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Where Are We up to with Vitamin, Mineral and Omega-3 Polyunsaturated Fatty Acid Gaps? Intake and Status Findings from the UK National Diet and Nutritional Survey 2019 to 2023

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Abstract

Inadequate vitamin, mineral and omega-3 intakes can have short and long-term implications for health. The recent UK National Diet and Nutrition Survey (years 2019 to 2023) provides updated dietary intake data and blood status biomarkers for certain micronutrients and long-chain n-3 polyunsaturated fatty acids. A Perspectus Global survey was also undertaken with n = 1505 UK respondents to evaluate vitamin, mineral and omega-3 knowledge, understanding and barriers to consumption. Vitamin D, riboflavin, folate (particularly in women of childbearing age), iron (especially among girls and women), calcium, potassium, iodine and selenium fell below dietary recommended intakes across the recent UK National Diet and Nutrition Survey. Consumption of oily fish was also well below recommended thresholds across all population groups. Those most vulnerable to inadequate intakes include females, women of childbearing age, young people and teenagers. Suboptimal intakes of key nutrients such as folate, iron and iodine in girls and across women of childbearing years are especially concerning given extended implications for inter-generational health. There has been much interest in plant-based diets and ultra-processed foods recently, yet much greater emphasis needs to be placed on the fundamentals, such as the nutrient density of foods and the importance of attaining dietary benchmarks. Ongoing government programmes and the dissemination of evidence-based practical information are needed to help raise the awareness of micronutrients and omega-3 fatty acids where there are present-day gaps. Suitable fortification initiatives, supplementation programmes and updated guidance which take on board the latest research findings should be considered. In conclusion, the optimisation of vitamin, mineral and omega-3 intakes could have extended health and wellbeing benefits for the health of the UK population. For example, in the COVID-19 pandemic hypovitaminosis D was widespread and improved status at the time could have had assisted immunomodulatory functions. Now is a good time to reflect on latest UK NDNS findings and to seriously consider how to improve the health and wellness of the nation 10 years from now.

Keywords

National Diet and Nutritional Survey, Micronutrients, Minerals, Vitamins, Omega-3 Fatty Acids

1. Introduction

Vitamins and minerals, often referred to as micronutrients are essential to human bodily functions with individuals needing to meet daily requirements via dietary sources [1]. Vitamins are organic compounds involved in cellular processes that are essential to a range of physiological functions in the human body and the prevention of disease risks [2]. Minerals also regulate a range of physiological functions which include enzyme function, nerve signalling, immune response and bone health [3]. Shortfalls in macrominerals (calcium, magnesium, and phosphate) may be associated with cardiovascular events, neuromuscular dysfunction and osteoporosis. Deficits in trace minerals such as selenium are also linked to health issues such as impaired antioxidant defences, oxygen transport and immune function, while iron shortages are associated with delayed wound healing, anaemia and increasing vulnerability to infectious diseases [3].

We are now in the fourth industrial revolution (or Industry 4.0) era which indeed is viewed as the information and communication technology and artificial intelligence (AI) era [4] [5]. Although this can bring benefits such as personalised nutrition services, the ubiquity of information online and through social media coupled with the integration of public opinion by sharing, can lead to the dissemination of nutrition misinformation [4] [6]. A lack of content regulation and unparalleled access to information means that misrepresentation is on the increase [7]. Some food and nutrition programmes have been strengthened by the technological era, which includes wide acceptance of plant-based foods [5], which, in turn, could have some wider ramifications on micronutrient intakes such as vitamin B12, vitamin D, calcium and iodine intakes [8].

