

# *A review of nutritional requirements for adults aged ≥65 years in the UK*

Article

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1 **A review of nutritional requirements for adults aged  $\geq 65$ y in the UK.**

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16

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21

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29

30 Abbreviations: BMD, bone mineral density; BP, blood pressure; COMA, Committee on

31 Medical Aspects of Food and Nutrition Policy; CVD, cardiovascular disease; MUFA,

32 monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; RCT, randomized controlled

33 trial; SACN, Scientific Advisory Committee for Nutrition; SFA, saturated fatty acids; T2D,

34 type 2 diabetes; TE, total energy; WHO, World Health Organisation.

## 35 **Abstract**

36 Appropriate dietary choices in later life may reduce the risk of chronic diseases and rate of  
37 functional decline, however there is little well-evidenced age-specific nutritional guidance in  
38 the UK for older adults, making it challenging to provide nutritional advice. Therefore, the  
39 aim of this critical review was to propose evidence-based nutritional recommendations for  
40 older adults (aged  $\geq 65$ y). Nutrients with important physiological functions in older adults  
41 were selected for inclusion in the recommendations. For these nutrients: 1) Recommendations  
42 from the UK Scientific Advisory Committee for Nutrition (SACN) reports were reviewed and  
43 guidance retained if recent and age-specific, and 2) A literature search conducted where  
44 SACN guidance was not sufficient to set or confirm recommendations for older adults,  
45 searching Web of Science up to March 2020. Data extracted from a total of 190 selected  
46 publications provided evidence to support age-specific UK recommendations for protein  
47 ( $1.2\text{g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$ ), calcium ( $1000\text{mg}\cdot\text{day}^{-1}$ ), folate ( $400\mu\text{g}\cdot\text{day}^{-1}$ ), vitamin B-12 ( $2.4\mu\text{g}\cdot\text{day}^{-1}$ )  
48 and fluid ( $1.6\text{L}\cdot\text{day}^{-1}$  women,  $2.0\text{L}\cdot\text{day}^{-1}$  men) for those  $\geq 65$ y. UK recommendations for  
49 carbohydrates, free sugars, dietary fibre, dietary fat and fatty acids, sodium and alcohol for the  
50 general population are likely appropriate for older adults. Insufficient evidence was identified  
51 to confirm or change recommendations for all other selected nutrients. In general, significant  
52 gaps in current nutritional research among older adults existed, which should be addressed to  
53 support delivery of tailored nutritional guidance to this age group to promote healthy ageing.

54

## 55 **Lay summary**

56 Food choice among older adults may affect risk of chronic disease and disability. However,  
57 the lack of well-evidenced age-specific nutritional guidance in the UK for older adults makes  
58 it challenging to provide nutritional advice. Therefore, the aim of this critical review was to

59 propose evidence-based nutritional recommendations for older adults (aged  $\geq 65$ y). Nutrients  
60 considered important to the health of this age group were chosen and, for each of these  
61 nutrients, recommendations from UK Scientific Advisory Committee for Nutrition (SACN)  
62 reports were kept if available, recent and age-specific. A literature search was conducted for  
63 all other nutrients. A total of 190 selected publications provided evidence supporting age-  
64 specific UK recommendations for protein ( $1.2\text{g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$ ), calcium ( $1000\text{mg}\cdot\text{day}^{-1}$ ), folate  
65 ( $400\mu\text{g}\cdot\text{day}^{-1}$ ), vitamin B-12 ( $2.4\mu\text{g}\cdot\text{day}^{-1}$ ) and fluid ( $1.6\text{L}\cdot\text{day}^{-1}$  women,  $2.0\text{L}\cdot\text{day}^{-1}$  men) for  
66 those  $\geq 65$ y. UK recommendations for carbohydrates, free sugars, dietary fibre, dietary fat and  
67 fatty acids, sodium and alcohol for the general population were considered likely to be  
68 appropriate for older adults. For all other nutrients there was not enough evidence to confirm  
69 or change recommendations. Gaps in current nutritional research among older adults were  
70 found, which should be addressed to support delivery of nutritional guidance targeted at this  
71 age group.

72

73 Keywords: Older adults; Elderly; Nutritional requirements; Nutritional recommendations;

74 Healthy ageing

## 75 **Introduction**

76 UK life expectancy has risen significantly over recent years (1). However, biological  
77 senescence, combined with accumulated health deficits, has resulted in a longer time lived  
78 with morbidity (2), increasing the health and social care burden, and adversely impacting  
79 quality of life. Appropriate nutrition among older adults is important for reducing risk of  
80 chronic diseases, like cardiovascular disease (CVD) and type 2 diabetes (T2D) (3), and  
81 promoting healthy ageing (4). However, altered central nervous system regulation reduces  
82 appetite (5), and changes in body composition and mobility lower energy requirements (6),  
83 predisposing individuals to inadequate dietary intake and protein and micronutrient  
84 deficiencies. Furthermore, ageing is associated with impaired micronutrient absorption and  
85 synthesis (7), anabolic resistance (8) and loss of bone and muscle mass (9,10). Consequently,  
86 nutritional recommendations for older adults should account for metabolic alterations, lower  
87 energy intake and inevitable physiological decline, aiming to reduce rate of functional  
88 deterioration and preserving physical and mental fitness and independence late into life (5).

89 In the UK, the Committee on Medical Aspects of Food and Nutrition Policy (COMA)  
90 1992 report on *The Nutrition of Elderly People* concluded that accurately determining protein  
91 and micronutrient, particularly vitamin, requirements of the elderly population was required  
92 (11). However, no similar review has been published since, meaning few well-evidenced age-  
93 specific guidelines exist for UK older adults (aged  $\geq 65$ y), unlike the US and Australia/New  
94 Zealand (e.g. for calcium and B vitamins), challenging delivery of tailored nutritional advice.  
95 Consequently, it seems prudent to propose UK-specific recommendations to support the  
96 ageing population, particularly for nutrients with key physiological roles. Therefore, this  
97 critical review aimed to propose evidence-based nutritional recommendations for UK adults  
98 aged  $\geq 65$ y.

