISMA, Prisma Fit, Skyra). Derived variables were extracted from the dataset to include left and right hippocampal volume, left and right hippocampal thickness, white matter hyperintensity volume (cube-transformed) and total estimated intra-cranial volume. Further details on the imaging acquisition and processing in the PREVENT dataset can be found elsewhere [45].

Self-reported diet quality

Participants were asked to indicate (yes or no) if they felt they ate a healthy diet. No further context was provided as to what defined a healthy diet and there was no set time period, rather participants were asked to respond about how they felt generally about their diet.

Covariates

Several covariates were assessed, including age, sex, years of education, *APOE*?*4,* parental history of dementia (self-reported), socioeconomic status (SES) group and physical activity. SES group was determined according to self-reported occupation using the National Statistics socio-economic classification (NS-SEC: https://www.ons.gov.uk/methodology/classificationsandstandards/otherclassifications/thenationalstatisticssocioeconomicclassificationnssecrebasedonsoc2010) and grouped in low, middle and high socioeconomic group or into a not in employment group. The not in employment group included both participants who reported they were unemployed and those who had taken early retirement. As total kilocalories were included in the EWG scores, the analyses were not adjusted for total energy intake. For analysis including the CAIDE score as the outcome measure, only parental history of dementia and physical activity were included as covariates so as not to over-correct the model. Where the FRS or QRisk3 was the outcome variable of interest, years of education *APOE*?*4,* parental history of dementia and physical activity were included as covariates. The National Adult Reading Test (NART) score was included as an additional covariate in the 4MT analysis as a measure of premorbid intelligence. Finally, for all the brain imaging models, intracranial volume was included as a covariate.

Statistical Analysis

All statistical analyses were completed using R (Version 4.1.0). Descriptive statistics were calculated for all participants. Where necessary, to ensure the fulfilment of distributional assumptions of the models fitted, data was transformed. For the main analysis, we excluded participants with missing data in the exposure, outcome, and covariate variables of interest from the analysis. Relationships between the binary EWG (BEWG) and graded EWG (GEWG) scores and the MedDiet scores were assessed using correlations. As the BEWG and GEWG scores were slightly skewed, generalised additive models were run. First, we tested the cohort as a whole and fitted univariate and fully adjusted generalised additive models to test for associations between BEWG and GEWG scores and the CAIDE score. The fully adjusted model included parental history of dementia, physical activity scores and SES group. We then ran univariate and fully adjusted generalised additive models to test for associations between BEWG and GEWG scores and measures of cardiometabolic health (SBP, DBP, BMI, WHR, FRS, QRisk3), brain health (4MT total score, cube-transformed white matter lesion volume, left and right hippocampal volume, and left and right hippocampal thickness), and self-rated diet quality. Covariates included in each model are detailed in the tables of results. Finally component level analysis was run for the CAIDE score (as the primary outcome) and for all other outcomes with a statistically significant fully adjusted model. An exploratory analysis tested for any differences in outcomes with the GEWG score by SES group. A formal sample size calculation was not undertaken as this was a secondary analysis of a large observational study.

Results

Descriptive statistics

A total of 517 participants were included in the primary analyses which investigated CAIDE risk scores and cardiometabolic health. Additional analyses involved fewer participants due to missing data, with sample sizes for each outcome detailed in Table 1. The sample included more women (59.6%), had a similar number of participants with and without a parental history of dementia (52.8% vs 47.2%), with 38.3% *APOE*ε*4* carriers Most participants fell in the highest SES group according to their occupations (64.6%), with a high number of years of education reported in the sample (16.72 (±3.31) years). See Table 1 for full demographic and descriptive details.

The sample had a mean BEWG score of 4.39 (±1.66) (range 0 to 9) and a mean GEWG score of 39.88 (±6.19) (range 16 to 53). Women had higher BEWG scores compared to men (4.55 (±1.66) vs 4.15 (±1.65), t: 2.70, p: 0.007) however this difference was smaller when comparing women to men for the GEWG scores (40.31 (±6.16) vs 39.24 (±6.20), t: 1.94, p: 0.05). Participants in the low SES group had lower GEWG scores than the high SES group (Low: 37.50 (±6.57); High: 40.55 (±5.90), p: 0.003), with no significant difference in BEWG scores by SES group. Age was significantly associated with higher BEWG and GEWG scores (BEWG β: 0.03, SE: 0.01, p: 0.03; GEWG β: 0.14, SE: 0.05, p: 0.004). Higher physical activity scores were associated with higher GEWG, but not BEWG, scores (β: 0.22, SE: 0.10, p: 0.02). There were no differences in BEWG or GEWG score by parental history of dementia or *APOE*4 status. There was no significant association between the total number of years of education and either the BEWG or GEWG scores. A breakdown of the number of contributing component information for each score is presented in Supplementary Table S4. All participants were consuming more than 5% of calories from sugars and so no participants were awarded a point for this component using the BEWG scoring methodology. This may be due to the way sugars were calculated from the SCQ-FFQ and is explored further in the discussion.

