

Diet Quality Index for older adults (DQI-65): development and use in predicting adherence to dietary recommendations and health markers in the UK National Diet and Nutrition Survey

Article

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1 **Diet Quality Index for older adults (DQI-65): development and use in predicting**
2 **adherence to dietary recommendations and health markers in the UK National Diet and**
3 **Nutrition Survey**

4

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16

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18

19 Keywords: Older adults; Elderly; Diet quality score; Cardiometabolic health; Healthy ageing

20

21 Abbreviations: 25(OH)D, 25-hydroxyvitamin D; AHEI-2010, Alternative Healthy Eating
22 Index-2010; BP, blood pressure; CHD, coronary heart disease; CRP, C-reactive protein;

23 CVD, cardiovascular disease; DBP, diastolic blood pressure; DQI, diet quality index; DQI-65,
24 Diet Quality Index for Older Adults; FDQI-65+PA, Food-based Diet Quality Index for Older
25 Adults with Physical Activity; HDL-C, high density lipoprotein cholesterol; HEI, Healthy
26 Eating Index; HEI-2015, Healthy Eating Index-2015; LDL-C, low density lipoprotein
27 cholesterol; MDS, Mediterranean Diet Scores; NDNS, National Diet and Nutrition Survey;
28 NFDQI-65, Nutrient and Food-based Diet Quality Index for Older Adults; NFDQI-65+PA,
29 Nutrient and Food-based Diet Quality Index for Older Adults with Physical Activity; SACN,
30 Scientific Advisory Committee on Nutrition; SBP, systolic blood pressure; T2D, type 2
31 diabetes; TC, total cholesterol; WC, waist circumference.

32 **Abstract**

33 Diet quality indexes (DQIs) are useful tools for assessing diet quality in relation to health and
34 guiding delivery of personalised nutritional advice, however existing DQIs are limited in their
35 applicability to older adults (aged ≥ 65 years). Therefore, this research aimed to develop a
36 novel evidence-based DQI specific to older adults (DQI-65). Three DQI-65 variations were
37 developed to assess the impacts of different component quantitation methods and inclusion of
38 physical activity. The variations were: Nutrient and Food-based DQI-65 (NFDQI-65),
39 NFDQI-65 with Physical Activity (NFDQI-65+PA) and Food-based DQI-65 with Physical
40 Activity (FDQI-65+PA). To assess their individual efficacy, the NFDQI-65, NFDQI-65+PA
41 and FDQI-65+PA were explored alongside the validated Healthy Eating Index-2015 (HEI-
42 2015) and Alternative Healthy Eating Index-2010 (AHEI-2010) using data from the cross-
43 sectional UK National Diet and Nutrition Survey (NDNS) rolling programme. Scores for
44 DQI-65 variations, the HEI-2015 and AHEI-2010 were calculated for adults ≥ 65 years from
45 years 2-6 of the NDNS (n=871). Associations with nutrient intake, nutrient status and health
46 markers were analysed using linear and logistic regression. Higher DQI-65s and HEI-2015
47 scores were associated with increased odds of meeting almost all of our previously proposed
48 age-specific nutritional recommendations, and with health markers of importance for older
49 adults, including lower body mass index, lower medication use and lower C-reactive protein
50 ($P < 0.01$). Few associations were observed for the AHEI-2010. This analysis suggests value of
51 all three DQI-65s as measures of dietary quality in UK older adults. However, methodological
52 limitations mean further investigations are required to assess validity and reliability of the
53 DQI-65s.

54

55 **Introduction**

56 The ageing global population⁽¹⁾ poses challenges to all aspects of society⁽²⁾, most notably
57 health and social care. To lessen this burden and support individuals to maintain their
58 physical, social and mental wellbeing later in life, exploring ways to promote healthy ageing
59 is of high priority. In particular, appropriate nutrition is considered an important factor in
60 reducing risk of cardiometabolic disease, slowing loss of bone and muscle mass, preserving
61 cognitive function, and helping to maintain physical and mental fitness in older age⁽³⁾.

62 Diet quality indexes (DQIs) are useful nutritional assessment tools, accounting for the
63 complexity of dietary exposure and the principle that people eat foods and not nutrients⁽⁴⁾, that
64 can be easily translated into food-based, dietary advice⁽⁵⁾. Their use is increasingly prevalent,
65 with several DQIs being investigated within older adults⁽⁶⁻¹⁸⁾. For example, Mediterranean
66 Diet Scores (MDS) have been inversely associated with risk of incident disability⁽¹⁵⁾ and with
67 overall, coronary heart disease (CHD) and cancer mortality^(8,13,16) in longitudinal studies.
68 Moreover, US Healthy Eating Index (HEI) scores have been positively associated with
69 components of the Fried et al. frailty phenotype⁽¹⁹⁾ and indicators of functional decline such as
70 gait speed and knee extensor power cross-sectionally⁽¹⁷⁾.

71 Nonetheless, component choice and scoring method mean current, widely used, DQIs
72 could be deemed unsuitable for older adults (aged ≥ 65 years) whereby a range of key health
73 outcomes related to mortality risk and quality of life, and impacts of physical and cognitive
74 decline, should be considered. Specifically, MDS discourage high dairy intake, a food group
75 beneficial for musculoskeletal health⁽²⁰⁾ and associated with lower risk of type 2 diabetes⁽²¹⁾
76 and cardiovascular disease (CVD)⁽²²⁾, whereas the HEI disregards the importance of oily fish
77 consumption, particularly long chain (LC) n-3 PUFA content, which has been associated with
78 reduced cognitive impairment⁽²³⁾, inflammation⁽²⁴⁾ and risk of CHD⁽²⁵⁾. Moreover, the

79 Alternative Healthy Eating Index-2010 (AHEI-2010) includes three fatty acid components,
80 resulting in strong associations with CVD risk⁽²⁶⁾, however overall dietary quality may not be
81 reflected in scores and associations with other health outcomes may be limited.

82 To our knowledge, only one DQI specifically tailored to older populations exists, the
83 US Elderly Dietary Index, for which scores have been cross-sectionally inversely associated
84 with CVD risk⁽⁹⁾. However, it has not been widely explored nor validated and may be limited
85 in its associations with physical function and sarcopenia by favouring only moderate protein
86 intake (highest scores awarded for only 1-2 servings/week each of meat, fish or seafood and
87 legumes) and excluding physical activity as high protein intake (1.0-1.2g/kg/day; equivalent
88 to ≥ 3 servings/day of meat, fish or seafood and legumes) has been associated with improved
89 or reduced loss of muscle mass and strength⁽²⁷⁾, and physical activity acts synergistically with
90 protein to enhance its effect⁽²⁸⁾. Moreover, current established and validated scores such as the
91 HEI and MDS were developed for use in US and Mediterranean populations respectively,
92 questioning the suitability within a UK population.

93 Therefore, this study aimed to develop three variations of an evidence-based DQI
94 suitable for UK older adults (aged ≥ 65 years) (DQI-65) that characterised an optimum dietary
95 pattern, and assess i) their ability to predict adherence to our previously proposed age-specific
96 nutritional recommendations for this population group⁽²⁷⁾ and ii) associations with health
97 markers of importance to older adults, using cross-sectional data. The novel DQI were
98 explored alongside the validated HEI-2015 and AHEI-2010 to identify whether the new DQI-
99 65s were better predictors of adherence to nutritional recommendations and health status.

100

101 **Methods**

102 *Development of the diet quality index for UK older adults*

103 *Index structure and variations*

104 DQI-65 development was based on the steps documented by Waijers, Feskens and Ocke⁽²⁹⁾
105 with all decisions being made by an experienced registered nutritionist (JAL) and registered
106 dietitian (RF), and a nutrition student (ND). Following a thorough evaluation of existing
107 indexes identified in the current literature, it was decided that the primary DQI-65 would be
108 comprised of the more frequently used combination of foods and nutrients, with physical
109 activity added due to the range of health benefits in older adults⁽³⁰⁾. However, it was deemed
110 appropriate to develop two further variations in order to test the effect of including physical
111 activity and the effect of exchanging nutrient components with food groups on the predictive
112 value of the index. The three DQI-65s were: Nutrient and Food-based DQI-65 (NFDQI-65),
113 which contained food groups and nutrients, NFDQI-65 with Physical Activity (NFDQI-
114 65+PA), which contained food groups, nutrients and physical activity, and Food-based DQI-
115 65 with Physical Activity (FDQI-65+PA), which contained solely food group components
116 with physical activity.

117

118 *Choice of index components*

119 All decisions regarding choice of components and scoring criteria were guided by the
120 nutritional recommendations for UK older adults (≥ 65 years) proposed in our previous critical
121 review, along with the practical food-based advice we devised⁽²⁷⁾. Nutrients from our
122 proposed age-specific nutritional recommendations were selected to be represented in the
123 index if new recommendations had been set (i.e. protein, calcium, vitamin B12, folate and
124 fluid) or if strong evidence supported their physiological role among older adults (i.e. dietary
125 fibre, free sugars, MUFA, PUFA and SFA, LC n-3 PUFA, sodium, vitamin D and alcohol).
126 Guidance from the UK *Eatwell Guide*⁽³¹⁾ was considered alongside these recommendations as

127 consistency between dietary guidelines, where appropriate based on the identified age-specific
128 evidence, would likely enhance adherence.

129 Twelve main components were devised, eleven of which were dietary components (a
130 mixture of food groups and nutrients) and the twelfth represented physical activity (except for
131 NFDQI-65 in which this was excluded).

132 Components 1-3 and 5-6 (fruit, vegetables, protein, low-fat dairy and wholegrain
133 carbohydrates) represent nutrients identified as important to older adults and, in the case of
134 protein, calcium, folate and vitamin B12, for which we proposed new, higher,
135 recommendations⁽²⁷⁾. Specifically, sufficient protein intake is important to support
136 maintenance of muscle mass and strength among older adults, which diminishes with age⁽³²⁾,
137 and we found that evidence suggests older adults have higher protein requirements due to
138 impaired absorption and utilisation⁽²⁷⁾. Furthermore, dairy provides bioavailable calcium, an
139 essential mineral required to minimise age-associated loss of bone mineral density⁽³³⁾, and,
140 along with animal proteins, is a good source of vitamin B12. Finally, fruit, vegetables and
141 wholegrain carbohydrates provide dietary fibre and a wide range of vitamins and minerals
142 (e.g., vitamins A, C, E and folate), supporting various physiological functions, and have been
143 associated with lower risk of CVD^(34,35).

144 Component 4 (oily fish) was selected due to oily fish containing LC n-3 PUFAs and
145 vitamin D, and being associated with lower risk of CHD⁽²⁵⁾.

146 Components 7-8 and 11 (free sugars, sodium, and alcohol) reflect nutrients in our
147 previously proposed nutritional recommendations that are considered detrimental to health of
148 older adults⁽²⁷⁾. Specifically, high intake of free sugar containing foods may displace protein
149 and micronutrient intake and increase risk of overweight or obesity⁽²⁷⁾ and sodium intake is a
150 major risk factor for hypertension⁽³⁶⁾ and has been positively associated with systolic blood

151 pressure (SBP) and diastolic blood pressure (DBP) in an elderly population⁽³⁷⁾. Moreover,
152 sensitivity to the toxicity of alcohol increases with age⁽³⁸⁾ and methodological limitations exist
153 within age-specific evidence supporting benefits of light-to-moderate intake on health (as is
154 appraised in the AHEI-2010), therefore discouraging alcohol consumption seems prudent in
155 this age group⁽²⁷⁾.