99

## 100 **Methods**

101 Initially all macronutrients and micronutrient were considered for inclusion in the  
102 recommendations, however nutrients were prioritized and selected based on the importance of  
103 their age-specific physiological functions (12). Current UK recommendations for the age  
104 group ( $\geq 65$ y) were obtained (13-24) (**Supplemental Table 1**).

105 Relevant publications were identified using a systematic approach. Firstly, the UK's  
106 Scientific Advisory Committee for Nutrition (SACN) reports were assessed where available,  
107 which are underpinned by quality assessment using the *Framework for the Evaluation of*  
108 *Evidence* (25), and report guidelines retained if recent and age-specific due to their  
109 comprehensive nature. Secondly, for nutrients where SACN guidance was unavailable or  
110 further evidence was required for retention, Web of Science was searched using the terms  
111 "elderly" and "older adults" and the nutrient name, e.g. "calcium". Additional searches  
112 performed specified the main age-associated function (12), the word "diet" to refine results, or  
113 "absorption" for nutrients which may differ in bioavailability. The search was originally  
114 performed to September 2017, and since updated to March 2020 to identify recent evidence.

115 Titles were screened for relevance by one researcher (ND), considering search terms  
116 and age group, excluding animal studies, those specific to individuals with disease, and those  
117 where the population was not primarily Caucasian (based on UK demographics (26)). The  
118 evidence hierarchy (27), study quality and relevance of results guided final study selection,  
119 from which data was extracted, and decisions relating to the nutritional recommendations and  
120 food-based advice. Study heterogeneity meant the literature was qualitatively evaluated.

121

## 122 **Outcome of literature review**



123 For selected nutrients, 8 SACN reports were available (17-23,28), yet only vitamin D advice  
124 was recent and well-evidenced for older adults, and so retained (22). Literature searches for  
125 all other nutrients yielded 80 990 publications for screening. After adding 15 further  
126 documents (international recommendations and SACN reports), 190 publications were used to  
127 guide the remaining recommendations. **Figure 1** summarizes the selection process.

128 Limited evidence was found for most nutrients (**Table 1**), except protein, dietary fat  
129 and fatty acids, calcium, alcohol, and the selected B vitamins (folate, vitamin B-12 and  
130 vitamin B-6). This suggests the research gaps identified by COMA for adults aged  $\geq 65$ y have  
131 not been sufficiently addressed (11), particularly for micronutrients, and challenged setting of  
132 quantitative recommendations. Nonetheless, nutritional recommendations are presented in  
133 Table 1 with food-based advice to aid implementation. Supporting evidence (summarized in  
134 **Supplemental Tables 2-7**) will subsequently be discussed.

135

## 136 **Evidence supporting the proposed nutritional recommendations**

### 137 *Carbohydrates, free sugars and dietary fibre*

138 The SACN 2015 *Carbohydrates and Health* report concluded overall carbohydrate  
139 intake was neither beneficial nor detrimental to general population health (21). Evidence  
140 among older adults was limited, poor quality due to high attrition (43) or very small sample  
141 size (44), and subject to confounding where adjusting total carbohydrate intake alters other  
142 dietary components (45). No widely accepted physiological mechanism indicates  
143 requirements differ among older adults, therefore current recommendations of 50% total  
144 energy (TE) remain unchanged.

145 High free sugar intake in the general population has been associated with increased  
146 risk of dental caries, T2D and excess energy intake (21). No contradictory evidence was

147 found for older adults. Moreover, Laclaustra *et al.* (46) reported a positive association  
148 between added sugar intake and frailty risk. However, sugar added in food production was  
149 found to be more strongly associated than table sugar, suggesting potential confounding  
150 effects of the nutritional composition of processed foods which should be considered in  
151 interpretation. Nonetheless, inverse associations have been observed between percentage  
152 energy intake from added sugars and intake of protein, dietary fibre and several key  
153 micronutrients (47,48), supporting the notion that free sugar containing foods may displace  
154 protein and micronutrient-rich dietary components (11). These inverse associations were not  
155 fully replicated when studying the UK population (49) but 4-day diet diaries may not  
156 completely capture habitual diet, unlike food frequency questionnaires used in the other  
157 studies. Consequently, available evidence, COMA 1992 recommendations (11) and recent  
158 SACN advice (21) suggests retaining current free sugars recommendations of  $\leq 5\%$  TE may  
159 promote nutrient density and minimize risk of adverse health outcomes.

160         Conversely, SACN reported inverse associations between dietary fibre intake and  
161 population CVD, T2D and colorectal cancer risk (21), diseases of importance as age is a key  
162 non-modifiable risk factor (3). Furthermore, Gopinath *et al.* (50) found an inverse association  
163 between fibre intake and 5y incident instrumental activities of daily living disability risk  
164 among older adults, although the mechanism is uncertain and fibre may be a proxy for a  
165 generally healthy diet. Nevertheless, altered gastrointestinal transit time, medication use and  
166 poor diet mean constipation is prevalent among older adults (51), and dietary fibre supports  
167 alleviation. Therefore, despite insufficient age-specific evidence, retaining recent SACN  
168 advice of  $30\text{g}\cdot\text{day}^{-1}$  seems appropriate to promote high intake (21).

169

170 *Protein*

171 A chronic imbalance between muscle synthesis and degradation causes skeletal muscle mass  
172 and strength loss with age (52). Contributory factors include impaired amino acid absorption  
173 and high splanchnic extraction (52), reducing available amino acids, anabolic resistance, with  
174 impaired muscle synthesis response to dietary protein (53), and increased protein catabolism,  
175 from chronic inflammation (54). Consequently, older adults may have elevated dietary protein  
176 requirements to maintain, or minimize loss of, muscle mass and strength.