The BEWG and GEWG scores were highly correlated with each other (R: 0.77, p<0.001). BEWG and GEWG scores were correlated with MedDiet scores to explore the similarity between the dietary patterns. All scores were moderately correlated (r= 0.3-0.4), with moderate correlations between the BEWG and GEWG scores with the three MedDiet scores (MEDAS, MEDAS continuous, Pyramid) (see Figure 1).

Analytical statistics

CAIDE

There was no significant association between the BEWG score or GEWG score and the CAIDE score in unadjusted or fully adjusted models (Fully adjusted scores; BEWG β: 0.07, SE: 0.07, p: 0.33; GEWG β: 0.02, SE: 0.02, p: 0.36) (see Table 2). Meeting fat requirements (i.e. ≤35% calories from fat) for both the BEWG and the GEWG scores was associated with a higher CAIDE score (Fully adjusted scores; BEWG β: 0.61, SE: 0.25, p: 0.01; GEWG β: 0.24, SE: 0.12, p: 0.04), with no other associations seen at the food or nutritional component level (see Supplementary Table S5 and Supplementary Table S6).

Cardiometabolic health

There were no significant associations between BEWG scores and SBP, DBP or BMI, and no significant associations between either scoring methodology and WHR, FRS or QRisk3 scores. In contrast, higher GEWG scores were associated with lower SBP and DBP (fully adjusted SBP β: -0.24, SE: 0.11, p: 0.03; DBP β: -0.16, SE: 0.06, p: 0.01), as well as with lower BMI (β: -0.09, SE: 0.04, p: 0.02) (see Table 2). Higher scores awarded for the GEWG total fat component (i.e. eating fewer total calories from fat and therefore being closer to achieving ≤35% calories from fat) were associated with higher SBP (β: 1.53, SE: 0.63, p: 0.01). Conversely, having higher scores for the fibre (indicating being closer to achieving the EWG dietary target of ≥22.6g/d of fibre), fruits and vegetables (indicating being closer to achieving the EWG dietary target of ≥400g/d of fruits and vegetables), and fish (indicating being closer to achieving the EWG dietary target of ≥10g/d of fish) GEWG score components was associated with significantly lower SBP (fibre β: -0.97, SE: 1.30, p: 0.007; fruits and vegetables β: -1.09, SE: 0.44, p: 0.01; fish β: -1.03, SE: 0.36, p: 0.005). Higher scores for the fibre, fruits and vegetables, and red and processed meat (indicating being closer to achieving the EWG dietary target of ≤70g/d of red or processed meat, i.e. higher scores reflect eating less of this food group) GEWG score components were associated with significantly lower DBP (fibre β: -0.61, SE: 0.22, p: 0.006; fruits and vegetables β: -0.79, SE: 0.27, p: 0.004; red and processed meats β: -0.77, SE: 0.29, p: 0.007). Only higher scores for the fruits and vegetables graded EWG score component were associated with lower BMI (β: -0.38, SE: 0.15, p: 0.01) Further details of these associations are provided in Supplementary Tables S7, S8 and S9.

Four Mountains Test and MRI variables

There was no significant association between either the BEWG or the GEWG score and the 4MT total score (BEWG β: 0.05, SE: 0.11, p: 0.68; GEWG β: 0.02, SE: 0.03, p: 0.58) (see Table 3). There were no significant associations between the BEWG or GEWG scores and any MRI variables in the fully adjusted models (see Table 3). In the high SES group only, there was a significant negative association between GEWG scores and left hippocampal volume (see Supplementary Table S9).

Perception of healthy eating

There was a significant association between the positive self-report of eating a healthy diet, and higher BEWG and GEWG scores (BEWG β: 0.92, SE: 0.21, $p<0.001$; GEWG β: 3.71, SE: 0.78, $p<0.001$) (see Table 3). There was a significant association between the positive self-report of eating a healthy diet and higher BEWG in the middle, high and not in-employment SES groups, but not in the low SES group, and with the GEWG in the high and not in employment SES groups but not low or middle SES groups (see Supplementary Table S9).