156 Component 9 (fat and fatty acids) reflects recommendations for dietary fat and fatty
157 acids in our previous review and accounts for the variable relationships between different
158 fatty acids and risk of chronic disease such as type 2 diabetes and CVD⁽²⁷⁾. Specifically, SFA
159 intake is discouraged and substitution with PUFA and MUFA is encouraged.

160 Component 10 (fluid) was selected as fluid intake is essential to prevent dehydration,
161 which is associated with impaired cognitive and physical function, and to lower risk of
162 constipation⁽³⁹⁾, which can impair appetite. Fluid intake is commonly low within this
163 demographic due to impaired thirst sensation, poor renal function and fear of incontinence⁽⁴⁰⁾,
164 meaning it should not be overlooked within dietary assessments among older adults.

165 Finally, component 12 (physical activity) was included in the FDQI-65+PA and
166 NFDQI-65+PA due to physical activity acting synergistically with protein to enhance muscle
167 maintenance or synthesis in response to amino acids⁽²⁸⁾, and its additional role in supporting
168 weight maintenance, cardiovascular health and preventing loss of bone strength⁽³⁰⁾.

169 No dietary variety component was included, but instead limitations were imposed
170 regarding number of portions of certain foods, notably for vegetables, fruit and protein,
171 preventing the maximum score being achieved without a varied diet. For example, for protein
172 only ≤ 1 portion each of legumes or nuts, dairy, and red meat were allowed per day, and for
173 vegetables only ≤ 1 portion each of legumes and tomato puree were allowed. These limitations

174 were based on a consensus decision by the nutrition experts, taking into account the health
175 benefits or detriments of each. Justification of these decisions are in **Supplementary Table 1**.

176

177 *Component measurement methods and recommendations*

178 Measurement methods chosen were either based on portions of representative foods or
179 nutrient intakes. The NFDQI-65/NFDQI-65+PA and FDQI-65+PA measured fruit,
180 vegetables, protein, low-fat dairy, wholegrain carbohydrates and fluid as portions of
181 representative foods, and the NFDQI-65/NFDQI-65+PA measured free sugars, sodium, fat
182 and fatty acid, and alcohol as nutrient intakes. In comparison, the FDQI-65+PA measured the
183 free sugars, sodium, fat and fatty acid, and alcohol components as portions of representative
184 foods which were selected based on main contributors to nutrient intakes in the NDNS and
185 the panel's consensus decision.

186 Guidelines for food-group components were based on number of portions eaten, with
187 a portion being a quantity considered as standard for UK adults (such as 80g for fruits and
188 vegetables)^(31,41,42) to ensure applicability of the index to general UK portion sizes, or a
189 quantity specified in SACN advice^(25,43). No age or sex-specific portion size guidance was
190 identified and therefore portion sizes were generalised to older adults and both men and
191 women. All portion weights were given as cooked or eaten. For nutrient components,
192 quantitation was as mg, g or percentage of total energy intake (as relevant) and was guided by
193 our previously proposed nutritional recommendations⁽²⁷⁾. For the NFDQI-65 and NFDQI-
194 65+PA, nutrient intake data for sodium and alcohol was used as mg and g, respectively, and
195 free sugars, MUFA, PUFA and SFA were as percentage of total energy intake. Physical
196 activity was assessed as minutes/day of moderate intensity activity which was calculated
197 within the NDNS dataset from data collected using an NDNS specific self-reported

198 questionnaire (Year 1) or the self-reported Recent Physical Activity Questionnaire (Years 2
199 onwards). Full details of physical activity assessment methods are detailed elsewhere⁽⁴⁴⁾.

200 Required numbers of portions for each food-based component were set by analysing
201 nutritional composition of specified foods and considering the evidence-base, as well as the
202 quantity required to meet specific nutritional recommendations. For example, for protein the
203 index recommendation is ≥ 3 portions/day to promote protein consumption at each meal due to
204 evidence of benefits of even protein distribution⁽⁴⁵⁾, and as it was determined that 3 portions
205 of protein, combined with specified quantities of other protein-rich foods in the index
206 including low-fat dairy, oily fish and wholegrain carbohydrates, would help support an
207 individual to meet the nutritional recommendation we proposed of 1.2g/kg/day⁽²⁷⁾. Similarly,
208 for low-fat dairy, the recommendation of ≥ 3 portions/day of the specified quantities was
209 calculated as each portion provides 200-250mg calcium therefore providing up to 75% of our
210 proposed daily calcium requirements of 1000mg which, in conjunction with other dietary
211 sources of calcium, should allow this to be met. Recommendations for oily fish were based on
212 the most recent UK Scientific Advisory Committee on Nutrition (SACN) advice⁽²⁵⁾, with 1
213 portion/week meeting advised LC n-3 PUFA intake, and for physical activity were taken from
214 the UK *Physical activity guidelines for older adults*⁽³⁰⁾. For the remainder of the components,
215 decisions were made from panel discussions, taking into account UK *Eatwell guide*
216 recommendations in the case of fruit, vegetables and wholegrain carbohydrates due to their
217 evidence-based nature and to promote consistency between guidelines where any reason to
218 differ did not exist. Full explanations for all components are in Supplementary Table 1.

219

220 *Index scoring*

221 The components were scored in a manner that accounted for their evidence-based associations
222 with health outcomes, negatively scoring those considered detrimental to health (i.e., lower
223 intake receives higher score) and positively scoring those considered beneficial to health (i.e.,
224 higher intake receives higher score). Specifically, the fruit, vegetables, protein, oily fish, low-
225 fat dairy, wholegrain carbohydrates, fat and fatty acids, fluid and physical activity
226 components were positively appraised due to their proposed health benefits and the free sugar,
227 sodium and alcohol components negatively appraised due to their proposed detrimental
228 effects and the conclusions from our previous review⁽²⁷⁾.

229 In the absence of qualitative evidence to suggest otherwise, components were equally
230 weighted, with scores for each ranging between 0-10 points. This is in line with other widely-
231 used DQIs, such as the HEI-2015 whose authors stated that dietary guidelines are to be
232 considered as a whole and “all concepts are equally important”⁽⁴⁶⁾. A score of 10 was awarded
233 for full adherence to each component recommendation, except for the fat and fatty acids
234 component of the NFDQI-65 and NFDQI-65+PA, which were subdivided into two sub-
235 components (MUFA+PUFA:SFA ratio and SFA intake) each worth up to 5 points. A
236 proportionate score was allocated for intakes between the minimum and maximum criteria
237 using a linear slope, for example if an individual consumed 1 portion of fruit/day (for which
238 the recommendation is ≥ 2 portions/day) they would score 5 out of 10 points, whereas 1.5
239 portions of fruit/day would score 7.5. The maximum total score was 120 points for FDQI-
240 65+PA and NFDQI-65+PA and 110 points for NFDQI-65. Higher scores reflect greater
241 adherence to the recommendations.

242 Full details of the components and scoring methods of the DQI-65 variations are in
243 **Table 1.**

244

245

246 *Ability of diet quality indices to predict adherence to dietary recommendations and health*
247 *markers*

248 The three DQI-65s were assessed alongside two widely used and validated scores: the
249 Healthy Eating Index-2015 (HEI-2015), which assesses adherence to the 2015-2020 US
250 Dietary Guidelines for Americans⁽⁴⁶⁾, and the US-based AHEI-2010, which assesses intake of
251 foods and nutrients associated with chronic disease risk⁽²⁶⁾.

252

253 *Study design and population*

254 Data was used for participants aged ≥ 65 years ($n=1076$) from years 2-6 of the UK NDNS
255 rolling programme (2009/2010-2013/2014)⁽⁴⁷⁾ (the most recent available NDNS data when the
256 DQI-65 was developed). The NDNS is a UK cross-sectional survey of randomly selected
257 individuals aged ≥ 1.5 years designed to assess dietary intake and nutritional status of a
258 representative UK population. The methodology of the NDNS has been fully described
259 elsewhere⁽⁴⁸⁾ and is summarised in the **Supplemental Methods**. Of importance, dietary
260 assessment is based on 4-day diet diaries and physical activity measured via self-reported
261 questionnaires on recent physical activity.

262 Individuals from year 1 were excluded due to the absence of physical activity data
263 ($n=174$), as were participants in years 2-6 where this data was not reported ($n=29$), and those
264 with energy intake < 600 kcal/day (600-4500 kcal reflected reasonable intake⁽⁴⁹⁾) ($n=2$), leaving
265 a total of 871 participants in the final analysis.

266

267 *Variables and measurement method*

268 In the present analysis, data for food and nutrient intake (excluding nutrients from vitamin,
269 mineral or other dietary supplements) from the NDNS were used to calculate DQI-65 scores
270 for each participant as per the index criteria (Table 1). Disaggregated foods were selected
271 from the NDNS dataset where available (fruit, vegetables, legumes, meat, fish, nuts, and
272 cheese), or data for individual food items was collated, using conversion factors and standard
273 recipes from *McCance and Widdowson's The Composition of Foods, 6th & 7th Summary*
274 *Editions*^(50,51) for obtaining cooked weights for wholegrain foods or disaggregating additional
275 dishes where necessary to contribute to the DQI-65 calculations.

276 HEI-2015 and AHEI-2010 scores were also calculated for all subjects based on their
277 original methodology^(26,46) in a similar manner to the DQI-65s. Insufficient guidance was
278 available for calculating the Elderly Dietary Index in our population⁽⁹⁾, so a comparison was
279 not possible. Details of components in the HEI-2015 and AHEI-2010 are in **Supplemental**
280 **Table 2.**

281

282 *Ethical considerations*

283 The NDNS was conducted according to the guidelines laid down in the Declaration of
284 Helsinki, and ethical approval for all procedures was granted by Local Research Ethics
285 Committees covering all areas covered in the survey. All participants gave informed consent.

286

287 *Statistical analysis*

288 Mean component and total scores, and percentages of subjects achieving maximum
289 component scores, were calculated for the DQI-65s, HEI-2015 and AHEI-2010 to assess
290 adherence to index recommendations. Data are expressed as mean (SD) or percentages.

291 Where mean (SD) is used, data is also represented as percentages to facilitate comparison
292 between scores.

293 Statistical tests were performed in SPSS Version 25.0 (SPSS Inc., Chicago, IL, USA),
294 where P-values <0.01 were considered statistically significant on account of multiple testing.
295 Data was visually inspected for normality. Variables identified as not normally distributed
296 were log-transformed prior to analysis (see table footnotes). Sample weights were generated
297 by the NDNS to adjust for differences in probability of selection and for non-response. The
298 three types of weights used were: 1) interviewer weights, which were applied to demographic
299 and dietary data to adjust for non-response to the individual interview and food diaries, 2)
300 nurse weights, which were applied to health outcome measures taken in the nurse visit (e.g.
301 weight, blood pressure (BP)) to adjust for differences in participants and non-participants with
302 these, and 3) blood sample weights, which were applied to all biomarkers of nutritional status
303 and health outcomes based on biochemical measures to adjust for non-response to blood
304 samples. Full details of how sample weights were calculated have been previously
305 published⁽⁵²⁾.