177 Two small metabolic studies supported proposed mechanisms, demonstrating delayed  
178 postprandial peak in serum amino acid concentration following a high protein mixed meal  
179 (55) and reduced protein accretion in response to a 7g amino acid bolus (53) in older  
180 compared to younger adults. A randomized controlled trial (RCT) found an increase in whole  
181 body lean mass and knee-extension power in men aged  $\geq 70$ y consuming  $1.6\text{g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$   
182 protein but no change from  $0.8\text{g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$  (56), although the sample size was small ( $n=29$ ).  
183 Nonetheless, a meta-analysis of high quality observational studies reported protein intakes of  
184  $>1.0\text{g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$  and  $>1.2\text{g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$  were also associated with higher percentage of lean  
185 mass and higher knee-extensor power compared to protein intake  $<0.8\text{g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$  (57).  
186 Moreover, almost all identified observational studies reported inverse associations between  
187 protein intake and loss of muscle mass or strength (37,38,58-60), although limitations exist  
188 including potential under- and over-reporting and inaccurate capture of habitual intake by  
189 dietary assessment methods, and the lack of evaluating changes in intake over follow-up.  
190 Additionally, reverse causation may exist where low muscle mass and/or strength impairs  
191 functional capacity, affecting food accessibility, preparation and choice.

192 Despite limitations, there is consistency in conclusions and, combined with metabolic  
193 studies and biological plausibility, higher protein intake among older adults is likely  
194 beneficial for muscle mass and function, and has potential additional benefits on other health  
195 outcomes such as risk of frailty and disability (61-63), cognition (64) and fracture risk (65).

196 Thus, evidence suggests that increasing the current UK population protein recommendations  
197 from  $0.75\text{g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$  to  $1.2\text{g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$  for adults aged  $\geq 65\text{y}$  may be of benefit. This is the  
198 higher end of recommendations suggested in the PROT-AGE study group's comprehensive  
199 literature review (54), selected as this level was associated with health benefits in several  
200 previously discussed studies, published since the PROT-AGE review.

201

### 202 *Dietary fat and fatty acids*

203 A vast evidence base exists relating to dietary fat or fatty acid intake and general  
204 population chronic disease risk. For older adults, study findings generally aligned with current  
205 UK population advice (15). For example, higher PUFA intake and substitution of SFA with  
206 PUFA have been associated with reduced 11y T2D risk (66), and serum cholesterol ester  $\alpha$ -  
207 linolenic acid inversely associated with incident CVD (67). Additionally, Blekkenhorst *et al.*  
208 reported a 77% increased atherosclerotic vascular disease mortality risk per  $11.26\text{g}\cdot\text{day}^{-1}$   
209 higher SFA intake and a 50% lower risk per  $8.7\text{g}\cdot\text{day}^{-1}$  higher MUFA intake (68). Finally,  
210 serum cholesterol ester linoleic acid has been inversely associated with 14.5y all-cause  
211 mortality risk (67), and SFA positively and PUFA, linoleic acid and n-3 fatty acids inversely  
212 associated with 12.5y mortality risk (69).

213 Conversely, Houston *et al.* (70) observed no associations between dietary total fat and  
214 SFA, MUFA and trans fatty acid intake and CVD in men and women aged 70-79y after  
215 adjustment for dietary confounders and relevant medication. As older adults studied had not  
216 previously suffered or died prematurely from CVD, potentially low baseline risk among  
217 subjects may have influenced results and they could suggest differing susceptibility to  
218 detrimental effects of dietary components among older adults, although this requires  
219 confirmation. Therefore, in absence of further age-specific evidence and due to elevated CVD

220 risk with age it seems appropriate to generalize current population recommendations for  
221 dietary fat ( $\leq 33\%$  TE), unsaturated fatty acids (12% TE MUFA, 6% TE PUFA), long chain n-  
222 3 PUFA ( $450\text{mg}\cdot\text{day}^{-1}$ ), trans fatty acids ( $\leq 2\%$  TE) and, as per the 2019 SACN report (23),  
223 those for SFA ( $\leq 10\%$  TE) to older adults.

224

## 225 *Calcium*

226 After reaching peak bone mass aged 30-40y (71) bone loss occurs (72), accelerating in the  
227 first 10y post-menopause among women (73) then slowing to equal that of men at age 60-65y  
228 (10). Inadequate dietary calcium can augment loss where bone mobilisation is stimulated to  
229 maintain blood calcium concentration (74), making sufficient intake key in preserving  
230 musculoskeletal health.

231 The WHO, US and Australia/New Zealand have specific calcium recommendations  
232 for post-menopausal women and the elderly (12,75,76). However, current UK  
233 recommendations do not stipulate differences between requirements of younger adults for  
234 maintaining bone mineral density (BMD) and those of older adults for minimising inevitable  
235 losses. The international recommendations are mainly based on supplementation studies. Such  
236 studies demonstrate benefits of high calcium with or without vitamin D on BMD maintenance  
237 over 1-7y follow-up (77-84), but supplements are typically  $>1000\text{mg}\cdot\text{day}^{-1}$ , dietary calcium  
238 intake is rarely reported and physiological regulation of intestinal calcium uptake (74) makes  
239 it uncertain how much supplemental calcium is absorbed, questioning whether supplemental  
240 studies should guide dietary recommendations.

241 Identified dietary studies reported calcium intake to be positively associated with  
242 BMD (85,88) and inversely associated with osteoporosis or fracture risk (89-91). Two large  
243 longitudinal cohort studies provide quantitative evidence to guide recommendations. Firstly,

244 Nieves *et al.* (89) observed an association between calcium intake  $>800\text{mg}\cdot\text{day}^{-1}$  and a 25%  
245 reduced 3y osteoporosis risk compared to  $<500\text{mg}\cdot\text{day}^{-1}$ , although misclassification bias is  
246 possible as non-dairy calcium intake was estimated at  $250\text{mg}\cdot\text{day}^{-1}$  (US average) for all  
247 subjects rather than accurately assessed. Secondly, Warensjö *et al.* (91) observed an  
248 association between calcium intake  $<751\text{mg}\cdot\text{day}^{-1}$  and an increased risk of 18% for any  
249 fracture, 29% for hip fracture and 47% for osteoporosis after median 19.2y follow-up  
250 compared to  $822\text{-}996\text{mg}\cdot\text{day}^{-1}$ . Additionally, no benefits of  $>1137\text{mg}\cdot\text{day}^{-1}$  were observed  
251 and a detrimental effect on hip fracture risk compared to lower intakes reported. Repeat food  
252 frequency questionnaires throughout follow-up allowed all major calcium sources to be  
253 recorded and subjects classified by the mean of their cumulative dietary intake, accounting for  
254 changes. The recent 32y longitudinal study by Feskanich *et al.* (92) supported this approach  
255 as positive associations between dairy food intake and hip fracture were similar for current  
256 and cumulative average intake but attenuated when baseline intake was used as the exposure.  
257 Nonetheless, reverse causation may still exist where dietary intake changed following  
258 osteoporosis diagnosis and could explain the detrimental effects seen from  $>1137\text{mg}\cdot\text{day}^{-1}$   
259 calcium intake.

