A review of nutritional requirements for adults aged ≥65y in the UK.

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Abbreviations: BMD, bone mineral density; BP, blood pressure; COMA, Committee on Medical Aspects of Food and Nutrition Policy; CVD, cardiovascular disease; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; RCT, randomised controlled trial; SACN, Scientific Advisory Committee for Nutrition; SFA, saturated fatty acids; T2D, type 2 diabetes; TE, total energy; WHO, World Health Organisation.

Abstract

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

Keywords: Older adults; Elderly; Nutritional requirements; Nutritional recommendations; Healthy ageing

Introduction

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

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

Methods

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

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

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

Outcome of literature review

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

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

Evidence supporting the proposed nutritional recommendations

Carbohydrates, free sugars and dietary fibre

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

High free sugar intake in the general population has been associated with increased risk of dental caries, T2D and excess energy intake (21). No contradictory evidence was found for older adults. Moreover, Laclaustra *et al.* (46) reported a positive association between added sugar intake and frailty risk. However, sugar added in food production was found to be more strongly associated than table sugar, suggesting potential confounding effects of the nutritional composition of processed foods which should be considered in interpretation. Nonetheless, inverse associations have been observed between percentage energy intake from added sugars and intake of protein, dietary fibre and several key micronutrients (47,48), supporting the notion that free sugar containing foods may displace protein and micronutrient-rich dietary components (11). These inverse associations were not fully replicated when studying the UK population (49) but 4-day diet diaries may not completely capture habitual diet, unlike food -frequency questionnaires used in the other studies. Consequently, available evidence, COMA 1992 recommendations (11) and recent SACN advice (21) suggests retaining current free sugars recommendations of ≤5% TE may promote nutrient density and minimise risk of adverse health outcomes.

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

Protein

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

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

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

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

Dietary fat and fatty acids

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

Conversely, Houston *et al.* (70) observed no associations between dietary total fat and SFA, MUFA and trans fatty acid intake and CVD in men and women aged 70-79y after adjustment for dietary confounders and relevant medication. As older adults studied had not previously suffered or died prematurely from CVD, potentially low baseline risk among subjects may have influenced results and they could suggest differing susceptibility to detrimental effects of dietary components among older adults, although this requires confirmation. Therefore, in absence of further age-specific evidence and due to elevated CVD risk with age it seems appropriate to generalise current population recommendations for dietary fat (≤33% TE), unsaturated fatty acids (12% TE MUFA, 6% TE PUFA), long chain n-3 PUFA (450mg·day^{-1}), trans fatty acids (≤2% TE) and, as per the 2019 SACN report (23), those for SFA (≤10% TE) to older adults.

Calcium

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

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

Identified dietary studies reported calcium intake to be positively associated with BMD (85,88) and inversely associated with osteoporosis or fracture risk (89-91). Two large longitudinal cohort studies provide quantitative evidence to guide recommendations. Firstly, Nieves *et al.* (89) observed an association between calcium intake >800mg·day^{-1} and a 25% reduced 3y osteoporosis risk compared to <500mg·day^{-1}, although misclassification bias is possible as non-dairy calcium intake was estimated at 250mg·day^{-1} (US average) for all subjects rather than accurately assessed. Secondly, Warensjö *et al.* (91) observed an association between calcium intake <751mg·day^{-1} and an increased risk of 18% for any fracture, 29% for hip fracture and 47% for osteoporosis after median 19.2y follow-up compared to 822-996mg·day^{-1}. Additionally, no benefits of >1137mg·day^{-1} were observed and a detrimental effect on hip fracture risk compared to lower intakes reported. Repeat food-frequency questionnaires throughout follow-up allowed all major calcium sources to be recorded and subjects classified by the mean of their cumulative dietary intake, accounting for changes. The recent 32y longitudinal study by Feskanich *et al.* (92) supported this approach as positive associations between dairy food intake and hip fracture were similar for current and cumulative average intake but attenuated when baseline intake was used as the exposure. Nonetheless, reverse causation may still exist where dietary intake changed following osteoporosis diagnosis and could explain the detrimental effects seen from >1137mg·day^{-1} calcium intake.