306 To investigate the predictive ability of the DQI-65s in relation to the proposed
307 nutritional recommendations for adults aged ≥ 65 years from our previous review⁽²⁷⁾, through
308 which our decisions around components, portion or nutrient recommendations and scoring
309 method could be explored, participants were classified by whether they met proposed
310 nutritional recommendations⁽²⁷⁾ based on daily nutrient intake from NDNS data. Associations
311 between DQI-65s, HEI-2015 and AHEI-2010 scores and odds of meeting these nutritional
312 recommendations for these categorical variables were assessed using binomial logistic
313 regression analysis.

314 To investigate health markers, associations between DQI-65s, HEI-2015 and AHEI-
315 2010 total scores and 1) biochemical markers of nutritional status (plasma 25-hydroxyvitamin
316 D [25(OH)D], serum vitamin B12, plasma total homocysteine, haemoglobin concentration,
317 plasma α -tocopherol, plasma β -carotene), 2) anthropometric measures (BMI, obesity, waist
318 circumference [WC], visceral obesity), 3) selected health indicators (medication use,
319 longstanding illness, self-assessed health, activity limitation due to illness), 4)
320 cardiometabolic risk factors (SBP, DBP, hypertension, total cholesterol [TC], fasting TG,
321 low-density lipoprotein cholesterol [LDL-C], high-density lipoprotein cholesterol [HDL-C],
322 TC:HDL-C, C-reactive protein [CRP], fasting glucose, glycated haemoglobin, classification
323 of metabolic syndrome⁽⁵³⁾) were assessed using linear regression analysis for continuous
324 variables and logistic regression analysis for categorical variables. Missing data in the NDNS
325 dataset meant different numbers of subjects were included in the health marker analyses.
326 Since the maximum score available differed between scores, they were adjusted by
327 proportional scaling for direct comparison between DQIs and to allow for a greater magnitude
328 of change to be assessed than when considering a 1-point change. Therefore, a change in
329 unadjusted B coefficient or odds ratio represents a 5% change in DQI-65, AHEI-2010 and
330 HEI-2015 scores (equivalent to a standard unit increase of 6 points for FDQI-65+PA and
331 NFDQI-65+PA, 5.5 points for NFDQI-65 and AHEI-2010 and 5 points for HEI-2015 scores).

332 Analyses of associations between DQI-65s, HEI-2015 and AHEI-2010 scores and
333 odds of meeting nutritional recommendations were performed unadjusted. However, for
334 health outcomes and biochemical markers of nutritional status, a step-wise approach for
335 confounder adjustment was implemented to assess whether the DQIs predicted risk above and
336 beyond other potential modifying factors. Confounders adjusted for were: age and sex (model
337 1), model 1 confounders plus BMI, WC, supplement use (nutrient biomarker analyses only),
338 BP and/or lipid lowering medication (where applicable) and smoking status (model 2), and

339 model 2 confounders plus income, marital status and education level (model 3). Unless
340 specified, the results discussed are from the most adjusted model.

341

342 **Results**

343 *Characteristics of study population, and DQI total and component scores*

344 The mean age of the 871 subjects included in the analysis was 74 (7) years, and 44.2% were
345 men. Study population characteristics are detailed in **Table 2**.

346 Mean total DQI-65 scores were 71.8 (15.1) out of 120 for the FDQI-65+PA (59.8%),
347 68.1 (14.4) out of 120 for the NFDQI-65+PA (56.8%) and 61.6 (12.8) out of 110 for the
348 NFDQI-65 (56.0%). Mean component scores in all DQI-65s were ≥ 7 out of 10 for vegetables,
349 fruit, protein, fluid and sodium, reflecting greater adherence to these recommendations,
350 whereas they were ≤ 3 out of 10 for low-fat dairy and NFDQI-65/NFDQI-65+PA free sugars
351 (**Figure 1**). Correspondingly, $\geq 50\%$ of subjects scored maximum points for the sodium
352 component in all DQI-65s, alcohol in the FDQI-65+PA and physical activity in the FDQI-
353 65+PA/NFDQI-65+PA. Conversely, a $\leq 10\%$ of subjects scored maximum points for protein,
354 low-fat dairy, wholegrain carbohydrates and NFDQI-65/NFDQI-65+PA fat and fatty acids,
355 suggesting low adherence to these recommendations in UK adults aged ≥ 65 years.

356 The mean HEI-2015 score was 59.9 (11.3) out of 100 (59.9%), with component scores
357 of ≥ 3.5 out of 5 or ≥ 7 out of 10 for total protein, refined grains, sodium and added sugars, and
358 ≤ 1.5 out of 5 or ≤ 3 out of 10 for wholegrains, fatty acids and SFA (**Figure 2**). For whole fruit,
359 total protein and refined grains, $\geq 50\%$ of subjects scored maximum points, yet for
360 wholegrains, fatty acids and SFA only $\leq 10\%$ of subjects scored maximum points.

361 Mean AHEI-2010 score was 50.1 (11.4) out of 110 (45.5%), with scores of ≥ 7 out of
362 10 for trans fatty acids, and of ≤ 3 out of 10 for the wholegrains and nuts and legumes
363 components (**Figure 3**). Proportions of subjects scoring maximum points was $\leq 10\%$ for
364 vegetables, fruit, wholegrains, nuts and legumes, red and processed meat and PUFA.

365 Full details of mean component scores and proportions meeting recommendations for
366 each component are in Supplemental Table 2.

367

368 *Associations between DQI-65s, HEI-2015 and AHEI-2010 scores and nutrient intake*

369 As per **Table 3**, higher FDQI-65+PA, NFDQI-65 and NFDQI-65+PA scores were
370 significantly associated with increased odds of meeting recommendations for almost all
371 nutrients, except carbohydrates, MUFA, PUFA, sodium and alcohol for the FDQI-65+PA and
372 MUFA and PUFA for the NFDQI-65+PA. In contrast, HEI-2015 and AHEI-2010 scores were
373 not associated with increased odds of meeting our previously proposed nutritional
374 recommendations⁽²⁷⁾ for several nutrients of age-specific importance including calcium,
375 vitamin D, vitamin B12 and alcohol (for the HEI-2015), and calcium, zinc, vitamin D, folate,
376 vitamin B12, vitamin B6 and alcohol (for the AHEI-2010).

377

378 *Associations between DQI scores and biomarkers of nutrient intake*

379 DQI-65s, HEI-2015 and AHEI-2010 scores were significantly positively associated with
380 nutritional intake biomarkers of relevance among older adults, particularly serum vitamin B12
381 and plasma 25(OH)D, when adjusted for age and sex only, but not with haemoglobin
382 concentration (**Supplemental Table 3**). After adjustment for all covariates, including
383 supplement use and socioeconomic factors (model 3), the associations between DQI-65s and

384 serum vitamin B12 became non-significant (**Table 4**) and AHEI-2010 scores became
385 significantly inversely associated with haemoglobin concentration. Results for all models are
386 in Supplemental Table 4.

387

388 *Associations between DQI scores and health markers*

389 When adjusting for age and sex only, DQI-65s, HEI-2015 and AHEI-2010 scores were all
390 significantly inversely associated with anthropometric measures (BMI and WC), medication
391 use, fasting TG, CRP, and odds of being classified with metabolic syndrome (except for
392 NFDQI-65 and NFDQI-65+PA). They were also significantly positively associated with odds
393 of good self-assessed health (**Supplemental Table 4**). Differential associations existed with
394 other cardiometabolic risk factors (i.e., cholesterol markers and BP), with higher FDQI-
395 65+PA scores being significantly associated with higher TC and HDL-C, and higher NFDQI-
396 65 and NFDQI-65+PA scores being significantly associated with lower DBP.

397 After adjustment for age, sex, BMI and WC (where appropriate), smoking, and
398 relevant medications (model 2), associations between FDQI-65+PA scores and TC were
399 attenuated to become non-significant, as were associations between NFDQI-65, NFDQI-
400 65+PA and AHEI-2010 and both TG and metabolic syndrome classification, and NFDQI-65
401 and odds of good self-assessed health. All other previously observed associations remained
402 significant in model 2.

403 After full adjustment, several of the associations were further attenuated to become
404 non-significant. However, significant inverse associations remained between all DQIs and
405 BMI, WC (except AHEI-2010 and FDQI-65+), medication use and CRP (**Table 5**).
406 Moreover, higher FDQI-65 scores remained significantly associated with lower odds of being
407 classified with metabolic syndrome and higher odds of good self-assessed health, and higher

408 NFDQI-65+PA and NFDQI-65 scores remained associated with lower DBP. Finally, higher
409 HEI-2015 scores remained significantly associated with higher odds of good self-assessed
410 health. AHEI-2010 scores did not remain associated with any other outcomes.

411

412 **Discussion**

413 This study developed three variations of the DQI-65, which were tailored to
414 nutritional and, in the case of FDQI-65+PA and NFDQI-65+PA, physical activity
415 recommendations for UK older adults aged ≥ 65 years. Unique aspects of the DQI-65s were
416 the positive appraisal of protein, inclusion of physical activity (FBDQI-65+PA/NFBDQI-
417 65+PA) and fluid, and the negative appraisal of alcohol. The DQI-65 variations differed in
418 component assessment method, with the FBDQI-65+PA using a food-based approach, such as
419 portions/day of sugary foods, number of alcoholic drinks and ratio of unsaturated fat rich oils
420 and spreads to those containing primarily SFA. In contrast, the NFBDQI-65+PA and
421 NFBDQI-65 assessed these components using a nutrient-based approach, such as mg/day,
422 alcohol units and % of total energy intake. These variations were created to assess the
423 optimum composition of a DQI for this age group through evaluating the impact of selecting
424 food groups (such as portions/day of sugary foods, number of alcoholic drinks), which would
425 more easily translate into dietary and lifestyle advice) vs food groups and nutrients (such as
426 sugar as % of total energy, alcohol units), and of the inclusion of physical activity on
427 associations with the index.

428 All three of the DQI-65 scores were associated with increased odds of meeting almost
429 all of our previously proposed nutritional recommendations⁽²⁷⁾ when using UK population
430 nutritional intake data for those aged ≥ 65 years. This demonstrates the DQI-65s, as composite
431 indexes, effectively represent individual age-specific nutritional recommendations upon

432 which they were developed. This was particularly the case for certain nutrients of importance
433 among older adults such as protein, calcium, vitamin D and zinc, for which the DQI-65s
434 demonstrated greater association with adherence to recommendations of these nutrients
435 (based on larger magnitude of effect) relative to the HEI-2015 and AHEI-2010. Since the
436 nutritional recommendations assessed against were also used to develop the DQS-65s, these
437 findings may be considered biased. However, it seems prudent that any DQI to be used within
438 this age group (whether this be the novel DQI-65s or existing HEI-2015/AHEI-2010) should
439 predict adherence to these evidence-based recommendations.

440 In contrast to the NFDQI-65 and NFDQI-65+PA, higher FBDQI-65+PA scores were
441 associated with a lower likelihood of meeting recommendations for alcohol intake. This was
442 surprising as all scores assessed units of alcohol, whether directly or via numbers of drinks. It
443 may be that those with higher alcohol intakes also had greater diet quality when considering
444 other components (e.g. lower intakes of salty or sugary foods, higher intakes of vegetables)
445 resulting in this unexpected association. Furthermore, there was a lack of association between
446 FBDQI-65+PA scores and sodium intake. This may be due to the assessment of portions/day
447 of salty foods rather than absolute sodium intakes (as per the NFDQI-65/NFDQI-65+PA). It is
448 likely that sodium intake was underestimated in the FBDQI-65+PA as only key sources of
449 sodium were included in the 'salty foods' classification. Therefore, component choices (food
450 vs. nutrition based) and scoring methods are important in DQI design, with current findings
451 suggesting the NFDQI-65 and NFDQI-65+PA may be superior to the FBDQI-65+PA when
452 assessing nutritional intake in relation to evidence-based requirements.