In 2016 Miller and Stanner published an important publication—"*Micronutrient status and intake in the UK—where might we be in* 10 *years' time*?" [9]. It was then identified that folate, vitamin D, calcium, iron and iodine shortfalls were most common amongst certain UK population subgroups which included ethnic minorities, adolescents, women of childbearing age and lower socio-economic groups [9]. It was projected that these micronutrients of concern could remain similar with iron and calcium potentially declining further if certain dietary trends were to continue, although fortification practices/policies, e.g. focusing on vitamin D and folate, could help to attenuate some decrements [9]. Ten years on, we have the answer to this postulation as the latest UK National Diet and Nutritional Survey (NDNS) 2019 to 2023 results have been published [10]. The aim of this publication is to evaluate vitamin, mineral and omega-3 Polyunsaturated Fatty Acids (n-3 PUFA) intakes from the latest 2019 to 2023 UK NDNS analysis, and the objective is to compare this with earlier analytical reports to determine whether nutrient intakes are improving or diminishing. Ramifications of nutrient shortfalls will also be described in relation to wider implications for health and future recommendations made.

2. Methods

The research methods used for this paper were two-fold:

- A secondary analysis of the NDNS data (2019 to 2023)
- An analysis of a 2025 survey on knowledge, understanding and barriers to intake regarding vitamins, minerals and omega-3 fatty acids

2.1. Analysis of the NDNS Data

The UK NDNS is a well-established cross-sectional survey funded jointly by the Department of Health and Social Care (DHSC) and the Food Standards Agency (FSA) and carried out by a consortium of the National Centre for Social Research (NatCen) and the Medical Research Council (MRC) Epidemiology Unit, University of Cambridge [10]. The UK NDNS recruits adults aged 18 months and over from all four UK countries living in private households. The sample is designed to be nationally representative and the data is used by UK governments to develop food and nutrition policies and evaluate progress towards achieving diet and nutrition objectives [10]. Alongside dietary intakes, the UK NDNS assesses the nutrient intakes and status of UK residents aged 18 months and over living in private households [11]. Previously, between 2008 and 2019 UK NDNS data was collected over 4 consecutive days using paper food diaries and estimated food portion weights but this transitioned to a web-based automated self-administered tool (Intake-24) in October 2019 which was used in the present survey analysis [11]. It should, however, be noted that data collection was suspended between March and October 2020 due to the COVID-19 pandemic [10].

2.2. Analysis of Data around the UK's Opinions on Knowledge, Understanding and Barriers to Intake

In addition to a secondary analysis of UK NDNS data, a Perspectus Global omnibus survey (n = 1505 UK respondents) was also undertaken and analysed to understand the UK public's knowledge and understanding of vitamins, minerals and omega-3 fatty acids alongside potential barriers to intake [12]. For reference, the

Reference Nutrient Intake (RNI) is the amount of a nutrient that meets the needs of most (around 97.5%) of people and the Lower Reference Nutrient Intake (LRNI) is the level of a nutrient that is enough for only a small number of people (around 2.5%) in a group who have low requirements, i.e. the majority [13]. An individual minimum of 0.2% n-3 Cis-PUFA has been advised for adults as a percentage of daily total energy intake [14].

3. Results

Between October 2019 and May 2023, n = 4089 participants (n = 1943 children and n = 2146 adults) completed at least 1 dietary recall, and 76% of individuals went on to complete all four dietary recalls [11]. Data are included from all four UK countries and designed to be nationally representative [10].

3.1. Vitamin A

In the latest 2019 to 2023 analysis, mean vitamin A intakes from food sources were 600 µg/day for adults aged 19- to 64-years [15]. This was 93% of the RNI, with 10% having intakes below the LRNI. Eight percent of children aged 4- to 10-years and 16% of 11- to 18-year-olds also had intakes below the LRNI for vitamin A [15]. Four percent of 65- to 74-year-olds and 6% of adults over the age of 75 years and 1 in 10 men in this age category had vitamin A intakes lower than the LRNI [15]. Regarding food contributions, whole milk, semi-skimmed milk, vegetables, eggs and egg dishes, and butter and ghee were some of the main dietary providers of vitamin A [15].

3.2. B Vitamins

Shortfalls of B vitamins from food sources were less common across gender and age groups. Thiamine and niacin shortfalls were generally uncommon. In the case of riboflavin, 23% of children aged 11- to 18-years (14% of boys and 32% of girls in this age category) had daily riboflavin intakes below the LRNI [15]. Fifteen percent of adults aged 19- to 64-year also had riboflavin (vitamin B2) intakes below the LRNI [15]. Vitamin B6 and B12 intakes were mostly satisfactory [15].