260 Despite limitations, observations by Nieves *et al.* and Warensjö *et al.* in  $>90\ 000$   
261 subjects, supported by supplementation studies and biological plausibility, suggest current UK  
262 population calcium recommendations of  $700\text{mg}\cdot\text{day}^{-1}$  may not be optimal for older adults. An  
263 intake up to  $1000\text{mg}\cdot\text{day}^{-1}$  combined with adequate vitamin D (91) may have greater benefit,  
264 although evidence confirming this quantity is lacking and, without dietary RCTs, reverse  
265 causation at higher intakes cannot be excluded. Furthermore, most studies were in post-  
266 menopausal women, typically aged  $\geq 50\text{y}$  or  $\geq 55\text{y}$ . It is uncertain whether conclusions would  
267 be replicated in analyses limited to those aged  $\geq 65\text{y}$  as Dawson-Hughes *et al.* reported no  
268 effect of calcium supplementation on BMD among early post-menopausal subjects ( $\leq 5\text{y}$  since

269 menopause) yet an inverse association with BMD loss in those >5y post-menopause (85).  
270 Consequently, results by Nieves *et al.* and Warensjö *et al.* may be underestimated for adults  
271 aged  $\geq 65$ y who would be beyond the early post-menopausal stage of accelerated bone loss.  
272 Finally, most bone health studies focus on women, making effects in men uncertain. Greater  
273 evidence in both sexes restricted to adults aged  $\geq 65$ y is required to increase certainty  
274 regarding proposed quantitative changes to recommendations.

275

### 276 *Sodium and salt*

277 In the general population, SACN reported salt intake to be positively associated with risk of  
278 hypertension (17), stroke and coronary heart disease mortality (28). A meta-analysis of 11  
279 RCTs in subjects aged  $\geq 60$ y similarly found sodium chloride intake to be positively  
280 associated with systolic and diastolic blood pressure (BP) (93). Higher sodium intake has also  
281 been associated with increased carotid intima-media thickness and atherosclerotic plaque  
282 prevalence (94). Quantitative age-specific evidence was lacking, therefore retaining SACN  
283 recommendations for maximum salt intake of  $6\text{g}\cdot\text{day}^{-1}$  (17) seems appropriate, although this  
284 may be too high due to arterial structural changes increasing hypertension risk with age (95-  
285 96). Nonetheless, salt enhances dietary palatability, helping prevent protein-energy  
286 malnutrition, which is prevalent among older adults (97).

287

### 288 *Potassium*

289 Physiological functions of potassium include supporting bone health and lowering BP. For  
290 bone health, two longitudinal studies reported positive associations between dietary potassium  
291 intake and BMD. However, Tucker *et al.* observed the association only in men (98), and Zhu  
292 *et al.* observed it within their female cohort but used urinary potassium excretion as the

293 exposure which was only weakly correlated with dietary intake (99) questioning whether a  
294 true benefit existed. For BP, SACN and the Committee of Toxicity recently reported inverse  
295 associations between potassium intake and systolic and diastolic BP and stroke risk in the  
296 general population (28), results that may or may not be replicated in older adults.  
297 Nonetheless, no evidence for adverse effects were found. Notably, concerns regarding  
298 hyperkalemia associated with reduced kidney function with age are limited to those with  
299 advanced chronic kidney disease (28), when dietary priorities differ and specialist medical  
300 and dietetic support would be received. Overall, evidence suggests potential benefits of high  
301 potassium intake, but without further studies current recommendations of  $3500\text{mg}\cdot\text{day}^{-1}$   
302 cannot be confirmed nor adjusted.

303

#### 304 *Iron*

305 Iron deficiency is associated with impaired aerobic, endurance and physical work capacity  
306 (100) and, within older adults, with poorer cognitive function and increased dementia risk  
307 (101). Consequently, iron deficiency should be prevented to avoid adverse effects on mental  
308 and physical function. Moreover, higher intake has been associated with improved gait speed  
309 in older men (102) and better cognitive performance in older men and women (103).  
310 However, no quantitative evidence was identified to guide setting dietary recommendations,  
311 although neither was evidence for altered absorption with age. Therefore, current  
312 recommendations for iron intake of  $8.7\text{mg}\cdot\text{day}^{-1}$  has been retained which, in contrast to  
313 younger adults, is the same for both sexes due to reduced menstrual losses.

314

#### 315 *Zinc*



316 Immunosenescence occurs with age, therefore zinc's role in supporting immune function makes  
317 ensuring adequate status important among older adults (104). A cross-over study in subjects  
318 aged  $\geq 82$ y found consumption of zinc-fortified milk for 2 months to lower incidence of  
319 infection and increase thymulin activity, T cell maturation and differentiation (105). No further  
320 evidence of benefits was found for dietary zinc or zinc supplementation at dietary levels in  
321 those with sufficient status on immune function. Two experimental studies reported similar zinc  
322 absorption rates within younger and older adults (106,107) suggesting general population  
323 recommendations may be suitable in absence of further evidence. Nonetheless, physiological  
324 adaptation to zinc status causes altered nutrient bioavailability and requirements (108), so very  
325 small sample sizes limits generalisability of results. Consequently, uncertainty exists  
326 surrounding retention of current recommendations of  $9.5\text{mg}\cdot\text{day}^{-1}$  (men) and  $7.0\text{mg}\cdot\text{day}^{-1}$   
327 (women) and higher zinc intakes could potentially optimize immune function.

328

### 329 *Vitamin A*

330 Vitamin A has various roles, although limited age-specific evidence was identified for  
331 beneficial effects. However, a large longitudinal cohort study reported an association between  
332 vitamin A intake  $\geq 2000\mu\text{g}\cdot\text{day}^{-1}$  and an 89% increased risk of hip fracture compared to  
333  $< 500\mu\text{g}\cdot\text{day}^{-1}$  (109), indicating possible importance of avoiding excessive intakes.