Despite limitations, observations by Nieves *et al.* and Warensjö *et al.* in >90 000 subjects, supported by supplementation studies and biological plausibility, suggest current UK population calcium recommendations of 700mg·day^{-1} may not be optimal for older adults. An intake up to 1000mg·day^{-1} combined with adequate vitamin D (91) may have greater benefit, although evidence confirming this quantity is lacking and, without dietary RCTs, reverse causation at higher intakes cannot be excluded. Furthermore, most studies were in post-menopausal women, typically aged ≥50y or ≥55y. It is uncertain whether conclusions would be replicated in analyses limited to those aged ≥65y as Dawson-Hughes *et al.* reported no effect of calcium supplementation on BMD among early post-menopausal subjects (≤5y since menopause) yet an inverse association with BMD loss in those >5y post-menopause (85). Consequently, results by Nieves *et al.* and Warensjö *et al.* may be underestimated for adults aged ≥65y who would be beyond the early post-menopausal stage of accelerated bone loss. Finally, most bone health studies focus on women, making effects in men uncertain. Greater evidence in both sexes restricted to adults aged ≥65y is required to increase certainty regarding proposed quantitative changes to recommendations.

Sodium and salt

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

Potassium

Physiological functions of potassium include supporting bone health and lowering BP. For bone health, two longitudinal studies reported positive associations between dietary potassium intake and BMD. However, Tucker *et al.* observed the association only in men (98), and Zhu *et al.* observed it within their female cohort but used urinary potassium excretion as the exposure which was only weakly correlated with dietary intake (99) questioning whether a true benefit existed. For BP, SACN and the Committee of Toxicity recently reported inverse associations between potassium intake and systolic and diastolic BP and stroke risk in the general population (28), results that may or may not be replicated in older adults. Nonetheless, no evidence for adverse effects were found. Notably, concerns regarding hyperkalaemia associated with reduced kidney function with age are limited to those with advanced chronic kidney disease (28), when dietary priorities differ and specialist medical and dietetic support would be received. Overall, evidence suggests potential benefits of high potassium intake, but without further studies current recommendations of 3500mg·day^{-1} cannot be confirmed nor adjusted.

Iron

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

Zinc

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

Vitamin A

Vitamin A has various roles, although limited age-specific evidence was identified for beneficial effects. However, a large longitudinal cohort study reported an association between vitamin A intake $\geq 2000 \mu g \cdot day^{-1}$ and an 89% increased risk of hip fracture compared to $< 500 \mu g \cdot day^{-1}$ (109), indicating possible importance of avoiding excessive intakes. Furthermore, Borel *et al.* (110) demonstrated impaired postprandial retinol transport and impaired regulation of plasma retinol concentration in elderly subjects despite similar intestinal absorption efficiency to younger adults, indicating risk of elevated serum concentrations and toxicity for older adults (111). Insufficient age-specific evidence for minimum dietary vitamin A intake and the potentially unaltered intestinal absorption rate (110) means current population recommendations of $700 \mu g \cdot day^{-1}$ (men) and $600 \mu g \cdot day^{-1}$

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

Vitamin C

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

Vitamin D

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

BMD, muscle strength and function, and risk of falls in adults aged ≥50y, when considering subjects with variable baseline 25-hydroxyvitamin D concentrations. An age-specific reference nutrient intake was advised by SACN based on a modelling exercise, therefore this recommendation of 10μg·day^{-1} is retained to support year-round maintenance of vitamin D sufficiency (22).

Vitamin E

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

Vitamin K

Vitamin K has a role in blood coagulation (119), bone health (120) and potentially cognition. Despite biological plausibility, evidence is somewhat lacking. In identified studies, increasing vitamin K intake was associated with reduced BMD loss (121), vitamin K deficiency with increased risk of knee osteoarthritis (122) and cartilage damage (123), higher plasma concentrations of phylloquinone with improved physical performance, gait speed and endurance (124), higher serum or dietary phylloquinone with better cognitive function (125,126), and higher dephospho-uncarboxylated matrix Gla protein concentration (considered a reliable marker of vitamin K status and utilisation) with lower handgrip strength and calf circumference (127). These studies are not without limitations, including potential confounding by other components of vitamin K rich foods, such as green leafy vegetables, not adjusted for in analyses. Therefore, current recommendations of 1μg·kg^{-1}·day^{-1} are retained, although limited evidence in the general population means this is only a safe intake level.