3.3. Folate

In the UK NDNS, both red blood cell (RBC) folate—an indicator of long-term folate status, and serum folate levels are measured [10]. RBC folate levels below 305 nmol per litre are indicative of folate deficiency [10]. From 2019 to 2023, just over 1 in 10 (12%) children aged 11- to 18-years had RBC folate levels below these deficiency thresholds [15]. Around 1 in 20 (4%) adults aged 19- to 64-years and 2% of adults over the age of 65 years have blood folate levels below these cut-off thresholds. Sixteen percent of adults (19- to 64-year) and 10% of older adults took folic acid supplements [15].

Concerningly, amongst women of childbearing age (ages 16- to 49-year), 1 in 10 (2019 to 2023 data) had folate intakes below the LRNI [15]. Eighty three percent of childbearing aged women had RBC folate levels lower than 748 nmol per litre, which poses an increased risk of neural tube defect-affected pregnancies [10] [15]. According to the World Health Organization, an RBC folate threshold of >400 ng/mL (906 nmol/L) can be used as an indicator of folate insufficiency in women of childbearing age [16]. Only 19% of women of childbearing age took folic acid supplements [15]. Within most population groups, breakfast cereals, whole milk, semi-skimmed milk, vegetables, and fruits were some of the main dietary providers of folate and folic acid [15].

3.4. Vitamins C and D

Vitamin C intakes from food sources were mostly sufficient. An LRNI has not been established for vitamin D, so subsequently habitual intakes can be compared against government guidance and derived as a percentage of the Reference Nutrient Intake (RNI). In the UK, it is advised that during the autumn and the winter months (October-March) everyone should take a supplement containing 10 micrograms (400 international units) of vitamin D a day to reinforce general health and in particular bone and muscle health [17]. During the COVID-19 pandemic, this was particularly important for those defined as clinically extremely vulnerable (CEV), i.e., having a specified medical condition that meant they were on or were added to the CEV list [17].

Amongst children aged 1.5- to 3-years and children aged 4- to 10-years, daily vitamin D intakes from food sources were just 19% and 21% of the RNI, respectively [15]. Amongst older children and teens aged 11- to 18-years, mean daily intakes were 1.8 μg/day, and 22% of the RNI [15]. Adult vitamin D intakes were 2.6 μg/day and 26% of the RNI. While still insufficient, older adults had marginally higher vitamin D intakes—2.9 and 2.8 μg/day for those aged 64 to 74 years and 75+ years and over (29% RNI and 28% RNI, respectively) [15]. Overall, amongst children aged 1.5- to 18-years and adults aged 19 years and over, mean daily vitamin D intakes from food sources only, were just 21% and 27% of the RNI [15].

Inadequate habitual vitamin D intakes are further reflected in blood biomarkers. Low vitamin D status (25-hydroxyvitamin D concentration less than 25 nmol per litre) was present in:

- 10% children aged 4-to-10-years;
- 1 in 5 (23%) children aged 11-to-18-years;
- 18% of adults aged 19-to-64-years;
- 12% of adults aged 65 years and over [15].

Vitamin D supplements were taken by:

- 40% of 1.5-to-3-year-olds;
- 33% of 4-to-10-year-olds;
- 19% of 11-to-18-year-olds;
- 28% of 19-to-64-year-olds;
- 35% of adults aged 65-to-74-years;
- Around one-third (36%) of adults over the age of 75 years [15].

The predominant dietary sources of vitamin D were breakfast cereals, yoghurt, fromage frais, and dairy desserts, beef and oily fish [15].