453 Similarly, results suggest that the NFDQI-65 and NFDQI-65+PA may be more suited
454 to assessing the dietary quality of UK older adults in relation to adequacy of nutritional intake
455 than the HEI-2015 and AHEI-2010. For example, the HEI-2015 showed weaker associations
456 with calcium and vitamin A intake than the DQI-65s, which could be attributed to the

457 quantification method for dairy, a rich source of these nutrients, where the HEI-2015 sums
458 total dairy irrespective of type (including fortified soy products), yet the DQI-65s account for
459 typical portion sizes of milk, yoghurt and cheese, which vary in their nutritional profiles. As
460 calcium intake is key in preserving bone health⁽²⁷⁾, this approach may enhance predictive
461 ability for musculoskeletal outcomes, although this would need confirmation using markers of
462 bone health. Moreover, neither the HEI-2015 nor AHEI-2010 were associated with odds of
463 meeting vitamin B12 recommendations, deficiency in which is prevalent among older adults
464 due to impaired absorption with aging and poor intake of vitamin B12-rich foods⁽⁵⁵⁾. Dairy
465 and other animal products are also good sources of vitamin B12, therefore the higher
466 weighting towards animal products in the DQI-65s may have contributed to the positive
467 association with odds of meeting vitamin B12 recommendations, supporting its use to assess
468 nutritional quality in an older population. Due to the HEI-2015 and AHEI-2010 being
469 developed for a US rather than UK population, and based on the DQI-65 closely reflecting
470 the proposed nutritional recommendations against which they were tested, greater suitability
471 of the DQI-65s may be unsurprising. Further investigation is required to confirm this
472 conclusion.

473 The DQI-65s, HEI-2015 and AHEI-2010 were all associated with various markers of
474 cardiometabolic risk. For example, NFDQI-65 and NFDQI-65+PA (but not FDQI-65+PA,
475 HEI-2015 and AHEI-2010) scores were inversely associated with DBP, and high BP is
476 considered the leading risk factor for morbidity and mortality globally⁽⁵⁶⁾, particularly relating
477 to CVD⁽⁵⁷⁾. Sodium intake has been positively associated with DBP in older adults⁽⁵⁸⁾,
478 therefore lack of association between DBP and the FDQI-65+PA may result from differential
479 assessment of sodium intake as previously discussed.

480 Higher DQI-65 scores were associated with lower medication use, and the FDQI-
481 65+PA with better self-assessed health, like the HEI-2015. This suggests potential value of

482 these indexes in predicting quality of life measures in an older population. The NFDQI-
483 65+PA, NFDQI-65 and HEI-2015 were also associated with lower WC, yet the FDQI-65 was
484 not. Higher WC is considered an independent risk factor for mortality⁽⁵⁹⁾, a key indicator of
485 insulin resistance and overall cardiometabolic health⁽⁶⁰⁾, and has been inversely associated
486 with grip strength⁽⁶¹⁾, which is a component of Fried's frailty phenotype⁽¹⁹⁾. Finally,
487 significant negative associations were also observed between CRP and all five DQIs. Like
488 WC, higher CRP is associated with lower grip strength⁽⁶²⁾ and increased disability risk⁽⁶³⁾.

489 When comparing the nutrient and food based DQI-65s with and without physical
490 activity, the magnitude of effect for associations between the NFDQI-65+PA and both CRP
491 and number of medications were higher than for the NFDQI-65, whereas this was lower for
492 associations with DBP. Few other differences existed in the present analysis with overall
493 associations between the two nutrient and food-based DQI-65s (with/without physical
494 activity) and nutrient, biochemical and health variables similar in both significance and
495 magnitude of effect. Therefore, without statistical comparison between indexes it cannot be
496 concluded whether including a physical activity component in the DQI-65s impacts
497 associations and requires further investigation. In contrast, the nutrient and food-based DQI-
498 65s may potentially be superior to the food-based DQI-65 due to marginally greater
499 associations with adherence to nutritional recommendations and some important health
500 markers (e.g., BMI, WC and DBP). However, associations with health markers are limited by
501 the methodology of the statistical analysis. Specifically, the cross-sectional NDNS data results
502 in potential for reverse causality where dietary change has occurred following chronic disease
503 diagnosis or identification of risk factors (e.g., high BP or TC), or where functional decline
504 affects food accessibility, meal preparation and impairs food choice. This affects validity of
505 associations, prevents cause and effect from being established, and limits conclusions
506 regarding both the predictive and comparative value of individual DQIs. In addition, 4-day

507 diet diaries may not reflect habitual diet, especially for components with weekly
508 recommendations (e.g., oily fish and alcohol), and bias may exist in dietary records, therefore
509 it is possible that subject misclassification exists. Consequently, prospective cohort studies
510 using dietary assessment methods that capture longer term habitual diet (such as food
511 frequency questionnaires) would help explore associations with clinical events, morbidity and
512 mortality to determine the value of the novel DQI-65 in assessing dietary quality in relation to
513 health outcomes. This is a future aim to scientifically validate the DQI-65.

514 This study's strengths include the development of three DQI-65 variations and
515 comparison with validated and widely-used indexes. Moreover, despite high non-response
516 rates in the NDNS for biological risk factors, applying sample weights reduced risk of
517 selection and non-response bias⁽⁵²⁾, and facilitated validation within a representative sample of
518 UK older adults. However, some limitations exist. Development of the DQI-65s required
519 subjectivity and, although decisions were justified by current research, different components
520 and scoring methods may alter associations. For example, assumptions were made in equally
521 weighting components (in line with approaches used by HEI-2015 and AHEI-2010) due to
522 absence of qualitative evidence to support a different approach and the aim of targeting a
523 range of markers of diet quality and health . Also, factor analysis was not performed to ensure
524 that all included components relate to a single underlying dimension. Protein
525 recommendations of 1.2g/kg/day may also be insufficient for those who undertake high levels
526 of physical activity which would not be captured in the index. Moreover, maximum DQI-65
527 scores were only obtainable if both dairy and oily fish were consumed as some consider the
528 anabolic potential of animal protein in older adults higher than plant protein⁽⁶⁴⁾, however
529 applicability to vegetarian or vegan groups is limited. Further investigation is required to
530 justify these decisions. Some measures of nutrient status (e.g., haemoglobin) may not directly
531 reflect dietary intake due to physical adaptation to low status increasing bioavailability,

532 affecting interpretation of results. Sodium content of water, which can be significant, was not
533 fully quantified in NDNS data, and may have impacted assessment of sodium intake.
534 Furthermore, less than 10% of individuals met many of our nutritional recommendations and
535 criteria for health marker variables, so the commonly used odds ratio^(18,65) may not be the
536 optimal measure, and multiple testing was not formally accounted for as analyses were treated
537 independently. Although a more conservative P-value for statistical significance was used,
538 <0.01, the potential for false positive results still cannot be excluded. Finally, linearity across
539 the DQI score range has been assumed. This is unlikely to be the case in all score categories,
540 however this approach is used widely in DQI analyses^(17,26). Nonetheless, scope for further
541 investigations exist, including scientific assessment of the validity and reliability of the DQI.

542 In conclusion, three variations of a novel DQI-65 were developed that effectively
543 assess adherence to our previously proposed evidence-based age-specific nutritional
544 recommendations for UK adults aged ≥ 65 years, potentially to a greater degree than existing
545 indexes tested. In addition, this cross-sectional analysis found the DQI-65s, HEI-2015 and
546 AHEI-2010 to be associated with a range of important health markers related to morbidity and
547 mortality within a UK representative sample of adults aged ≥ 65 years, although
548 methodological limitations may affect the validity of conclusions. The data from this analysis
549 suggest the DQI-65s may be valuable tools for assessing diet quality in older adults in the
550 UK, particularly when aiming to evaluate nutrient intake, and could support delivery of
551 tailored nutritional advice. It is possible that the nutrient and food-based DQI-65s (NFDQI-
552 65/NFDQI-65+PA) may be superior to the food-based DQI-65 (FDQI-65+PA), however the
553 added benefit of including physical activity within the index is uncertain. Assessment of the
554 DQI-65s predictability in relation to clinical and health outcomes was limited, yet these
555 results indicate that further exploration is warranted. This would require use of longitudinal

556 study data, including clinical outcomes and mortality, with further comparisons against
557 existing indexes to support DQI-65 validation.

558

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560

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563

564 Author contributions: ND, RF, MW and JAL designed research; ND conducted research; ND
565 analysed data; DH assisted in calculation of diet quality scores; ND drafted the paper. All
566 authors read and approved the final manuscript.

567

568 Supplemental Methods, Supplemental Table 1-5 and Supplemental References are available
569 from the "Supplementary data" link in the online posting of the article and from the same link
570 in the online table of contents at <https://academic.oup.com/jn/>.

References

1. World Health Organisation (2018) Ageing and health. <https://www.who.int/news-room/fact-sheets/detail/ageing-and-health> (accessed 20th August 2019).
2. Government Office for Science (2016) Future of an ageing population. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/816458/future-of-an-ageing-population.pdf (accessed 20th August 2019).
3. Jong JCK, Mathers JC & Franco OH (2014) Nutrition and healthy ageing: the key ingredients. *Proc Nutr Soc* **73**(2), 249-59.
4. MacDonell SO, Miller JC, Waters DL *et al.* (2016) Dietary patterns in the frail elderly. *Curr Nutr Rep* **73**(2), 68-75.
5. Franco RZ, Fallaize R, Hwang F *et al.* (2019) Strategies for online personalised nutrition advice employed in the development of the eNutri web app. *Proc Nutr Soc* **78**, 407-417.
6. de Haas SCM, de Jonge EAL, Voortman T *et al.* (2018) Dietary patterns and changes in frailty status: the Rotterdam study. *Eur J Nutr* **57**(7), 2365-2375.
7. Harnack L, Nicodemus K, Jacobs DR, Jr. *et al.* (2002) An evaluation of the Dietary Guidelines for Americans in relation to cancer occurrence. *Am J Clin Nutr* **76**(4), 889-896.
8. Knoop KTB, de Groot LCPGM, Kromhout D, Perrin A-E *et al.* (2004) Mediterranean diet, lifestyle factors, and 10-year mortality in elderly European men and women: The HALE project. *JAMA* **292**(12), 1433-1439.
9. Kourlaba G, Polychronopoulos E, Zampelas A *et al.* (2009) Development of a diet index for older adults and its relation to cardiovascular disease risk factors: The Elderly Dietary Index. *J Am Diet Assoc* **109**(6), 1022-1030.
10. Lasheras C, Fernandez S & Patterson AM (2000) Mediterranean diet and age with respect to overall survival in institutionalized, nonsmoking elderly people. *Am J Clin Nutr* **71**(4), 987-992.