Folate, vitamin B-12 and vitamin B-6

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

Impaired vitamin B-12 absorption from atrophic gastritis is prevalent among older adults (129) making high dietary intake key to prevent deficiency. Furthermore, a range of evidence was identified relating to cognitive outcomes, although with inconsistent conclusions. To summarise, plasma folate has been inversely associated with measures of cognitive function and cognitive decline risk (130,131) but also no associaton with cognitive decline or depression observed (132-134), although selection bias may exist where Hughes *et al.* excluded those with pre-existing vitamin B-12 deficiency and Morris *et al.* studied a well-educated population within whom high cognitive reserve may lower dementia risk (135). Low low plasma or serum vitamin B-12 have been associated with greater 8y decline in cognitive function (133), and cross-sectionally with reduced mental processing speed (136), increased risk of cognitive impairment (137) and depression (134), yet Tucker *et al.* (130) reported no association between plasma vitamin B-12 and spatial copying independent of folate, vitamin B-6 and homocysteine concentrations. Finally, plasma vitamin B-6 has been inversely associated with cognitive decline risk (138), however Kado *et al.* (131) and Tucker *et al.* (130) reported no association between plasma vitamin B-6 and cognitive function or cognitive decline risk independent of biochemical status of other B vitamins.

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

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

Alcohol

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

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

A few studies have attempted to overcome these limitations. For example, Stampfer *et al.* (146) accounted for changes in intake across 20y follow-up and minimised bias resulting from poor health of former drinkers by assessing baseline and 4-yearly alcohol intake and excluding participants who reported abstention when undertaking follow-up cognitive assessment but previously reported alcohol intake. Furthermore, three studies conducted analyses with former drinkers in isolation, in addition to the standard abstention group, reporting associations between former drinking and increased congestive heart failure risk (152), detrimental effects of former drinking and no association or a protective effect of never drinking on mortality risk (154), and a 1.5x increased risk of all-cause mortality for ex-drinkers compared to never-drinkers (158), highlighting abstainers to be a group of individuals with diverse health status. The study by Ortolá *et al.* (158) additionally categorized participants according to both current and lifetime alcohol intake to account for possible misclassification, with no associations between occasional, light or moderate drinking and mortality risk observed for either exposure. Further studies similarly addressing key sources of bias are essential to increase confidence in nutritional recommendations.

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

Fluid

Impaired thirst sensation, poor renal function and fear of incontinence make inadequate fluid intake common among older adults (161), increasing risk of dehydration and subsequent effects including cognitive impairment and constipation (162). Consequently, it should be a key nutritional consideration among the elderly. UK population advice is non-specific, recommending 6-8 cups per day, equalling approximately 1.2-1.6L (16), yet age-specific advice in several European countries (163) and in the comprehensive evidence based European Society for Clinical Nutrition and Metabolism (ESPEN) guidelines (164) is for 2.0L·day^{-1} (men) and 1.6L·day^{-1} (women). Therefore, adjustments to quantitative recommendations are proposed to account for reduced homeostatic regulation with age (160).

Conclusions

The literature relating to nutritional requirements for older adult was reviewed using a systematic approach. Identified evidence was limited in many cases, but seemed to- support changes to current UK population recommendations for those aged ≥65y for protein (from 0.75g·kg^{-1}·day^{-1} to 1.2g·kg^{-1}·day^{-1}), calcium (from 700mg·day^{-1} to 1000mg·day^{-1}), folate (from 200µg·day^{-1} to 400µg·day^{-1}) and vitamin B-12 (from 1.5µg·day^{-1} to 2.4µg·day^{-1}), and emphasis on sufficient fluid intake (2L·day^{-1} men, 1.6L·day^{-1} women), as well as retention of current recommendations for carbohydrates, free sugars, dietary fibre, dietary fat and fatty acids, sodium, vitamin D and alcohol. For the other selected nutrients (potassium, iron, zinc, vitamin A, vitamin C, vitamin E, vitamin K, vitamin B-6), insufficient evidence prevented current UK population recommendations from being confirmed or adjusted.