3.5. Macrominerals

3.5.1. Calcium and Magnesium

Overall, among children aged 1.5- to 18-years, 8% had calcium intakes below the LRNI and around 1 in 10 (9%) adults, had calcium intakes below the LRNI [15]. Calcium intakes from food sources were in shortfall across older children aged 11- to 18-years, as 17% had intakes below the LRNI (mean intake 761 mg/day) [15]. Adults aged 19- to 64-years, the mean daily calcium intake was 790 mg/day, and 9% had calcium intakes beneath the LRNI [15]. Older adults aged 64- to 74-years and 75 years and over, had better calcium intakes, with 7% and 6% respectively falling below the LRNI [15]. The main dietary sources of calcium were breakfast cereals, whole milk, semi-skimmed milk, cheese, yoghurt and fromage frais, and dairy desserts. Magnesium intakes were mostly sufficient [15].

3.5.2. Potassium

Potassium intakes were lacking across children aged 11- to 18-years, with around one-third (32%) having daily intakes from food sources below the LRNI [15]. Twenty-seven percent of boys and 37% of girls aged 11- to 18-years had potassium intakes below the LRNI [15]. Similarly, amongst adults aged 19- to 64-years, 28% had potassium intakes below the LRNI [15]. With advancing age, 14% adults aged 64- to 74-years and around 1 in 5 adults aged 75 years and over (23%) had potassium intakes below the LRNI [15]. Breakfast cereals, semi-skimmed milk, beef, poultry, vegetables, fruit, chips and fried potatoes, and savoury snacks were some of the main dietary sources of potassium [15].

3.6. Trace/Microminerals

3.6.1. Iron

Iron appears to be a nutrient of concern for every life stage, but particularly a challenge for UK girls and women. Six percent of young children aged 1.5- to 3-years had iron intakes below the LRNI [15]. A concerning 29% of children (just under one-third) aged 11- to 18-years, had iron intakes under the LRNI and 19% of adults aged 19- to 64-years [15]. More specifically, girls aged 11- to 18- years had mean daily iron consumption levels of 8.3 mg. As a result, 56% of the same population group consumed the RNI but just under half (49%) had intakes below the LRNI [15]. Twenty-eight percent of girls aged 11- to 18-years and 9% of women aged 19- to 64 years had ferritin levels, an indicator of iron storage below the advised thresholds [18]. Nine percent of girls aged 11- to 18-years had both haemoglobin and ferritin levels under the recommended levels [18].

Women aged 19- to 64-years also had mean daily iron intakes of 8.6 mg/day, which was equivalent to 71% of the RNI. However, a concerning one-third (34%) had iron intakes below the LRNI [15]. Overall, 15% of children and adults had iron intakes under the LRNI [15]. Shortfalls across older adults were not as common, which is likely due to the lowering of dietary requirements. Four percent of 64- to 74-year-olds and 7% of 75+ -year-olds had intakes beneath the LRNI [15]. Breakfast cereals, beef, poultry and vegetables were some of the main food sources of iron [15].

3.6.2. Zinc

Zinc intakes were lacking across certain UK population groups. Among children aged 1.5- to 3-years, just 3% had zinc intakes below the LRNI [15]. However, as children become older, 7% had intakes below the LRNI (age 4- to 10-years) and 18% of those aged 11- to 18-years [15]. Twenty-three percent of girls and 14% of boys in this age range (11 - 18 years) had zinc intakes below the LRNI, indicating particular shortfalls in this age range [15]. Around 1 in 10 UK adults aged 19- to 64-years had daily zinc intakes below the LRNI. Among older age groups, 6% of 64- to 74-year-olds and 10% of those over the aged of 75 years had daily zinc intakes under the LRNI [15]. Breakfast cereals, whole milk, cheese, yoghurt, beef, poultry, vegetables, and nuts and seeds were some of the main dietary sources of zinc [15].