334 Furthermore, Borel *et al.* (110) demonstrated impaired postprandial retinol transport and  
335 impaired regulation of plasma retinol concentration in elderly subjects despite similar  
336 intestinal absorption efficiency to younger adults, indicating risk of elevated serum  
337 concentrations and toxicity for older adults (111). Insufficient age-specific evidence for  
338 minimum dietary vitamin A intake and the potentially unaltered intestinal absorption rate  
339 (110) means current population recommendations of  $700\mu\text{g}\cdot\text{day}^{-1}$  (men) and  $600\mu\text{g}\cdot\text{day}^{-1}$

340 (women) are unchanged, but evidence supports consideration of the UK safe upper limit when  
341 delivering dietary advice.

342

### 343 *Vitamin C*

344 Within older adults, longitudinal studies supported associations between vitamin C intake  
345  $>388\text{mg}\cdot\text{day}^{-1}$  and 45% lower risk of overall and 62% lower risk of coronary heart disease  
346 mortality compared to intake of  $<90\text{mg}\cdot\text{day}^{-1}$  (112), higher dietary vitamin C intake and lower  
347 rate of 7y cognitive decline (113) and higher total vitamin C intake and lower 15-17y fracture  
348 risk (114). However, in observational studies high vitamin C intake may be a marker for a  
349 healthier diet and lifestyle. Notably, Sahyoun *et al.* observed no association with mortality  
350 when assessing vitamin C supplementation alone (112), suggesting other beneficial nutrients  
351 in vitamin C rich foods (like fruit and vegetables) may confound results. Without further  
352 quantitative evidence where confounding can be eliminated, nor evidence for altered  
353 absorption with age, current recommendations for preventing deficiency disease of  $40\text{mg}\cdot\text{day}^{-1}$   
354 are retained, although meeting *UK Eatwell guide* recommendations for fruits and vegetables  
355 (24) may facilitate reaching higher, potentially beneficial, amounts.

356

### 357 *Vitamin D*

358 Vitamin D supports calcium and phosphorous homeostasis for musculoskeletal health (74).  
359 However, endogenous vitamin D production is lower in older compared to younger adults (6)  
360 due to reduced 7-dehydrocholesterol concentration in the skin, lower rate of synthesis and  
361 limited sun exposure from impaired mobility, making it key to consider dietary and  
362 supplemental intake within this age group. The 2016 *Vitamin D and Health SACN* report (22)  
363 found beneficial associations between higher vitamin D intake (from supplementation) and

364 BMD, muscle strength and function, and risk of falls in adults aged  $\geq 50$ y, when considering  
365 subjects with variable baseline 25-hydroxyvitamin D concentrations. An age-specific  
366 reference nutrient intake was advised by SACN based on a modeling exercise, therefore this  
367 recommendation of  $10\mu\text{g}\cdot\text{day}^{-1}$  is retained to support year-round maintenance of vitamin D  
368 sufficiency (22).

369

### 370 *Vitamin E*

371 Vitamin E studies have reported associations between higher dietary intake or plasma or  
372 serum concentrations and lower inflammatory markers (115), better cognitive function (116),  
373 and reduced CVD events (117). Moreover, the meta-analysis by Dong *et al.* (118) found an  
374 inverse association between serum vitamin E and Alzheimer's disease risk in case-control  
375 studies, however these cannot demonstrate a causal relationship between exposure and  
376 outcome and reverse causation from poor cognitive function affecting food intake may exist.  
377 Due to insufficient evidence, current recommendations of  $4\text{mg}\cdot\text{day}^{-1}$  (men) and  $3\text{mg}\cdot\text{day}^{-1}$   
378 (women) cannot be confirmed nor changed.

379

### 380 *Vitamin K*

381 Vitamin K has a role in blood coagulation (119), bone health (120) and potentially cognition.  
382 Despite biological plausibility, evidence is somewhat lacking. In identified studies, increasing  
383 vitamin K intake was associated with reduced BMD loss (121), vitamin K deficiency with  
384 increased risk of knee osteoarthritis (122) and cartilage damage (123), higher plasma  
385 concentrations of phylloquinone with improved physical performance, gait speed and  
386 endurance (124), higher serum or dietary phylloquinone with better cognitive function  
387 (125,126), and higher dephospho-uncarboxylated matrix Gla protein concentration

388 (considered a reliable marker of vitamin K status and utilisation) with lower handgrip strength  
389 and calf circumference (127). These studies are not without limitations, including potential  
390 confounding by other components of vitamin K rich foods, such as green leafy vegetables, not  
391 adjusted for in analyses. Therefore, current recommendations of  $1\mu\text{g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$  are retained,  
392 although limited evidence in the general population means this is only a safe intake level.

393

#### 394 *Folate, vitamin B-12 and vitamin B-6*

395 Folate, vitamin B-12 and vitamin B-6 are of interest due to roles in DNA methylation, and  
396 risks of megaloblastic anemia and irreversible neurological impairment from folate and  
397 vitamin B-12 deficiency respectively. Current UK recommendations for older adults are lower  
398 than suggested by the WHO (12) and set for the US (128) and Australia/New Zealand (76).

399         Impaired vitamin B-12 absorption from atrophic gastritis is prevalent among older  
400 adults (129) making high dietary intake key to prevent deficiency. Furthermore, a range of  
401 evidence was identified relating to cognitive outcomes, although with inconsistent  
402 conclusions. To summarize, plasma folate has been inversely associated with measures of  
403 cognitive function and cognitive decline risk (130,131) but also no association with cognitive  
404 decline or depression observed (132-134), although selection bias may exist where Hughes *et*  
405 *al.* excluded those with pre-existing vitamin B-12 deficiency and Morris *et al.* studied a well-  
406 educated population within whom high cognitive reserve may lower dementia risk (135). Low  
407 low plasma or serum vitamin B-12 have been associated with greater 8y decline in cognitive  
408 function (133), and cross-sectionally with reduced mental processing speed (136), increased  
409 risk of cognitive impairment (137) and depression (134), yet Tucker *et al.* (130) reported no  
410 association between plasma vitamin B-12 and spatial copying independent of folate, vitamin  
411 B-6 and homocysteine concentrations. Finally, plasma vitamin B-6 has been inversely

412 associated with cognitive decline risk (138), however Kado *et al.* (131) and Tucker *et al.*  
413 (130) reported no association between plasma vitamin B-6 and cognitive function or cognitive  
414 decline risk independent of biochemical status of other B vitamins.