It should be acknowledged that, despite decisions being justified by current research, nutrients with significant yet not widely documented physiological effects in older adults may have been excluded. Moreover, the literature review was not exhaustive as all alternative nutrient names were not included and reference lists of reviews were not hand-searched, however publications were identified based on title, content and keywords and overall conclusions from relevant reviews and systematic reviews identified were considered alongside individual studies. No structured quality assessment was conducted but publications were critiqued qualitatively to inform the degree to which they guided setting of nutritional recommendations. Additionally, adults aged ≥65y were assumed to be homogeneous, yet intra-individual variation in the rate of physiological change exists, with interactions between genes and lifestyle factors affecting nutrient response and disease progression. Furthermore, these recommendations are not applicable to most older adults with acute or chronic illnesses, for whom protein, dietary fat and free sugar requirements may be elevated due to hypermetabolism, and recommendations may be under- or overestimated for those of ethnic minority groups. This should be accounted for when considering transferability of recommendations to other populations.

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

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Supplemental Methods is available from the "Supplementary data" link in the online posting of the article and from the same link in the online table of contents at https://academic.oup.com/jn/.

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Table 1. Proposed nutritional recommendations for UK adults aged ≥65y based on the literature review[1].

Nutrient	No. publications selected	Recommendation	Maximum intake	Food-based advice
Carbohydrates[2,3]	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[3.4]	7	<5% energy intake	-	Limit consumption of sweet snacks like cakes, biscuits and pastries, as well as sugar sweetened beverages and confectionery.
Protein[3.4,5]	32	1.2 $g \cdot kg^{-1} \cdot day^{-1}$	-	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[2,3]	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[2,3,4,6]		<10% energy intake	-	
Trans fatty acids[3.4,6]		<2% energy intake	-	
PUFA[2,3]		6% energy intake	-	
MUFA[2,3]		12% energy intake	-	
LC n-3 PUFA[4,7]	-	450 $mg \cdot day^{-1}$	-	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[3.4]	4	30 $g \cdot day^{-1}$	-	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[3.4]	23	1000 mg·day^{-1}	1500 mg·day^{-1}	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[3.4]	8	1600 mg·day^{-1}	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[3.4]		4 g·day^{-1}	6 g·day^{-1}	
Potassium[3,8]	7	3500 mg·day^{-1}	-	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[4,8]	5	8.7 mg·day^{-1}	17 mg·day^{-1}	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[4,8]	6	9.5 mg·day^{-1} (men) 7 mg·day^{-1} (women)	25 mg·day^{-1}	Consume lean meat, fish, legumes, nuts and seeds, wholegrains and dairy regularly.
Vitamin A[4,8]	5	700 µg·day^{-1} (men) 600 µg·day^{-1} (women)	1500 µg·day^{-1}	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[3.8]	7	40 mg·day^{-1}	-	Have at least 5 portions of a variety of fruit and vegetables per day. 1 portion = 80g fresh, 30g dried, 150mL juice
Vitamin D[4,9]	1	10 µg·day^{-1}	25 µg·day^{-1}	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[4,8]	6	4 mg·day^{-1} (men) 3 mg·day^{-1} (women)	540 mg·day^{-1}	Consume healthy fats from nuts, seeds and vegetable oils.

Vitamin K[4,8]	7	1µg·kg^{-1}·day^{-1}	-	Frequently choose leafy green vegetables such as kale, spinach and lettuce.
Folate[4,8]	24	400 µg·day^{-1}	1 mg·day^{-1}	Consume foods high in folate including leafy green vegetables like spinach and broccoli, legumes, yeast extract and fortified cereals.
Vitamin B-12[4,8,10]		2.4 µg·day^{-1}	-	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[4,8]		1.4 mg·day^{-1} (men) 1.2 mg·day^{-1} (women)	10 mg·day^{-1}	Consume lean meat, poultry, fish, nuts and seeds, legumes and wholegrains regularly.
Alcohol[3.11]	30	≤14 units·week^{-1}	-	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[3.12]	5	2.0 L·day^{-1} (men) 1.6 L·day^{-1} (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.

[1] 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.
[2] Recommendation is for population average.
[3] Practical advice based on *UK Eatwell Guide* (16) and literature review, portion sizes based on standard portions (29).
[4] Recommendation is reference nutrient intake.
[5] 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)
[6] Practical advice based on recommendations from SACN *Saturated fat and health* report for swapping SFA with unsaturated fatty acids (23).
[7] 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.
[8] Practical advice based on key sources of nutrient (41).
[9] 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).
[10] 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).
[11] Practical advice based on Chief Medical Officer's *Low risk drinking guidelines* (24) and literature review.
[12] Practical advice remains consistent with recommendations for limiting free sugars and alcohol intake.

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