3.6.3. Copper

As with vitamin D, copper does not have an LRNI. Subsequently, intakes are typically expressed as a percentage of the RNI. Most population groups had mean intakes that exceeded the RNI [15]. Mean intakes as a percentage of the RNI were 89% for girls aged 11- to 18-years [15]. Equally, for women aged 19- to 64-years mean copper intakes, as a percentage of the RNI were 77% and 90% for men in this age category [15]. Across the older age groups, copper intakes as a percentage of the RNI was 89% for those aged 65- to 74-years and 88% as a percentage of the RNI for those aged 75 years and older [15]. Breakfast cereals, cheese, beef, vegetables, baked beans, potatoes, fruit and fruit and vegetable juice and smoothies were some of the main dietary providers of copper [15].

3.6.4. Selenium

Selenium intakes are often insufficient from early childhood onwards. More than one-third (36%) of children aged 11- to 18-years had selenium intakes from dietary sources below the LRNI [15]. Concerningly, nearly half (45%) of UK adults aged 19- to 64-years and 65- to 74-years had selenium intakes below the LRNI [15]. Girls and women across the life cycle appear to be particularly vulnerable to selenium shortfalls. Forty-five percent of girls aged 11- to 18-years had selenium intakes under the LRNI [15]. A staggering 57% of women aged 19- to 64-years had selenium intakes below the LRNI, 54% of women aged 65- to 74-years and 59% of women over the age of 75 years [15]. Breakfast cereals, semi-skimmed milk, cheese, yoghurt, eggs and egg dishes, beef, fish, nuts and seeds were some of the main dietary sources of selenium [15].

3.6.5. Iodine

One in five (21%) children aged 11- to 18-years had dietary iodine intakes from food sources less than the LRNI, and 13% adults aged 19- to 64-years [15]. Urinary iodine concentrations (UIC) were suitable for most populations, but there was evidence of insufficiency across girls aged 11- to 18-years and women of childbearing age (16- to 49-years) who had UIC levels below 100 µg per litre [15]. Since the introduction of UIC measurements by the UK NDNS from 2013, there has been a year-on-year decline in UIC with this decreasing by 29% for girls aged 11- to 18-years and by 25% for adults aged 19- to 64-years between 2013 and 2023 [15]. Breakfast cereals, whole milk, semi-skimmed milk, cheese, yoghurt, fish and fruit were some of the main dietary sources of iodine [15].

3.7. Cis-n-3 Polyunsaturated Fatty Acids and Fish/Oily Fish Intakes

Omega-3 fatty acids are one of the key building blocks of cell membranes. They are also found in the central nervous system and has immunomodulating properties [19]. Within the latest UK NDNS analysis (2019 to 2023) Cis-n-3 PUFA intakes are presented in g/day [15]. Mean intakes were:

- 1 g/day for children aged 1.5-to 3-years;
- 1.3 g/day for children aged 4-to-10-years;
- 1.6 g/day for older children aged 11-to-18-years;
- 1.8 g/day for adults aged 19-to-64-years [15].

Older adults aged 65 years to 74 years have mean intakes of 1.7 g/day, which was similar amongst those aged 75 years and over (mean intake 1.5 g/day) [15]. As a percentage of energy, which excluded alcohol Cis-n-3 PUFA intakes contributed to:

- 0.8% of energy for 1.5-to-3-year-olds and 4-to-10-year-olds;
- 0.9% of energy for 11-to-18-year-olds;
- 1.0% of energy for adults aged 19 years and over [15].

Oily fish intakes (g/day) were just 2 g/day among children aged 1.5 year to 18 years. Among adults aged 19- to 64-years mean oily fish intakes were 5 g/day and 7 - 8 g/day amongst adults aged 65- to 74 years and 75 years and over [20]. In the UK, it is advised that we should aim to eat two portions of fish weekly, of which one should be oily [21].

- For children aged 1.5-years to 3 years, one portion is equivalent to one quarter to three quarters of a small fillet, or one to three tablespoons [21].
- For 4-to-6-year-olds, a portion is about half-one small fillet or two to four tablespoons [21].
- For 7- to 11-year-olds, one to one and a half small fillets or four to six tablespoons is equivalent to a portion [21].
- For adults (those aged 12 years and over), a portion constitutes 140 g (5 oz) of fresh fish, or one small can of oily fish [21].