Discussion

Both the BEWG and GEWG scores created in this analysis were moderately correlated with three commonly used MedDiet scores (the MEDAS, MEDAS continuous and Pyramid scores). There were no associations between either EWG score and the primary outcome of the CAIDE score. However, when looking at individual cardiometabolic components of the CAIDE there was an association between higher GEWG scores and lower SBP, DBP and BMI. In particular, achieving more points (indicating being closer to meeting the EWG criteria in full) for fruits and vegetables was associated with better cardiometabolic health. There were no associations noted between binary or graded EWG scores and brain health as assessed by cognitive or brain volume outcomes. There was a significant association between self-perception of a healthy diet and higher binary and graded EWG scores, with the association strongest in the high SES group as well as in those participants who were not in employment at the time of dietary data collection.

There were no significant associations between either the binary or graded EWG scores and the CAIDE score, suggesting EWG adherence is not associated with risk for dementia in this midlife cohort. The CAIDE score was selected as one of the most commonly used dementia risk scores, with associations between the score and neuroimaging outcomes previously reported in the PREVENT dementia cohort [46-49]. Importantly the CAIDE score reflects the accumulation of cardiovascular risk for dementia, factors which may be the most amenable to dietary interventions. However, the CAIDE score is not without limitations and validation work outside of the original cohort where the score was developed has suggested there is very little discrimination compared to age alone [50]. It is also important to consider that many of the components of the CAIDE score would not be modifiable by diet (age, sex, education and *APOEε4*) which may explain the lack of association reported in this analysis. The CAIDE score in the population included in this analysis from the PREVENT cohort is lower compared to the FINGER cohort intervention study where the score was originally developed (PREVENT: 5.95 vs FINGER: 7.76 (intervention) and 7.27 (control) [51]), and it may be that any EWG score associations would only be seen in a cohort with a higher mean CAIDE score where there is more potential for modification. As age is one of the important contributors to the overall CAIDE score, it is worth replicating this analysis between EWG scores and CAIDE score in an older cohort (such as the NICOLA or UK Biobank cohorts [52, 53]) to understand if there is an association in later in midlife, where the mean cohort CAIDE score would be expected to be higher due to age.

Despite no statistically significant associations with the CAIDE score, there were a number of significant associations between the GEWG score and cardiometabolic health which themselves are likely protective of brain health. Importantly these are the elements of the CAIDE score which would be expected to be modifiable by diet. GEWG scores were associated with lower SBP, DBP and BMI. As there were no significant associations between the BEWG score and cardiometabolic health measures, this suggests the GEWG score is more appropriate to apply to this population with partial compliance to EWG criteria important for health. This may reflect previously reported statistics that only 0.1% of the UK population adhere to all nine recommendations [26]. In the context of dementia prevention efforts, it is particularly important to note that the GEWG was associated with lower blood pressure and BMI values, given both hypertension and obesity are known midlife risk factors for AD [54]. A ten-point change in the GEWG was associated with a 2.4 mmHg reduction in SBP, a 1.6 mmHg reduction in DBP and a 0.9kg/m^2 reduction in BMI. A 2mmHg reduction in SBP has been estimated to decrease the risk of death from stroke by 10% [55], although larger reductions in SBP may be needed to reduce the risk of dementia with a potential U-shaped association where both low and high BP confers risk [56, 57]. Similarly, a 2 mmHg reduction in DBP has been estimated to result in a 17% decrease in hypertension and a 15% reduction of risk from stroke and transient ischaemic attacks [58]. In midlife, each 1 unit increase in BMI was associated with a higher risk of dementia in a 38-year follow-up of the Framingham Study [59].

There were no associations seen between either EWG score and any of the brain health outcome measures, with the exception of an association between higher GEWG score and lower left hippocampal volume in the high SES group only. As this was only seen in the left and not right hippocampus and in a single SES group only, it should be interpreted with caution, although previous studies have also found a stronger effect of a healthy diet in the left compared to the right hippocampus [60, 61] and this warrants further research. Exploring whether the EWG scores are associated with functional brain imaging measures as well as with AD pathology (such as amyloid beta, tau and neurofilament light) will also be important next steps for research.