11. Milaneschi Y, Bandinelli S, Corsi AM *et al.* (2011) Mediterranean diet and mobility decline in older persons. *Exper Gerontol* **46**(4), 303-8.
12. Newby PK, Hu FB, Rimm EB *et al.* (2003) Reproducibility and validity of the Diet Quality Index Revised as assessed by use of a food-frequency questionnaire. *Am J Clin Nutr* **78**(5), 941-949.
13. Osler M & Schroll M (1997) Diet and mortality in a cohort of elderly people in a north European community. *Int J Epidemiol* **26**(1), 155-159.
14. Seymour JD, Calle EE, Flagg EW *et al.* (2003) Diet Quality Index as a predictor of short-term mortality in the American Cancer Society Cancer Prevention Study II Nutrition Cohort. *Am J Epidemiol* **157**(11), 980-988.
15. Talegawkar SA, Bandinelli S, Bandeen-Roche K *et al.* (2012) A higher adherence to a Mediterranean-style diet is inversely associated with the development of frailty in community-dwelling elderly men and women. *J Nutr* **142**(12), 2161-2166.
16. Trichopoulou A, Kourisblazos A, Wahlqvist ML *et al.* (1995) Diet and overall survival in elderly people. *BMJ* **311**(7018), 1457-1460.
17. Xu B, Houston DK, Locher JL *et al.* (2012) Higher healthy eating index-2005 scores are associated with better physical performance. *J Gerontol A Biol Sci Med Sci* **67**(1), 93-99.
18. Xu B, Houston D, Locher JL *et al.* (2012) The association between Healthy Eating Index-2005 scores and disability among older Americans. *Age Ageing* **41**(3), 365-371.
19. Fried LP, Tangen CM, Walston J *et al.* (2001) Frailty in older adults: evidence for a phenotype. *J Gerontol A Biol Sci Med Sci* **56**(3), M146-156.
20. Kim J & Lee Y (2011) Frequency of dairy consumption and functional disability in older persons. *J Nutr Health Aging* **15**(9), 795-800.
21. Aune D, Giovannucci E, Boffetta P *et al.* (2017) Fruit and vegetable intake and the risk of cardiovascular disease, total cancer and all-cause mortality-a systematic review and dose-response meta-analysis of prospective studies. *Int J Epidemiol* **46**(3), 1029-1056.

22. Deghan M, Mente A, Rangarajan S (2018) Association of dairy intake with cardiovascular disease and mortality in 21 countries from five continents (PURE): A prospective cohort study. *The Lancet* **392**(10161), P2288-2297.
23. De Spiegeleer A, Petrovic M, Boeckxstaens P *et al.* (2016) Treating sarcopenia in clinical practice: where are we now? *Acta Clin Belg* **71**(4), 197-205.
24. Bollwein J, Diekmann R, Kaiser MJ *et al.* (2013) Dietary quality is related to frailty in community-dwelling older adults. *J Gerontol A Biol Sci Med Sci* **68**(4), 483-489.
25. Scientific Advisory Committee on Nutrition (2004) *Advice on fish consumption: Benefits & risks*. London, UK: TSO.
26. Chiuve SE, Fung TT, Rimm EB *et al.* (2012) Alternative dietary indices both strongly predict risk of chronic disease. *J Nutr* **142**(6), 1009-1018.
27. Dorrington N, Fallaize R, Hobbs DA, Weech M, Lovegrove JA (2020) A review of nutritional requirements of adults aged ≥ 65 years in the UK. *J Nutr* **150**(9), 2245-2256.
28. Breen L & Phillips SM (2011) Skeletal muscle protein metabolism in the elderly: Interventions to counteract the 'anabolic resistance' of ageing. *Nutr Metab* **8**, 68.
29. Waijers P, Feskens EJM & Ocke MC (2007) A critical review of predefined diet quality scores. *Br J Nutr* **97**(2), 219-231.
30. Department of Health (2011) Physical activity guidelines for older adults (65+ years). https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/213741/dh_128146.pdf (accessed 21st September 2017).
31. Public Health England (2016) The Eatwell guide. Helping you eat a healthy, balanced diet. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/551502/Eatwell_Guide_booklet.pdf (accessed 20th September 2017).
32. Koopman R, Van Loon LJC. Aging, exercise and muscle protein metabolism. *J Appl Physiol* 2009;106(6):2040-2048.
33. Hunter DJ, Sambrook PN. Bone loss: Epidemiology of bone loss. *Arthritis Res* 2000;2(6):441-445.

34. Aune D, Giovannucci E, Boffetta P *et al.* (2017) Fruit and vegetable intake and the risk of cardiovascular disease, total cancer and all-cause mortality-a systematic review and dose-response meta-analysis of prospective studies. *Int J Epidemiol* **46**(3), 1029-1056.
35. Li Y, Hruby A, Bernstein AM *et al.* (2015) Saturated fat as compared with unsaturated fats and sources of carbohydrates in relation to risk of coronary heart disease: A prospective cohort study. *J Am Coll Cardiol* **66**(14), 1538-1548.
36. Scientific Advisory Committee on Nutrition (2003) *Salt and health*. London, UK: TSO.
37. Alam S, Purdie DM, Johnson AG (1999) Evaluation of the potential interaction between NaCl and prostaglandin inhibition in elderly individuals with isolated systolic hypertension. *J Hypertens* **17**(8), 1195-202.
38. Truswell AS (2009) Dietary guidance for older Australians. *Nutr Diet* **66**(4), 243-248.
39. El-Sharkawy AM, Sahota O, Lobo DN (2015) Acute and chronic effects of hydration status on Health. *Nutr Rev* **73**(Suppl 2), 97-109.
40. Bernstein M & Munoz N (2012) Position of the Academy of Nutrition and Dietetics: Food and nutrition for older adults: Promoting health and wellness. *J Academy of Nutrition and Dietetics* **112**(8), 1255-1277.
41. British Dietetic Association (2016) Food fact sheet: Portion sizes.
<https://www.bda.uk.com/foodfacts/portionsizesfoodfactsheet.pdf> (accessed 1st November 2017).
42. Drink Aware (n.d.) Alcohol limits and unit guidelines.
<https://www.drinkaware.co.uk/alcohol-facts/alcoholic-drinks-units/alcohol-limits-unit-guidelines/> (accessed 1st November 2017).
43. Scientific Advisory Committee on Nutrition (2010) *Iron and health*. London, UK: TSO.
44. Mindell J (2008) *National Diet and Nutrition Survey. Results from Years 1-4 (combined) of the Rolling Programme (2008/2009-2011/2012). Appendix V. Measuring physical activity in adults using the Recent Physical Activity Questionnaire (RPAQ)*. London, UK: Public Health England. Available at: <https://www.gov.uk/government/statistics/national-diet-and->

- nutrition-survey-results-from-years-1-to-4-combined-of-the-rolling-programme-for-2008-and-2009-to-2011-and-2012.
45. Tieland M, Beelan J, Laan ACM, Poon S, de Groot LCPGM, Seeman E, Wang X, Iuliano S (2017) An even distribution of protein intake daily promotes protein adequacy but does not influence nutritional status in institutionalized elderly. *J Am Med Dir Assoc* **19**(1), 33-39.
 46. Krebs-Smith SM, Pannucci TE, Subar AF, Kirkpatrick SI, Lerman JL, Tooze JA, Wilson MM, Reedy J (2018) Update of the Healthy Eating Index: HEI-2015. *J Acad Nutr Diet* **118**(9), 1591-1602.
 47. NatCen Social Research, MRC Elsie Widdowson Laboratory, UCL Medical School (2015) National Diet and Nutrition Survey Years 1-6, 2008/09-2013/14.[data collection]. 7th Edition. *UK Data Service. SN:6533. doi: 10.5255.UKDA-SN-6533-7* (accessed 8th November 2017).
 48. Public Health England (2014) *National Diet and Nutrition Survey. Results from Years 1, 2, 3 and 4 (combined) of the Rolling Programme (2008/2009 - 2011/2012)*. London, UK: Public Health England.
 49. Fallaize R, Forster H, Macready AL, Walsh MC, Mathers JC, Brennan L, Gibney ER, Gibney MJ, Lovegrove JA (2014) Online dietary intake estimation: Reproducibility and validity of the Food4Me food frequency questionnaire against a 4-day weighed food record. *J Med Internet Res* **1**(8): e190.
 50. Public Health England (2014) *McCance and Widdowson's The Composition of Foods. 7th Summary Edition*. Cambridge, UK: Royal Society of Chemistry.
 51. Food Standards Agency (2002) *McCance and Widdowson's The Composition of Foods. 6th Summary Edition*. Cambridge, UK: Royal Society of Chemistry.
 52. Tipping S (2014) *National Diet and Nutrition Survey. Results from Years 1-4 (combined) of the Rolling Programme (2008/2009-2011/2012). Appendix B. Weighting the National Diet and Nutrition Survey Rolling Programme sample*. London, UK: Public Health England.
Available at: <https://www.gov.uk/government/statistics/national-diet-and-nutrition-survey->

- results-from-years-1-to-4-combined-of-the-rolling-programme-for-2008-and-2009-to-2011-and-2012.
53. Expert Panel on Detection, Evaluation and Treatment of High Blood Cholesterol in Adults (2001) Executive summary of the third report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). *JAMA* **285**(19), 2486-2497.
 54. Public Health England (2018) *Appendix AA. Calculation of free sugars and AOAC fibre in the NDNS RP*. London, UK: Public Health England. Available at: <https://www.gov.uk/government/statistics/national-diet-and-nutrition-survey-results-from-years-1-to-4-combined-of-the-rolling-programme-for-2008-and-2009-to-2011-and-2012>.
 55. Fernández-Barrés S, Martín N, Canela T, García-Barco M, Basora J, Arija V (2016) Dietary intake in the dependent elderly: Evaluation of the risk of nutritional deficit. *J Human Nutr Diet* **29**(2), 174-184.
 56. Forouzanfar MH, Afshin A, Alexander LT *et al.* (2016) Global, regional and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990-2015: a systematic analysis for the Global Burden of Disease Study 2015. *Lancet* **388**(10053), 1659-1724.
 57. Forouzanfar MH, Liu P, Roth GA *et al.* (2017) Global burden of hypertension and systolic blood pressure of at least 110 to 115 mm Hg, 1990-2015. *JAMA* **317**(2), 165-182.
 58. Alam S, Purdie DM, Johnson AG (1999). Evaluation of the potential interaction between NaCl and prostaglandin inhibition in elderly individuals with isolated systolic hypertension. *J Hypertens* **17**(8), 1195-1202.
 59. Cerhan JR, Moore SC, Jacobs EJ *et al.* (2014) A pooled analysis of waist circumference and mortality in 650,000 adults. *Mayo Clin Proc* **89**(3), 335-345.
 60. Després J-P, Lemieux I, Bergeron J *et al.* (2008) Abdominal obesity and the metabolic syndrome: contribution to global cardiometabolic risk. *Arterioscler Thromb Vasc Biol* **28**(6), 1039-1049.

61. Keevil VL, Luben R, Dalzell N *et al.* (2015) Cross-sectional associations between different measures of obesity and muscle strength in men and women in a British cohort study. *J Nutr Health Aging* **19**(1), 3-11.
62. Hamer M & Molloy GJ (2009) Association of C-reactive protein and muscle strength in the English Longitudinal Study of Ageing. *Age* **31**(3), 171-177.
63. Legrand D, Vaes B, Mathei C *et al.* (2014) Muscle strength and physical performance as predictors of mortality, hospitalization, and disability in the oldest old. *J Am Geriatr Soc* **62**(6), 1030-1038.
64. Gorissen SHM & Witard OC (2018) Characterising the muscle anabolic potential of dairy, meat and plant-based protein sources in older adults. *Proc Nutr Soc* **77**(1), 20-31.
65. Huijbregts P, Fekens E, Räsänen L *et al.* (1998) Dietary patterns and cognitive function in elderly men in Finland, Italy and the Netherlands. *Eur J Clin Nutr* **52**, 826–831.