Overall, habitual fish/oily fish intakes were considerably lower than the advised weekly portions of oily fish.

4. Earlier Survey Comparisons

4.1. Children Aged 1.5 to 10 Years

As shown in Figure 1 and Figure 2, there have been few improvements in vitamin and mineral intakes amongst children aged 1.5 to 3 years and 4 to 10 years since 2008. Amongst younger children aged 1.5- to 3-years vitamin A, iron, iodine and zinc appear to be nutrients of concern and amongst older children aged 4- to 10-years vitamin A, iodine, zinc, selenium, potassium, calcium, iron, folate, riboflavin and vitamin B6 most commonly fall below the LRNI.

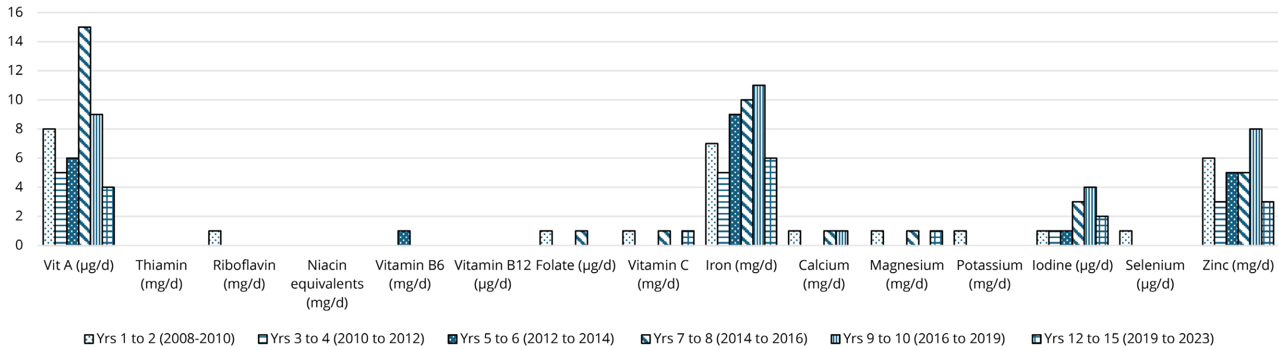

Figure 1. Percentage of children aged 1.5 to 3 years with vitamins & mineral intakes below the LRNI (from 2008 to 2023).

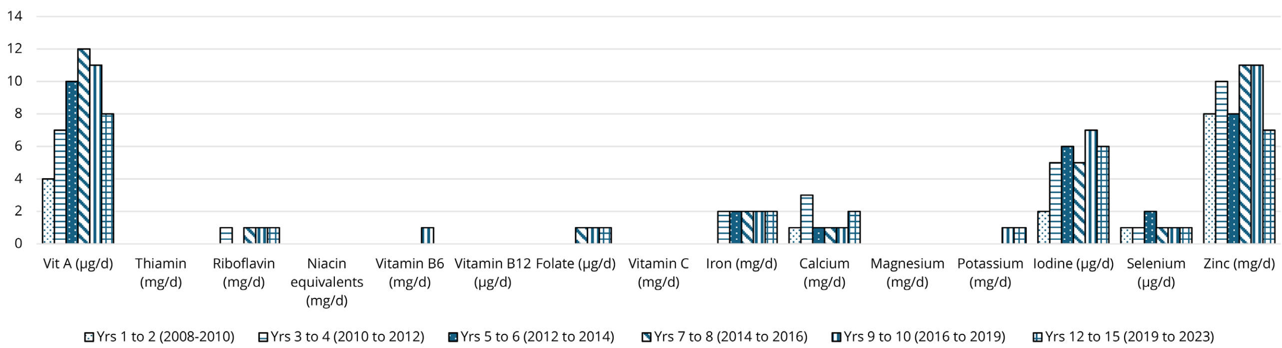

Figure 2. Percentage of children aged 4 to 10 years with vitamins & mineral intakes below the LRNI (from 2008 to 2023).