Unsurprisingly and reassuringly, there were significant but moderate correlations between the EWG scores and MedDiet scores which demonstrates some overlap in these healthy eating patterns as well as a divergence in how the scores are created. For example, whilst both dietary patterns prioritise the consumption of fruits and vegetables and fish, with limited red and processed meats, the EWG otherwise focuses on a recommended macronutrient intake whilst the MedDiet recommends foods such as olive oil, legumes, and nuts. This should be a noted limitation of the EWG compared to MedDiet scores when translating to public health approaches, as the EWG requires people to know their nutrient intake and understand percentages of intake by calories. Further development of the EWG to translate the recommendations to a more food-based approach, as in the MedDiet and recommended by the Nutrition for Dementia Prevention Working Group [62], will be important. In particular, evidence suggests that using olive oil as the predominant fat in a diet has promise for mitigating vascular risk factors for AD [63].

This is particularly pertinent given most of the positive individual food component associations with cardiometabolic health were seen in the food groups rather than the nutrient intakes, except for higher fibre consumption associated with lower SBP. Meeting, or approaching the set criteria, for fruit and vegetable consumption (≥400g/d) was associated with lower SBP, DBP and BMI. A one-point change on this criteria (indicating being closer to consuming ≥400g/d of fruit and vegetables) was associated with a 1.09 mmHg reduction in SBP, a -0.79 mmHg reduction in DBP, and a -0.38 kg/m^2 reduction in BMI. This has been seen in a number of studies [64, 65], included in Scheelbeck *et al* where fruit and vegetable consumption was associated with the largest reduction in mortality risk [26]. Given adopting dietary change is complex and multifactorial [66], public health messaging (alongside policy changes to ensure affordability) focusing on increasing fruit and vegetable intake as the one food group consistently associated with better health outcomes may be a sensible approach. A rapid review of the EWG has suggested a number of recommendations for better communication of the tool which, if adopted, may result in better adherence to the dietary guidelines [67].

There are some noted limitations of this analysis. The use of total fat as a diet quality measure is recognised to be crude and potentially misleading. We observed significant associations between meeting or getting higher scores on the fat component (i.e. eating, or being closer to eating, less than 35% of calories from fat) and both higher CAIDE score (greater risk for future dementia) and higher SBP, in the absence of any specific findings with SFA. Understanding the role of dietary fats in health has been a topic of much debate in the scientific literature and there is consensus that total fat content alone has little meaning for many health outcomes [68]. Indeed, we know from many studies that nuts (source of omega 3 polyunsaturated fatty acids) and olive oil (source of monounsaturated fatty acids alongside some saturated and polyunsaturated fatty acids) is associated with favourable health outcomes [63, 69]. This again suggests that further development of the EWG scores to better reflect the foods contributing to the macronutrients rather than the macronutrients themselves may be a more helpful approach to untangle the complexity of dietary fats. Finally, no participants met criteria for the sugars cut off applied to the dataset (≤5% calories from sugar), which is likely caused by the sugars calculated for PREVENT reflecting total sugars (glucose, galactose, fructose, sucrose, maltose and lactose) as opposed to free sugars (added sugars and naturally occurring sugars excluding galactose and lactose). Future nutritional analysis should consider a more detailed breakdown of sugars to better explore this component.

This study developed scoring methodologies for a BEWG and GEWG score. Whilst there was no association between these scores and either risk for dementia or brain health in this mid-life cohort, there were significant associations between higher graded EWG scores and lower SBP, DBP and BMI. Adhering to fibre, fish, and fruit and vegetable were particularly associated with better cardiovascular health. Future research should further develop the EWG scores to reflect a food-based approach as opposed to the current reliance on macronutrient contributions to overall energy intake. Higher adherence to the EWG may be an important part of dementia risk reduction interventions through reductions in hypertension and obesity, both of which are important modifiable risk factors for dementia [54].

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Author contributions

SG, OS: Conceptualization, Methodology, Formal Analysis, Writing- Original Draft, Writing- Reviewing and Editing; AG, AJ, FCM, JM, RT, NW: Methodology, Formal Analysis, Writing- Reviewing and Editing; SP-S: Methodology, Writing-Reviewing and Editing; A-MM, GMT, CWR, ES: Supervision, Writing- Reviewing and Editing.

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Conflict of interest.

None.