Table 1. Components and scoring method of DQI-65 variations¹.

Component	Recommendation	Criteria for minimum score (0 points)	Criteria for maximum score	Maximum score
FDQI-65+PA				
Vegetables ^{2,3}	≥3 portions/day	0 portions/day	≥3 portions/day	10
Fruit ^{2,4}	≥2 portions/day	0 portions/day	≥2 portions/day	10
Protein ⁵	≥3 portions/day	0 portions/day	≥3 portions/day	10
Oily fish ⁶	≥1 portion/week	0 portions/day	≥1 portion/week	10
Low fat dairy ⁷	≥3 portions/day	0 portions/day	≥3 portions/day	10
Wholegrain carbohydrates ^{2,8}	≥3 portions/day	0 portions/day	≥3 portions/day	10
Free sugars ^{9,10}	≤1 portion/day	>2 portions/day	≤1 portion/day	10
Sodium ^{9,11}	≤1 portion/day	>2 portions/day	≤1 portion/day	10
Fat and fatty acids ^{9,12}	100% unsaturated	0% unsaturated	100% unsaturated	10
Fluid ^{9,13}	≥6 portions/day	0 portions/day	≥6 portions/day	10
Alcohol ^{9,14}	≤14 units/week	>14 units/week	0 units/week	10
Physical activity ¹⁵	≥20 minutes/day moderate activity	0 minutes/day	≥20 minutes/day	10
Maximum Total Score				120
NFDQI-65+PA (and NFDQI-65)				
Vegetables ^{2,3}	≥3 portions/day	0 portions/day	≥3 portions/day	10
Fruit ^{2,4}	≥2 portions/day	0 portions/day	≥2 portions/day	10
Protein ⁵	≥3 portions/day	0 portions/day	≥3 portions/day	10
Oily fish ⁶	≥1 portion/week	0 portions/day	≥1 portion/week	10
Low fat dairy ⁷	≥3 portions/day	0 portions/day	≥3 portions/day	10
Wholegrain carbohydrates ^{2,8}	≥3 portions/day	0 portions/day	≥3 portions/day	10

Free sugars ^{9,16}	≤5% energy intake	>10% energy intake	≤5% energy intake	10
Sodium ^{9,17}	≤2400 mg/day	>3200 mg/day	≤2400 mg/day	10
Fat and fatty acids ¹⁸				
Ratio of PUFA+MUFA to SFA ^{9,19}	(PUFA+MUFA)/SFA ≥2	(PUFA+MUFA)/SFA <1	(PUFA+MUFA)/SFA ≥2	5
SFA ⁹	≤10% energy intake	>20% energy intake	≤10% energy intake	5
Fluid ^{9,13}	≥6 portions/day	0 portions/day	≥6 portions/day	10
Alcohol ^{9,20}	≤14 units/week	>14 units/week	0 units/week	10
Physical activity ^{15,21}	≥20 minutes/day moderate activity	0 minutes/day	≥20 minutes/day	10
Maximum Total Score²¹				120 (110)

¹ % energy intake refers to total energy; BMI, body mass index; DQI-65, diet quality index for older adults; FDQI-65+PA, Food-based Diet Quality Index for older adults with physical activity; MUFA, monounsaturated fatty acids; NDNS, National Diet and Nutrition Survey; NFDQI-65, Nutrient and Food-based Diet Quality Index for older adults; NFDQI-65+PA, Nutrient and Food-based Diet Quality Index for older adults with physical activity; PUFA, polyunsaturated fatty acids; SFA, saturated fatty acids; SACN, Scientific Advisory Committee for Nutrition.

² Quantification based on the UK *Eatwell Guide* recommendations⁽³¹⁾.

³ Portion sizes based on standard portions⁽³¹⁾: 80 g vegetables or legumes, 15 g tomato puree; only up to 1 portion of legumes and 1 portion of tomato puree allowed.

⁴ Portion sizes based on standard portions⁽³¹⁾: 80 g fruit, 150 mL fruit juice, 30 g dried fruit; only up to 1 portion of dried fruit or fruit juice allowed.

⁵ Represents food group from the UK *Eatwell Guide*⁽³¹⁾; based on portions required to meet our previously proposed protein recommendations⁽²⁷⁾; standard portion sizes used⁽⁴¹⁾: 70 g red meat, 100 g poultry, 140 g fish or shellfish, approximately 120 g or 2 eggs, 150 g legumes, 30 g nuts, 250 mL milk, 30 g cheese, 125 g yoghurt, 100 g meat alternatives; only up to 1 portion of red meat (not processed meat), 1 portion of legumes or nuts and 1 portion of dairy or alternatives allowed per day.

⁶ Quantification and portion size based on SACN advice⁽²⁵⁾; portion size 140 g cooked fish.

⁷ Represents food group from the UK *Eatwell Guide*⁽³¹⁾; quantification based on portions required to meet proposed calcium recommendations; low fat milk, low fat yoghurt, reduced fat or low fat cheese only, no other dairy included nor dairy alternatives; high fat dairy if BMI <18.5 kg/m²; portion sizes based on standard portions⁽⁴¹⁾: 250 mL milk, 30 g cheese, 125 g yoghurt; 1 portion of cheese allowed per day.

⁸ Portion sizes based on standard portions⁽⁴¹⁾: 190 g cooked pasta, rice or grains, 80 g bread or crackerbreads, 30 g breakfast cereals or flour.

⁹ Quantification based on our previously proposed nutritional recommendations⁽²⁷⁾.

¹⁰ Foods chosen are main contributors to free sugar intake in NDNS; portion sizes based on average available portions: 40 g cakes, biscuits or cereal bars, 100 g buns, pastries, pancakes, dairy desserts and sponge puddings, 20 g confectionery or sweet preserves, 330 mL sugar sweetened beverages, 15 g sugar.

¹¹ Foods chosen are main contributors to sodium intake in NDNS; portion sizes based on average available portions or standard portion sizes⁽⁴³⁾: 25 g salty savoury snacks, crisps or salted nuts, 70 g processed meat.

¹² Based on cooking oils and spreads; percentage of spreads and oils predominantly comprised of unsaturated fatty acids; unsaturated oils and spreads defined as having fat composition of (MUFA+PUFA)/SFA≥2; percentage calculated as proportion of MUFA/PUFA oils and spreads out of total oils and spreads; score of 5 assigned if no cooking oils or spreads used.

¹³ Portion sizes based on the UK *Eatwell Guide* recommendations⁽³¹⁾: 250 mL; only up to 150 mL portion of fruit or vegetable juice allowed according to the UK *Eatwell Guide*⁽³¹⁾; not including alcohol or sugar sweetened beverages.

¹⁴ 1 portion equals 1 alcohol unit⁽⁴²⁾: 75 mL wine, 220 mL beer, lager, cider or alcoholic soft drinks, 25 mL spirits, liqueurs or fortified wine; not including low or no alcohol versions.

¹⁵ Quantification based on UK *physical activity guidelines*⁽³⁰⁾; includes walking, cycling, swimming, dancing, gardening, and other active leisure pursuits.

¹⁶ Represented as % total energy intake; based on non-milk extrinsic sugars where free sugars not available.

¹⁷ No lower limit set as recommendation to increase sodium intake only justified based on diagnosis of low blood electrolytes; represented as mg/day; adjusted to account for underreporting in analysis based on average underreporting in NDNS sample compared to urinary sodium; adjusted score based on 10 points for ≤2000 mg/day and 0 points for ≤2800 mg/day.

¹⁸ Component split into two parts

¹⁹ Ratio determined by recommended relative % contribution to energy intake for MUFA, PUFA and SFA.

²⁰ Represented as g/day; 1 unit is 8 g alcohol.

²¹ Component not included in NFDQI-65.

²² Total score for NFDQI-65 110 points.

Table 2. Characteristics of study population from UK NDNS¹.

Characteristic	Total (n = 871)
Male (%)	44.2
Age (year)	73.6±6.6
Age group (%)	
65-79 years	80.1
≥80 years	19.9
BMI category (%)	
Underweight <18.5kg/m ²	0.9
Healthy 18.5-24.99kg/m ²	24.0
Overweight 25-29.9kg/m ²	37.6
Obese ≥30kg/m ²	24.9
Not available	12.6
Ethnicity (%)	
White	96.8
Mixed ethnic group	0.8
Black or Black British	0.7
Asian or Asian British	0.9
Any other group	0.9
Smoking (%)	
Current smoker	9.8
Ex-regular smoker	39.2
Never regular smoker	51.0
Education (%)	
Degree or equivalent	11.6
Higher education, below degree level	6.1
GCE, A level, or equivalent	6.8
GCSE A*-C or equivalent	15.8
GCSE grades D-G, commercial qualifications or apprenticeship	3.3
Foreign or other qualifications	11.3
No qualifications	44.0
Refused	1.2
Income (%)	
≤£10,000	4.4
>£10,000-£20,000	33.2
>£20,000-£40,000	29.8
>£40,000	10.8
Not available	21.9
Marital status (%)	
Married	58.7
Widowed	21.0
Divorced	3.1
Separated	12.9
Never married	4.3
Vegetarian (%)	
Vegetarian	1.0
Vegan	0.3
Neither	98.7
Supplement use (%)	40.5

¹ Values for continuous variables are $\bar{x} \pm SD$ and values for categorical variables are percentages of subjects within each category; NDNS interviewer weights applied; BMI, body mass index; NDNS, National Diet and Nutrition Survey.

Table 3. Association between DQI-65 s, HEI-2015 and AHEI-2010 scores and odds of meeting nutritional recommendations for subjects aged ≥ 65 y from UK NDNS years 2-6 ($n=871$)¹