415 Biochemical concentrations in longitudinal studies were only assessed at baseline,  
416 therefore it is possible that improvements in biochemical status in subjects with low status  
417 meant no association was observed or effects indicate benefits of supplementation (likely  
418 supra-dietary amounts). If true benefits of higher plasma or serum concentration exist, altered  
419 absorption among older adults, particularly for vitamin B-12, makes the dietary intake  
420 required to maintain a desired concentration uncertain. van Wijngaarden *et al.* (139) found  
421 doubling vitamin B-12 intake to be associated with 9% higher serum total B-12 in older adults  
422 with elevated plasma homocysteine, however generalisation to all older adults cannot be  
423 assumed, making dietary studies essential. Nonetheless, quantitative evidence was lacking,  
424 conclusions were similarly inconsistent for associations between folate, vitamin B-12 and  
425 vitamin B-6 intake and cognition (130-132,138,140,141), and inverse associations were  
426 observed between folate intake and risk of frailty (142) and folate and vitamin B-6 intake and  
427 depression (132,142,143) yet these were supported by limited studies.

428 Although evidence was inconclusive, impaired vitamin B-12 absorption in older adults  
429 is of concern, a vast evidence base including observational, metabolic and epidemiological  
430 studies underpins Australia/New Zealand and US dietary recommendations for folate and  
431 vitamin B-12 (76,128), and no studies reported detrimental effects at their proposed higher  
432 intakes. Therefore, current UK population recommendations for older adults have been  
433 adjusted to align with these recommendations (folate  $400\mu\text{g}\cdot\text{day}^{-1}$ , vitamin B-12,  $2.4\mu\text{g}\cdot\text{day}^{-1}$ ).  
434 Limited evidence supported international vitamin B-6 recommendations, so current UK  
435 recommendations of  $1.4\text{mg}\cdot\text{day}^{-1}$  (men) and  $1.2\text{mg}\cdot\text{day}^{-1}$  (women) remain unchanged.

436

437 *Alcohol*

438 Observational studies identified among older adults reported associations between light-to-  
439 moderate alcohol consumption and various outcomes including improved cognitive function  
440 (144,145), reduced risk of cognitive impairment (146,147) and decline (146), reduced risk of  
441 any type and vascular dementia (148), increased likelihood of healthy ageing assessed based  
442 on physical performance and/or health deficits (150,151), reduced congestive heart failure risk  
443 (152), myocardial infarction and coronary death risk (153), and reduced mortality risk (154-  
444 156) compared to abstention.

445         Definitions of light-to-moderate alcohol intake vary from  $\leq 1$  drink $\cdot$ day $^{-1}$  up to 1-3  
446 drinks $\cdot$ day $^{-1}$  or 15-20 units $\cdot$ week $^{-1}$  (1 drink = 8-14g ethanol), challenging assessment of  
447 optimal amounts. Moreover, limitations in alcohol consumption studies questions the  
448 reliability of conclusions. Firstly, never and former drinkers often differ in health status but  
449 are typically grouped as abstainers, so results may be a statistical artefact rather than  
450 indicating a relationship unless the two groups are separated. Secondly, alcohol intake is  
451 commonly underreported, causing inaccuracies in exposure. Thirdly, only assessing baseline  
452 alcohol intake contributes to misclassification bias due to changes over time, particularly key  
453 in older adults within whom alcohol intake has been demonstrated to reduce or cease in  
454 response to health deficit accumulation (157). Finally, moderate alcohol intake may be a proxy  
455 marker for a generally healthy lifestyle, social class or educational attainment, making  
456 confounding likely unless analyses are adequately adjusted.

457         A few studies have attempted to overcome these limitations. For example, Stampfer *et*  
458 *al.* (146) accounted for changes in intake across 20y follow-up and minimized bias resulting  
459 from poor health of former drinkers by assessing baseline and 4-yearly alcohol intake and

460 excluding participants who reported abstinence when undertaking follow-up cognitive  
461 assessment but previously reported alcohol intake. Furthermore, three studies conducted  
462 analyses with former drinkers in isolation, in addition to the standard abstinence group,  
463 reporting associations between former drinking and increased congestive heart failure risk  
464 (152), detrimental effects of former drinking and no association or a protective effect of never  
465 drinking on mortality risk (154), and a 1.5x increased risk of all-cause mortality for ex-  
466 drinkers compared to never-drinkers (158), highlighting abstainers to be a group of  
467 individuals with diverse health status. The study by Ortolá *et al.* (158) additionally  
468 categorized participants according to both current and lifetime alcohol intake to account for  
469 possible misclassification, with no associations between occasional, light or moderate  
470 drinking and mortality risk observed for either exposure. Further studies similarly addressing  
471 key sources of bias are essential to increase confidence in nutritional recommendations.

472 Despite potential, although questionable, benefits of light-to-moderate alcohol intake, reduced  
473 body water, hepatic function and blood flow increases sensitivity to alcohol's toxicity within  
474 older adults (159), meaning the adverse effects on BP, liver function and cancer risk observed  
475 in the general population (160) may be exacerbated. Therefore, UK population safe alcohol  
476 intake of 14 units·week<sup>-1</sup> (1 alcohol unit = 8 g ethanol) for men and women (24) should be  
477 emphasized as a maximum and intake not promoted.

#### 478 *Fluid*

479 Impaired thirst sensation, poor renal function and fear of incontinence make inadequate fluid  
480 intake common among older adults (161), increasing risk of dehydration and subsequent  
481 effects including cognitive impairment and constipation (162). Consequently, it should be a  
482 key nutritional consideration among the elderly. UK population advice is non-specific,  
483 recommending 6-8 cups per day, equalling approximately 1.2-1.6L (16), yet age-specific

484 advice in several European countries (163) and in the comprehensive evidence based  
485 European Society for Clinical Nutrition and Metabolism (ESPEN) guidelines (164) is for  
486  $2.0\text{L}\cdot\text{day}^{-1}$  (men) and  $1.6\text{L}\cdot\text{day}^{-1}$  (women). Therefore, adjustments to quantitative  
487 recommendations are proposed to account for reduced homeostatic regulation with age (160).