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Variable	Whole cohort n= 517		Very low adherence (0 - 2.5 points) n= 56	Low adherence (3 - 4.5 points) n= 228	Moderate-to-high adherence (5 - 9 points) n= 233
	n (%) / Mean (SD)	Range			
Sex (male) (n, %)	210 (40.6)	N/A	27 (48.2)	100 (43.9)	83 (35.6)
Parental history of dementia (yes) (n, %)	273 (52.8)		30 (53.6)	119 (52.2)	124 (53.2)
*APOE*ε4 (yes) (n, %)	198 (38.3)		19 (33.9)	93 (40.8)	86 (36.9)
Age (years) (mean, SD)	51 (5.38)	40 - 59	50 (5.27)	51 (5.50)	52 (5.27)
Education (years) (mean, SD)	17 (3.31)	9 – 38	16 (3.31)	17 (3.45)	17 (3.15)
SES Group (n, %). Low	40 (7.7)	N/A	7 (12.5)	17 (7.5)	16 (6.9)
Middle	81 (15.7)		13 (23.2)	39 (17.1)	29 (12.4)
High	334 (64.6)		30 (53.6)	141 (61.8)	163 (70.0)
Not in employment	62 (12.0)		6 (10.7)	31 (13.6)	25 (10.7)
Physical activity score (mean, SD)	10.91 (2.82)	0 - 15	10.43 (2.92)	10.78 (2.89)	11.15 (2.70)
BEWG score (mean, SD)	4.39 (1.66)	0 – 9	1.64 (0.60)	3.56 (0.50)	5.85 (1.09)
GEWG score (mean, SD)	39.88 (6.19)	16 - 53	30.62 (5.78)	37.95 (4.09)	43.99 (4.44)
MEDAS (mean, SD)	5.44 (1.72)	1 - 12	3.95 (1.27)	5.29 (1.56)	5.94 (1.73)
MEDAS continuous (mean, SD)	7.29 (1.58)	1.68 – 12.59	5.87 (1.35)	7.20 (1.47)	7.71 (1.53)
Pyramid score (mean, SD)	8.11 (1.55)	2.35 – 14.54	6.77 (1.62)	8.05 (1.37)	8.50 (1.50)
CAIDE score (mean, SD)	5.95 (2.83)	0 - 13	5.57 (2.98)	6.05 (2.98)	5.94 (2.64)
SBP (mmHg) (mean, SD)	124.91 (15.54)	82.67 – 182.67	129.02 (14.67)	125.12 (15.00)	123.71 (16.14)
DBP (mmHg) (mean, SD)	76.25 (9.57)	46.00 – 122.67	79.21 (7.63)	76.31 (9.88)	75.49 (9.58)
BMI (kg/m^2) (mean, SD)	27.23 (5.19)	16.52 – 69.06	27.57 (5.59)	27.68 (5.71)	26.70 (4.47)

Variable	Whole cohort n= 516		Very low adherence n= 56	Low adherence n= 228	Moderate-to-high adherence n= 232
	n (%)	Range			
Self-rated healthy diet (yes) (n, %)	442 (85.7)	N/A	33 (58.9)	193 (84.6)	216 (93.1)

Variable	Whole cohort n= 503		Very low adherence n= 54	Low adherence n= 220	Moderate-to-high adherence n= 229
	Mean (SD)	Range			
FRS (mean, SD)	8.69 (6.41)	1.04 – 30.00	9.29 (6.96)	8.99 (6.75)	8.26 (5.92)
QRisk3 (mean, SD)	4.81 (4.04)	0.43 – 30.70	4.76 (3.55)	4.94 (4.59)	4.70 (3.58)

Variable	Whole cohort n= 342		Very low adherence n= 39	Low adherence n= 159	Moderate-to-high adherence n= 232
	Mean (SD)	Range			
4MT total score (mean, SD)	9.85 (3.39)	0 - 15	9.46 (3.71)	9.82 (3.37)	10.00 (3.34)

Variable	Whole cohort n= 514		Very low adherence n= 56	Low adherence n= 226	Moderate-to-high adherence n= 232
	Mean (SD)	Range			
Cube-transformed white matter lesion volume (mL) (mean, SD)	1.21 (0.40)	0.35 – 3.38	1.17 (0.42)	1.24 (0.43)	1.20 (0.36)
Left hippocampus volume (mm^3) (mean, SD)	4034.01 (393.11)	2744.4 – 4374.8	4045.12 (397.54)	4052.21 (381.55)	4013.59 (401.54)
Right hippocampus volume (mm^3) (mean, SD)	4158.40 (428.04)	2939.7 – 5676.5	4160.46 (436.81)	4184.51 (427.47)	4132.47 (426.77)

Left hippocampus thickness (mm) (mean, SD)	2.44 (0.07)	2.24 – 2.66	2.43 (0.06)	2.43 (0.08)	2.44 (0.07)
Right hippocampus thickness (mm) (mean, SD)	2.43 (0.07)	2.23 – 2.60	2.43 (0.07)	2.43 (0.07)	2.43 (0.06)

Table 1:Demographic and descriptive statistics of sample included in Eatwell Guide score analysis. 4MT: Four Mountains Test; BMI: body mass index; DBP: diastolic blood pressure; EWG: Eatwell Guide; FRS: Framingham Risk Score; SBP: systolic blood pressure; SES: socioeconomic status.