Nutrient	Recommendation ²	Mean (SD)	Proportion meeting recommendations (%)	FDQI-65+PA		NFDQI-65+PA		NFDQI-65		HEI-2015		AHEI-2010	
				OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
Carbohydrate ³	50% total energy	45.8 (6.8)	79.9	1.00 (0.95,1.06)	0.969	1.13 (1.07,1.20)	<0.001	1.16 (1.10,1.23)	<0.001	1.10 (1.04,1.17)	0.002	1.05 (0.98,1.14)	0.193
Free sugars ⁴	$\leq 5\%$ total energy	11.0 (5.6)	13.8	1.11 (1.04,1.19)	0.001	1.26 (1.18,1.36)	<0.001	1.29 (1.19,1.38)	<0.001	1.11 (1.03,1.19)	0.006	1.16 (1.10,1.22)	<0.001
Protein ⁵	≥ 1.2 g/kg body weight/day	1.0 (0.3)	18.8	1.23 (1.16,1.31)	<0.001	1.30 (1.22,1.40)	<0.001	1.31 (1.22,1.40)	<0.001	1.18 (1.11,1.26)	<0.001	1.10 (1.03,1.18)	0.007
Fat	$\leq 33\%$ total energy	33.8 (5.9)	44.8	1.15 (1.10,1.20)	<0.001	1.23 (1.17,1.29)	<0.001	1.23 (1.17,1.29)	<0.001	1.47 (1.39,1.56)	<0.001	1.31 (1.22,1.41)	<0.001
SFA	$\leq 10\%$ total energy	13.2 (3.4)	17.8	1.18 (1.11,1.25)	<0.001	1.30 (1.22,1.39)	<0.001	1.31 (1.22,1.40)	<0.001	1.97 (1.79,2.17)	<0.001	0.85 (0.80,0.90)	<0.001
Trans fatty acids ⁶	$\leq 2\%$ total energy	0.6 (0.3)	100	-	-	-	-	-	-	-	-	-	-
MUFA ³	12% total energy	11.8 (2.4)	66.3	0.91 (0.87,0.95)	<0.001	0.91 (0.87,0.96)	<0.001	0.90 (0.86,0.95)	<0.001	0.85 (0.81,0.90)	<0.001	0.85 (0.80,0.90)	<0.001
PUFA ³	6% total energy	9.2 (2.8)	66.9	0.90 (0.86,0.95)	<0.001	0.87 (0.83,0.92)	<0.001	0.87 (0.83,0.92)	<0.001	0.84 (0.80,0.89)	<0.001	0.80 (0.75,0.85)	<0.001
AOAC fibre ⁷	≥ 30 g/day	18.5 (6.5)	5.9	1.51 (1.35,1.70)	<0.001	1.32 (1.18,1.46)	<0.001	1.29 (1.16,1.44)	<0.001	1.34 (1.20,1.49)	<0.001	1.28 (1.15,1.44)	<0.001
Calcium	≥ 1000 mg/day	835 (300)	21.0	1.28 (1.21,1.36)	<0.001	1.22 (1.15,1.29)	<0.001	1.19 (1.12,1.26)	<0.001	1.05 (0.99,1.11)	0.135	1.07 (1.00,1.14)	0.038
Sodium ⁸	≥ 1600 mg/day ≤ 2400 mg/day	1980 (685)	47.3	1.00 (0.96,1.05)	0.865	1.15 (1.10,1.20)	<0.001	1.20 (1.14,1.26)	<0.001	1.16 (1.10,1.22)	<0.001	1.15 (1.09,1.22)	<0.001
Potassium	≥ 3500 mg/day	2830 (772)	17.7	1.51 (1.40,1.62)	<0.001	1.37 (1.28,1.47)	<0.001	1.32 (1.23,1.42)	<0.001	1.32 (1.23,1.42)	<0.001	1.22 (1.14,1.31)	<0.001
Iron	≥ 8.7 mg/day	10.1 (3.2)	59.7	1.28 (1.22,1.34)	<0.001	1.25 (1.19,1.32)	<0.001	1.22 (1.16,1.29)	<0.001	1.24 (1.18,1.31)	<0.001	1.13 (1.07,1.19)	<0.001
Zinc	≥ 9.5 mg/day (men) ≥ 7 mg/day (women)	8.2 (2.5)	48.3	1.28 (1.22,1.34)	<0.001	1.23 (1.17,1.29)	<0.001	1.22 (1.16,1.28)	<0.001	1.13 (1.08,1.19)	<0.001	1.01 (0.96,1.06)	0.733
Vitamin A	≥ 700 μ g/day (men) ≥ 600 μ g/day (women)	1270 (1510)	49.9	1.10 (1.06,1.15)	<0.001	1.09 (1.05,1.15)	<0.001	1.10 (1.05,1.16)	<0.001	1.05 (1.00,1.10)	0.058	1.07 (1.01,1.13)	0.015
Vitamin C	≥ 40 mg/day	82.1 (48.5)	80.4	1.70 (1.57,1.83)	<0.001	1.69 (1.57,1.83)	<0.001	1.62 (1.50,1.75)	<0.001	1.67 (1.54,1.81)	<0.001	1.28 (1.19,1.37)	<0.001

Vitamin D	≥10 µg/day	3.4 (2.3)	1.7	1.73 (1.38,2.16)	<0.001	1.46 (1.20,1.79)	<0.001	1.41 (1.16,1.73)	0.001	1.16 (0.96,1.40)	0.135	1.06 (0.86,1.29)	0.605
Vitamin E	≥4 mg/day (men) ≥3 mg/day (women)	8.8 (3.5)	98.0	1.63 (1.36,1.96)	<0.001	1.75 (1.43,2.13)	<0.001	1.75 (1.44,2.13)	<0.001	1.59 (1.30,1.95)	<0.001	1.35 (1.10,1.66)	0.004
Folate	≥400 µg/day	256 (100)	8.5	1.37 (1.26,1.50)	<0.001	1.25 (1.15,1.37)	<0.001	1.23 (1.13,1.35)	<0.001	1.27 (1.16,1.39)	<0.001	1.09 (1.00,1.20)	0.063
Vitamin B12	≥2.4 µg/day	6.5 (5.2)	93.0	1.20 (1.10,1.31)	<0.001	1.14 (1.04,1.25)	0.005	1.15 (1.05,1.26)	0.003	1.05 (0.95,1.15)	0.359	0.98 (0.88,1.09)	0.699
Vitamin B6	≥1.4 mg/day (men) ≥1.2 mg/day (women)	2.0 (0.8)	86.5	1.47 (1.36,1.58)	<0.001	1.40 (1.30,1.50)	<0.001	1.35 (1.25,1.45)	<0.001	1.45 (1.34,1.57)	<0.001	1.08 (1.00,1.17)	0.053
Alcohol	≤14 alcohol units/week	7.9 (12.8)	78.1	0.91 (0.86,0.96)	<0.001	1.15 (1.09,1.22)	<0.001	1.25 (1.18,1.33)	<0.001	0.93 (0.87,0.98)	0.010	0.96 (0.90,1.02)	0.182

¹ Values are OR of meeting recommendations based on a 5% increase in DQI-65, AHEI-2010 or HEI-2015 total score; two models presented; maximum scores available 120 points (NFDQI-65, AHEI-2010 and HEI-2015 scores adjusted to maximum 120 points prior to analysis for comparison); P-values for significance of OR by logistic regression (NDNS interviewer weights applied); % energy intake refers to total energy; AHEI-2010, Alternative Healthy Eating Index-2010; AOAC, Association of Analytical Chemists; CI, confidence intervals; DQI-65, Diet Quality Index for older adults; FDQI-65+PA, Food-based Diet Quality Index for older adults with physical activity; HEI-2015, Healthy Eating Index-2015; MUFA, monounsaturated fatty acids; NDNS, National Diet and Nutrition Survey; NFDQI-65, Nutrient and Food-based Diet Quality Index for older adults; NFDQI-65+PA, Nutrient and Food-based Diet Quality Index for older adults with physical activity; PUFA, polyunsaturated fatty acids; SFA, saturated fatty acids.

² Recommendations based on nutritional requirements for UK adults ≥65y proposed in our recent review⁽²⁷⁾.

³ Nutrient recommendations set as population average; meeting recommendations classified as within ±20% of recommendation: carbohydrates 45-55% total energy, MUFA 10.4-15.6% total energy, PUFA 4.8-7.2% total energy.

⁴ Free sugars represented by non-milk extrinsic sugars from NDNS.

⁵ Results from 800 subjects due to non-response for body weight measurement.

⁶ No association reported as all subjects meeting recommendations for trans fatty acids.

⁷ Nutrient intake approximate conversion from non-starch polysaccharide fibre to AOAC; conversion factor 1.33 as used in NDNS⁽⁵⁴⁾.

⁸ Adjusted for underreporting in analysis based on average underreporting of 25% in NDNS from comparison with urinary sodium; meeting recommendations based on 1200 mg/day-2000 mg/day instead of 1600 mg/day-2400 mg/day.

2.0 ± 0.8

Table 4. Association between DQI-65s, HEI-2015 and AHEI-2010 scores and biomarkers of nutrient intake for subjects aged ≥ 65 y from UK NDNS years 2-6¹

Biomarkers of nutrient intake	Mean \pm SD	FDQI-65+PA		NFDQI-65+PA		NFDQI-65		HEI-2015		AHEI-2010	
		B (95% CI)	P value	B (95% CI)	P value	B (95% CI)	P value	B (95% CI)	P value	B (95% CI)	P value
Serum vitamin B12 ^{2,3} (pmol/L)	270 \pm 103	0.01 (0.00,0.02)	0.125	0.01 (0.00,0.01)	0.037	-0.01 (-0.04,0.01)	0.310	0.00 (-0.01,0.01)	0.786	0.00 (-0.01,0.01)	0.969
Plasma 25-hydroxy Vitamin D ⁴ (nmol/L)	44.7 \pm 20.5	0.33 (-1.05,1.71)	0.637	0.62 (-0.27,1.51)	0.172	-3.60 (-6.79,-0.40)	0.027	0.63 (-0.61,1.88)	0.319	-0.89 (-2.04,0.26)	0.130
Haemoglobin concentration ⁵ (g/dL)	13.7 \pm 1.4	0.11 (0.01,0.21)	0.025	0.02 (-0.05,0.08)	0.600	-0.14 (-0.36,0.08)	0.220	0.01 (-0.08,0.10)	0.771	-0.13 (-0.21,-0.05)	0.002
Plasma total homocysteine ^{2,6} (μ mol/L)	11.0 \pm 4.5	-0.02 (-0.03,-0.01)	<0.001	-0.02 (-0.02,-0.01)	<0.001	-0.01 (-0.02,-0.01)	<0.001	-0.01 (-0.02,-0.01)	0.001	-0.01 (-0.02,0.00)	0.067
Plasma α -tocopherol ⁷ (μ mol/L)	28.3 \pm 6.9	0.18 (-0.29,0.65)	0.454	0.05 (-0.25,0.35)	0.759	1.42 (0.34,2.50)	0.010	0.37 (-0.06,0.80)	0.089	0.47 (0.08,0.86)	0.018
Plasma β -carotene ^{2,8} (μ mol/L)	0.5 \pm 0.4	0.03 (0.01,0.04)	<0.001	0.03 (0.02,0.04)	<0.001	0.03 (0.02,0.04)	<0.001	0.03 (0.02,0.04)	<0.001	0.03 (0.01,0.04)	<0.001

¹ Values are unstandardised B coefficients for continuous variables of change in dependent variable intake with a 5% increase in DQI-65, AHEI-2010 or HEI-2015 total score and OR for categorical variables indicating odds of health outcome based on a 5% increase in DQI-65, AHEI-2010 or HEI-2015 total score; maximum score available 120 points (FNDQI-65 no PA, AHEI-2010, HEI-2015 scores adjusted to maximum 120 points for comparison); P-values are test for significance of relationship between DQI-65, AHEI-2010 or HEI-2015 score and nutrient intake by linear regression for continuous variables or significance of OR by logistic regression for categorical variables; NDNS blood weights applied; most adjusted model presented; model 3 adjusted for age, sex, BMI, waist circumference, supplement use (and iron medication), education, marital status and income; AHEI-2010, Alternative Health Eating Index-2010; CI, confidence intervals; DQI-65, Diet Quality Index for older adults; FDQI-65+PA, Food-based Diet Quality Index for older adults with physical activity; HEI-2015, Healthy Eating Index-2015; NDNS, National Diet and Nutrition Survey; NFDQI-65, Nutrient and Food-based Diet Quality Index for older adults; NFDQI-65+PA, Nutrient and Food-based Diet Quality Index for older adults with physical activity; OR, odds ratio.

² Dependent variable transformed by \log_{10} to improve normality; unstandardised B coefficient and CI are log-increase in variable by 5% increase in total score.