488

## 489 **Conclusions**

490 The literature relating to nutritional requirements for older adult was reviewed using a  
491 systematic approach. Identified evidence was limited in many cases, but seemed to support  
492 changes to current UK population recommendations for those aged  $\geq 65\text{y}$  for protein (from  
493  $0.75\text{g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$  to  $1.2\text{g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$ ), calcium (from  $700\text{mg}\cdot\text{day}^{-1}$  to  $1000\text{mg}\cdot\text{day}^{-1}$ ), folate  
494 (from  $200\mu\text{g}\cdot\text{day}^{-1}$  to  $400\mu\text{g}\cdot\text{day}^{-1}$ ) and vitamin B-12 (from  $1.5\mu\text{g}\cdot\text{day}^{-1}$  to  $2.4\mu\text{g}\cdot\text{day}^{-1}$ ), and  
495 emphasis on sufficient fluid intake ( $2.0\text{L}\cdot\text{day}^{-1}$  men,  $1.6\text{L}\cdot\text{day}^{-1}$  women), as well as retention  
496 of current recommendations for carbohydrates, free sugars, dietary fibre, dietary fat and fatty  
497 acids, sodium, vitamin D and alcohol. For the other selected nutrients (potassium, iron, zinc,  
498 vitamin A, vitamin C, vitamin E, vitamin K, vitamin B-6), insufficient evidence prevented  
499 current UK population recommendations from being confirmed or adjusted.

500 It should be acknowledged that, despite decisions being justified by current research,  
501 nutrients with significant yet not widely documented physiological effects in older adults may  
502 have been excluded. Moreover, the literature review was not exhaustive as all alternative  
503 nutrient names were not included and reference lists of reviews were not hand-searched,  
504 however publications were identified based on title, content and keywords and overall  
505 conclusions from relevant reviews and systematic reviews identified were considered  
506 alongside individual studies. No structured quality assessment was conducted but publications  
507 were critiqued qualitatively to inform the degree to which they guided setting of nutritional



508 recommendations. Additionally, adults aged  $\geq 65$ y were assumed to be homogeneous, yet  
509 intra-individual variation in the rate of physiological change exists, with interactions between  
510 genes and lifestyle factors affecting nutrient response and disease progression. Furthermore,  
511 these recommendations are not applicable to most older adults with acute or chronic illnesses,  
512 for whom protein, dietary fat and free sugar requirements may be elevated due to  
513 hypermetabolism, and recommendations may be under- or overestimated for those of ethnic  
514 minority groups. This should be accounted for when considering transferability of  
515 recommendations to other populations.

516 Overall, the lack of age-specific evidence for most nutrients, particularly assessing  
517 dietary intake, limited the ability to confidently propose nutritional recommendations. Where  
518 changes were suggested, insufficient evidence existed to differentiate requirements of men  
519 and women or young-older adults (aged 65-79y) and old-older adults ( $\geq 80$ y), and hesitation  
520 remains regarding quantitation. Due to the increasing UK life expectancy and the likely role  
521 nutrition has in supporting maintenance of quality of life with age, it is vital that high-quality  
522 research is conducted (including meta-analyses and dietary RCTs) in adults aged  $\geq 65$ y into  
523 the areas highlighted throughout this critical review to address important gaps in the literature.

524

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527 analysed data; ND drafted the paper. All authors read and approved the final manuscript.

528

529 Supplemental Table 1-7 and Supplemental References are available from the “Supplementary  
530 data” link in the online posting of the article and from the same link in the online table of  
531 contents at <https://academic.oup.com/jn/>.

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**Table 1.** Proposed nutritional recommendations for UK adults aged  $\geq 65$ y based on the literature review<sup>1</sup>.

<b>Nutrient</b>	<b>No. publications selected</b>	<b>Recommendation</b>	<b>Maximum intake</b>	<b>Food-based advice</b>
Carbohydrates <sup>2,3</sup>	9	50% energy intake	-	Have 1 portion of starchy carbohydrates with each meal such as pasta, rice, bread and cereals. Opt for wholegrains. 1 portion = 190g cooked pasta, rice or grains, 80g bread or crackerbreads, 30g breakfast cereal or flour
Free sugars <sup>3,4</sup>	7	<5% energy intake	-	Limit consumption of sweet snacks like cakes, biscuits and pastries, as well as sugar sweetened beverages and confectionery.
Protein <sup>3,4,5</sup>	32	1.2 g·kg <sup>-1</sup> ·day <sup>-1</sup>	-	Have a portion of lean meat, poultry, fish, eggs, dairy or legumes with each meal. Animal protein is beneficial for maintaining muscle strength so try to include this regularly, although red and processed meat should be limited. 1 portion = 70g red meat, 100g poultry, 140g fish or shellfish, 120g or 2 eggs, 150g legumes, 30g nuts, 200mL milk, 30g cheese, 125g yoghurt, 100g meat alternatives
Fat <sup>2,3</sup>	21	<33% energy intake	-	Butter should be swapped for plant oil based spreads and vegetable oils chosen for cooking. Limit the amount of high fat meat, high fat dairy and pastries consumed.
SFA <sup>2,3,4,6</sup>		<10% energy intake	-	
Trans fatty acids <sup>3,4,6</sup>		<2% energy intake	-	
PUFA <sup>2,3</sup>		6% energy intake	-	
MUFA <sup>2,3</sup>		12% energy intake	-	
LC n-3 PUFA <sup>4,7</sup>	-	450 mg·day <sup>-1</sup>	-	Consume at least 2 portions of fish per week, one of which is oily, such as salmon or mackerel. Consuming up to 4 portions of oily fish per week considered safe. 1 portion = 140g
Dietary fibre <sup>3,4</sup>	4	30 g·day <sup>-1</sup>	-	Replace refined grains like white bread and pasta with wholegrains and consume at least 5 portions of a variety of fruit and vegetables per day. 1 portion = 80g fresh, 30g dried, 150mL juice