Dietary score	Unadjusted			Fully adjusted		
	β	SE	p	β	SE	p
CAIDE						
EWG	0.03	0.07	0.64	0.07	0.07	0.32
EWG graded	0.0001	0.02	0.96	0.02	0.02	0.36
Systolic Blood Pressure						
EWG	-0.77	0.41	0.06	-0.45	0.39	0.25
EWG graded	-0.27	0.11	0.01	-0.24	0.11	0.03
Diastolic Blood Pressure						
EWG	-0.44	0.25	0.08	-0.22	0.24	0.37
EWG graded	-0.19	0.07	0.006	-0.16	0.06	0.01
BMI						
EWG	-0.14	0.14	0.32	-0.04	0.14	0.78
EWG graded	-0.12	0.04	0.001	-0.09	0.04	0.02
WHR						
EWG	-0.005	0.003	0.06	-0.0006	0.002	0.79
EWG graded	-0.002	0.0007	0.02	-0.0006	0.0006	0.32
FRS						
EWG	-0.27	0.17	0.11	-0.25	0.17	0.14
EWG graded	-0.09	0.05	0.05	-0.06	0.05	0.17
QRisk3						
EWG	-0.08	0.11	0.46	-0.06	0.11	0.58
EWG graded	-0.01	0.03	0.61	0.0003	0.03	0.99

Table 2: Table of generalised additive models for associations between EWG and EWG graded with CAIDE and cardiometabolic health outcomes. BMI: body mass index; EWG: Eatwell Guide score; FRS: Framingham Risk Score; WHR: waist-to-hip ratio. CAIDE score fully adjusted model includes parental history of dementia, physical activity score and socioeconomic status as covariates. Systolic/diastolic blood pressure, BMI and WHR models include age, sex, education, *APOEε4,* parental history of dementia, physical activity score and socioeconomic status as covariates. FRS and QRisk3 models include education, *APOEε4,* parental history of dementia, physical activity score and socioeconomic status as covariates.

Dietary score	β	SE	p	β	SE	p
Four Mountains Test						
EWG	0.04	0.11	0.72	0.05	0.11	0.68
EWG graded	0.02	0.03	0.52	0.02	0.03	0.58
White Matter Lesion Volume						
EWG	-0.004	0.01	0.69	-0.005	0.01	0.59
EWG graded	-0.002	0.003	0.40	-0.003	0.003	0.31
Left Hippocampus						
EWG	-15.81	0.82	0.06	-13.61	8.48	0.11
EWG graded	-4.61	2.21	0.04	-3.96	2.32	0.09
Right Hippocampus						
EWG	-15.78	9.05	0.08	-14.32	9.31	0.12
EWG graded	-1.17	2.44	0.63	-0.68	2.55	0.79
Left Hippocampal Thickness						
EWG	0.002	0.002	0.32	0.002	0.002	0.30
EWG graded	0.0008	0.0005	0.12	0.0009	0.0005	0.09
Right Hippocampal Thickness						
EWG	0.001	0.002	0.59	0.001	0.002	0.49
EWG graded	0.0005	0.0005	0.30	0.0007	0.0005	0.18
Self-reported healthy eating						
EWG	1.04	0.20	<0.001	0.92	0.21	<0.001
EWG graded	4.47	0.75	<0.001	3.71	0.78	<0.001

Table 3: Table of generalised additive models for associations between EWG and EWG graded with cardiometabolic risk scores, 4MT score and self-reported healthy eating. 4MT: Four Mountains Test; EWG: Eatwell Guide score; FRS: Framingham Risk Score. 4MT score fully adjusted model includes age, sex, education, *APOEε4,* parental history of dementia, NART score, physical activity score and socioeconomic status as covariates. Self-reported healthy eating score includes age, sex, education, *APOEε4,* parental history of dementia, *APOEε4,* physical activity score and socioeconomic status as covariates