³ $n=382$

⁴ n=374
⁵ n=326
⁶ n=306
⁷ n=378
⁸ n=377

Table 4. Associations between DQI-65s, HEI-2015 and AHEI-2010 scores and health status measures and metabolic markers for subjects aged ≥ 65 y from UK NDNS years 2-6¹

Health marker	Mean \pm SD	FDQI-65+PA		NFDQI-65+PA		NFDQI-65		HEI-2015		AHEI-2010	
		B (95% CI)	P value	B (95% CI)	P value	B (95% CI)	P value	B (95% CI)	P value	B (95% CI)	P value
BMI² (kg/m²)	27.8 \pm 5.0	-0.20 (-0.33,-0.07)	0.003	-0.29 (-0.42,-0.15)	<0.001	-0.25 (-0.38,-0.11)	<0.001	-0.26 (-0.40,-0.13)	<0.001	-0.30 (-0.45,-0.16)	<0.001
Waist circumference³ (cm)	96.3 \pm 13.4	-0.20 (-0.39,-0.02)	0.030	-0.90 (-1.24,-0.56)	<0.001	-0.80 (-1.15,-0.44)	<0.001	-0.99 (-1.36,-0.62)	<0.001	-0.98 (-1.38,-0.58)	<0.001
Number of prescribed medicines^{4,16}	4.3 \pm 2.8	-0.25 (-0.34,-0.17)	<0.001	-0.22 (-0.30,-0.14)	<0.001	-0.10 (-0.20,-0.01)	0.002	-0.19 (-0.28,-0.09)	<0.001	-0.14 (-0.24,-0.04)	0.005
SBP⁵ (mmHg)	135 \pm 16.8	-0.01 (-0.58,0.56)	0.966	-0.03 (-0.62,0.55)	0.910	-0.19 (-0.79,0.42)	0.549	0.52 (-0.10,1.14)	0.102	0.56 (-0.11,1.23)	0.101
DBP⁵ (mmHg)	71.4 \pm 9.9	-0.07 (-0.40,0.25)	0.664	-0.58 (-0.91,-0.25)	0.001	-0.77 (-1.11,-0.43)	<0.001	-0.14 (-0.50,0.21)	0.430	-0.27 (-0.65,0.11)	0.168
TC⁶ (mmol/L)	5.1 \pm 1.2	0.03 (-0.02,0.07)	0.240	0.00 (-0.05,0.04)	0.951	0.00 (-0.05,0.05)	0.934	0.00 (-0.05,0.05)	0.978	0.01 (-0.04,0.06)	0.691
LDL-C^{7,15} (mmol/L)	3.1 \pm 1.1	0.01 (0.00,0.01)	0.106	0.00 (0.00,0.01)	0.400	0.00 (0.00,0.01)	0.536	0.00 (-0.01,0.01)	0.761	0.00 (-0.01,0.01)	0.628
HDL-C^{6,15} (mmol/L)	1.5 \pm 0.5	0.01 (0.00,0.01)	0.012	0.00 (0.00,0.01)	0.666	0.00 (-0.01,0.01)	0.909	0.00 (0.00,0.01)	0.279	0.00 (0.00,0.01)	0.230
TC:HDL-C ratio^{6,15}	3.5 \pm 1.0	0.00 (-0.01,0.00)	0.112	0.00 (-0.01,0.01)	0.739	0.00 (-0.01,0.01)	0.950	0.00 (-0.01,0.00)	0.282	0.00 (-0.01,0.00)	0.420
TG^{7,15} (mmol/L)	1.2 \pm 0.6	-0.01 (-0.02,0.00)	0.004	-0.01 (-0.02,0.00)	0.055	-0.01 (-0.02,0.00)	0.069	-0.01 (-0.02,0.00)	0.023	-0.01 (-0.02,0.00)	0.059

CRP^{8,15,16} (mg/L)	4.7 ± 7.4	-0.04 (-0.06,-0.02)	<0.001	-0.06 (-0.08,-0.05)	<0.001	-0.04 (-0.06,-0.02)	<0.001	-0.06 (-0.07,-0.04)	<0.001	-0.05 (-0.07,-0.03)	<0.001
Fasting glucose^{9, 16} (mmol/L)	5.3 ± 0.9	-0.01 (-0.05,0.03)	0.511	0.00 (-0.05,0.04)	0.869	0.01 (-0.04,0.05)	0.831	0.00 (-0.04,0.04)	0.953	0.03 (-0.02,0.07)	0.274
HbA1c^{10, 16} (%)	5.8 ± 0.4	0.00 (-0.02,0.02)	0.821	0.01 (-0.01,0.03)	0.451	0.01 (-0.01,0.03)	0.507	0.01 (-0.01,0.03)	0.352	0.01 (-0.01,0.03)	0.420
Health marker	Proportion meeting criteria (%)	FDQI-65+PA		NFDQI-65+PA		NFDQI-65		HEI-2015		AHEI-2010	
		OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
Self-assessed health¹² Good or very good	72.2	1.18 (1.08,1.29)	<0.001	1.12 (1.03,1.22)	0.010	1.03 (0.95,1.13)	0.471	1.14 (1.04,1.24)	0.005	0.98 (0.89,1.09)	0.748
		1.19 (1.08,1.31)	<0.001	1.12 (1.02,1.23)	0.022	1.05 (0.96,1.16)	0.301	1.15 (1.05,1.27)	0.004	1.00 (0.90,1.12)	0.960
Longstanding illness¹²	59.4	0.95 (0.88,1.02)	0.155	0.92 (0.85,0.99)	0.036	0.98 (0.91,1.06)	0.581	0.95 (0.88,1.03)	0.204	1.01 (0.93,1.10)	0.841
Activities limited due to illness^{13, 16}	56.1	0.94 (0.85,1.04)	0.244	0.93 (0.84,1.03)	0.150	1.00 (0.90,1.11)	0.958	0.92 (0.83,1.01)	0.086	0.96 (0.86,1.08)	0.530
Hypertension⁵ SBP >140 mmHg or DBP >90 mmHg or Taking BP lowering medication	57.2	1.01 (0.92,1.10)	0.888	1.06 (0.97,1.16)	0.199	1.05 (0.96,1.16)	0.271	1.06 (0.96,1.16)	0.239	1.03 (0.93,1.14)	0.612
Metabolic syndrome¹⁴ ≥3 of the following: Waist circumference >102cm (men) and >88cm (women) TG >1.7mmol/L HDL-C <1.03 (men) and <1.29mmol/L (women) BP >130/85mmHg Fasting glucose >6.1mmol/L	11.9	0.73 (0.59,0.90)	0.003	0.84 (0.69,1.02)	0.080	0.87 (0.71,1.06)	0.168	0.82 (0.67,1.01)	0.062	0.79 (0.63,1.00)	0.052

¹ Values are unstandardised B coefficient for continuous variables of change in dependent variable intake with a 5% increase in DQI-65, AHEI-2010 or HEI-2015 total score and OR for categorical variables indicating odds of health outcome based on a 5% increase in DQI-65, AHEI-2010 or HEI-2015 total score; maximum score available 120 points (NFDQI-65 no PA, AHEI-2010, HEI-2015 scores adjusted to maximum 120 points for comparison); P-values are test for significance of relationship between DQI-65 or HEI-2010 score and nutrient intake by linear regression for continuous variables or significance of OR by logistic regression for categorical variables; fully adjusted model(s) presented; AHEI-2010, Alternative Healthy Eating Index-2010; BMI, body mass index; CI, confidence intervals; CRP, C-reactive protein; DBP, diastolic blood pressure; DQI-65, Diet Quality Index for older adults; FDQI-65+PA, Food-based Diet Quality Index for older adults with physical activity; HbA1C, glycated haemoglobin; HDL-

C, high-density lipoprotein cholesterol; HEI-2015, Healthy Eating Index-2015; LDL-C, low-density lipoprotein cholesterol; NDNS, National Diet and Nutrition Survey; NFDQI-65, Nutrient and Food-based Diet Quality Index for older adults; NFDQI-65+PA, Nutrient and Food-based Diet Quality Index for older adults with physical activity; OR, odds ratio; SBP, systolic blood pressure; TG, triacylglycerols; TC, total cholesterol.

² $n=767$; NDNS interviewer weights applied; adjusted for age, sex, smoking, education, marital status and income.

³ $n=566$; NDNS nurse weights applied; adjusted for age, sex, BMI, smoking, education, marital status and income.

⁴ $n=471$; NDNS nurse weights applied.

⁵ $n=419$; NDNS nurse weights applied; adjusted for age, sex, BMI, waist circumference, blood pressure medication (for SBP and DBP), smoking, education, marital status and income.

⁶ $n=333$; NDNS blood weights applied; adjusted for age, sex, BMI, waist circumference, lipid medication, smoking, education, marital status and income.

⁷ $n=330$; NDNS blood weights applied; adjusted for age, sex, BMI, waist circumference, lipid medication, smoking, education, marital status and income.

⁸ $n=381$; NDNS blood weights applied.

⁹ $n=336$; known diabetics excluded; NDNS blood weights applied.

¹⁰ $n=333$; known diabetics excluded; NDNS blood weights applied.

¹¹ $n=443$; NDNS nurse weights applied.

¹² $n=451$; NDNS interviewer weights applied; adjusted for age, sex, BMI, waist circumference, smoking, education, marital status and income; model 4 (self-assessed health only) adjusted for age, sex, BMI, waist circumference, smoking, education, marital status, income and longstanding illness.

¹³ $n=291$; NDNS interviewer weights applied.

¹⁴ $n=321$; subjects included if 5 variables available or ≥ 3 variables available when ≥ 3 variables meet criteria for metabolic syndrome; NDNS blood weights applied; adjusted for age, sex, BMI, blood pressure medication, lipid medication, smoking, education, marital status and income.

¹⁵ log₁₀ transformation applied to improve normality; unstandardized B coefficient and CI is log-increase in variable by 5% change in dietary score.

¹⁶ Adjusted for age, sex, BMI, waist circumference, smoking, education, marital status and income.

Figure 1. Mean \pm SEM score per component of FDQI-65+PA and NFDQI-65+PA calculated using data for adults aged ≥ 65 y from UK National Diet and Nutrition Survey (NDNS) rolling programme Years 2-6 (n=871). NFDQI-65 component scores identical to NFDQI-65+PA, except for physical activity which is not included in the NFDQI-65. Maximum score of 10 available per component. NDNS interviewer weights applied. FDQI-65+PA, Food-based Diet Quality Index for older adults with physical activity; NFDQI-65, Nutrient and Food-based Diet Quality Index for older adults; NFDQI-65+PA, Nutrient and Food-based Diet Quality Index for older adults with physical activity.

Figure 2. Mean \pm SEM score per component of HEI-2015 calculated using data for adults aged ≥ 65 y from UK National Diet and Nutrition Survey (NDNS) rolling programme Years 2-6 (n=871). Maximum score of 5 available for fruit, whole fruit, vegetables, greens and beans, total protein, and seafood and plant protein components. Maximum score of 10 available for wholegrains, dairy, fatty acids, refined grains, sodium, added sugars and SFA components. NDNS interviewer weights applied. HEI-2015, Healthy Eating Index-2015.

Figure 3. Mean \pm SEM score per component of AHEI-2010 calculated using data for adults aged ≥ 65 y from UK National Diet and Nutrition Survey (NDNS) rolling programme Years 2-6 (n=871). Maximum score of 10 available per component. NDNS interviewer weights applied. AHEI-2010, Alternative Healthy Eating Index-2010.