Calcium <sup>3,4</sup>	23	1000 mg·day <sup>-1</sup>	1500 mg·day <sup>-1</sup>	Dairy products are a key source of calcium. Consume 3 portions of low fat dairy per day such as milk, yoghurt or low fat cheese. Alternatively, choose calcium-fortified dairy-free alternatives. 1 portion = 200mL milk, 30g cheese, 125g yoghurt
Sodium <sup>3,4</sup>	8	1600 mg·day <sup>-1</sup>	Graded response	Limit consumption of processed meats and salty snacks like crisps and salted peanuts. Reduce the amount of salt added to food in cooking and at the table.
Salt <sup>3,4</sup>		4 g·day <sup>-1</sup>	6 g·day <sup>-1</sup>	
Potassium <sup>3,8</sup>	7	3500 mg·day <sup>-1</sup>	-	Fruits and vegetables provide high amounts of potassium. Have at least 5 portions of a variety of fruits and vegetables per day. 1 portion = 80g fresh, 30g dried, 150mL juice
Iron <sup>4,8</sup>	5	8.7 mg·day <sup>-1</sup>	17 mg·day <sup>-1</sup>	Animal sources of protein such as lean meat, fish and eggs provides the most easily absorbed form of iron, although red and processed meat intake should be limited. Other sources include pulses, nuts, green leafy vegetables and fortified breakfast cereals, although it is advantageous to consume a source of vitamin C alongside plant sources of iron to improve absorption.
Zinc <sup>4,8</sup>	6	9.5 mg·day <sup>-1</sup> (men) 7 mg·day <sup>-1</sup> (women)	25 mg·day <sup>-1</sup>	Consume lean meat, fish, legumes, nuts and seeds, wholegrains and dairy regularly.
Vitamin A <sup>4,8</sup>	5	700 µg·day <sup>-1</sup> (men) 600 µg·day <sup>-1</sup> (women)	1500 µg·day <sup>-1</sup>	Dairy and fish are good sources of vitamin A, and yellow, red and green vegetables include β-carotene which can be converted to vitamin A in the body. Liver and liver products are good sources of vitamin A but should be consumed in moderation.
Vitamin C <sup>3,8</sup>	7	40 mg·day <sup>-1</sup>	-	Have at least 5 portions of a variety of fruit and vegetables per day. 1 portion = 80g fresh, 30g dried, 150mL juice
Vitamin D <sup>4,9</sup>	1	10 µg·day <sup>-1</sup>	25 µg·day <sup>-1</sup>	Consume vitamin D rich foods such as oily fish, egg yolks and fortified dairy. Also take a 10 µg/day vitamin D supplement.
Vitamin E <sup>4,8</sup>	6	4 mg·day <sup>-1</sup> (men) 3 mg·day <sup>-1</sup> (women)	540 mg·day <sup>-1</sup>	Consume healthy fats from nuts, seeds and vegetable oils.

Vitamin K <sup>4,8</sup>	7	1 µg·kg <sup>-1</sup> ·day <sup>-1</sup>	-	Frequently choose leafy green vegetables such as kale, spinach and lettuce.
Folate <sup>4,8</sup>	24	400 µg·day <sup>-1</sup>	1 mg·day <sup>-1</sup>	Consume foods high in folate including leafy green vegetables like spinach and broccoli, legumes, yeast extract and fortified cereals.
Vitamin B-12 <sup>4,8,10</sup>		2.4 µg·day <sup>-1</sup>	-	Consume foods fortified with vitamin B-12 such as breakfast cereals or yeast extract, or animal products including lean meat, fish, poultry, eggs and dairy.
Vitamin B-6 <sup>4,8</sup>		1.4 mg·day <sup>-1</sup> (men) 1.2 mg·day <sup>-1</sup> (women)	10 mg·day <sup>-1</sup>	Consume lean meat, poultry, fish, nuts and seeds, legumes and wholegrains regularly.
Alcohol <sup>3,11</sup>	30	≤14 units·week <sup>-1</sup>	-	Alcohol consumption should be kept to a minimum. It is not recommended to take up drinking. Do not drink large quantities of alcohol on one day. Spread out intake across the week. 1 alcohol unit = 8g ethanol
Fluid <sup>3,12</sup>	5	2.0 L·day <sup>-1</sup> (men) 1.6 L·day <sup>-1</sup> (women)	-	Drink at least 6-8 servings of 250 mL of fluid per day. This can include water, tea, coffee and milk. Limit consumption of sugar-sweetened beverages and alcohol and try to have a maximum 150ml fruit juice per day.

<sup>1</sup> Quantitative recommendations set based on literature review; % energy intake refers to total energy; LC n-3 PUFA, long chain n-3 polyunsaturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; SFA, saturated fatty acids.

<sup>2</sup> Recommendation is for population average.

<sup>3</sup> Practical advice based on *UK Eatwell Guide* (16) and literature review, portion sizes based on standard portions (29).

<sup>4</sup> Recommendation is reference nutrient intake.

<sup>5</sup> Practical advice based on evidence that even protein distribution supports sufficient protein intake (30) despite inconsistent evidence for health benefits (31-34) and on evidence indicating animal protein to support muscle protein synthesis (35-39)

<sup>6</sup> Practical advice based on recommendations from SACN *Saturated fat and health* report for swapping SFA with unsaturated fatty acids (23).

<sup>7</sup> Practical advice based on recommendations from SACN *Advice on fish consumption: risks & benefits* report (18); maximum intake set to limit exposure to toxins such as methylmercury and polychlorinated biphenyls (40), portion size based on SACN report.

<sup>8</sup> Practical advice based on key sources of nutrient (41).

<sup>9</sup> Practical advice based on recommendations from SACN *Vitamin D and health* report; few vitamin D rich foods exist and there is no mandatory fortification in the UK making it challenging to meet the recommendation from dietary sources alone without supplementation (22).

<sup>10</sup> Vitamin B-12 in fortified foods and supplements is in the crystalline form and considered of greater bioavailability than the natural form in animal foods (42).

<sup>11</sup> Practical advice based on Chief Medical Officer's *Low risk drinking guidelines* (24) and literature review.

<sup>12</sup> Practical advice remains consistent with recommendations for limiting free sugars and alcohol intake.

**Figure 1.** Flow chart summarising literature searches for all nutrients.