4.2. Children 11 to 18 Years

As seen in Figure 3, across children aged 11- to 18-years there appears to have been minimal dietary health improvements and some decrements in certain nutrient intakes over time. For example, 13% of children and young people in this age category had riboflavin intakes below the LRNI in years 1 to 2 of the NDNS (2008 to 2010) which peaked to 20% below the LRNI in years 7 to 8 (2014 to 2016), and was 23% below the LRNI in years 12 to 15 (2019 to 2023) [15]. Iron intakes have not changed substantially over time, 24% of children and young people had intakes below the LRNI in years 1 to 2 of the NDNS, and 29% a decade later in years 12 to 15 (2019 to 2023) [15]. Shortfalls of calcium and potassium appear to have increased over time. In the NDNS from 2008 to 2010, the percentage of children and young people (11 to 18 years) below the LRNI was 11% for calcium and

23% for potassium and by 2019-2023 this had increased to 17% and 32%, respectively [15].

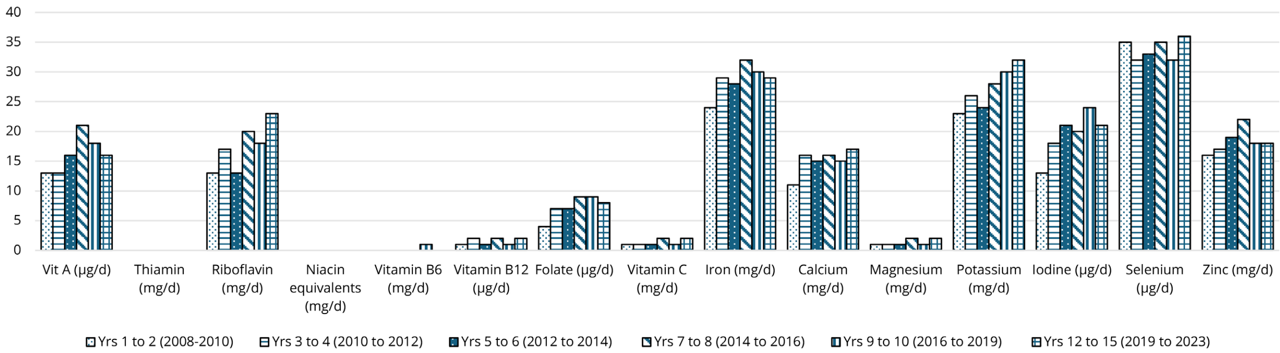

Figure 3. Percentage of children aged 11 to 18 years with vitamins & mineral intakes below the LRNI (from 2008 to 2023).

4.3. Adults 19 to 64 Years

As displayed in **Figure 4**, across adults aged 19- to 64-years there are pockets where intakes of certain vitamins and minerals have further declined over time. The percentage of adults with intakes of nutrients from food sources below the LRNI appears to have risen for riboflavin, folate (of particular concern amongst women of childbearing age), iron, calcium, potassium, iodine, selenium and zinc [15]. In 2008 to 2010, the percentage of adults below the LRNI (level below which deficiency may occur) for riboflavin, folate (women of childbearing age), iron, calcium, potassium, iodine, selenium and zinc was:

- 7% below the LRNI-riboflavin;
- 3% below the LRNI-folate;
- 11% below the LRNI-iron;
- 5% below the LRNI-calcium;
- 16% below the LRNI-potassium;
- 7% below the LRNI-iodine;
- 38% below the LRNI-selenium;
- 6% below the LRNI-zinc.

By 2019 to 2023, this had risen to:

- 15% below the LRNI-riboflavin;
- 10% below the LRNI-folate (amongst women of childbearing age);
- 19% below the LRNI-iron;
- 9% below the LRNI-calcium;
- 28% below the LRNI-potassium;
- 13% below the LRNI-iodine;
- 45% below the LRNI-selenium;
- 10% below the LRNI-zinc [15].

In women of childbearing age (16- to 49-years), the mean folate intakes were 251 µg/day in 2008-2010 and these were 219 µg/day in 2019 to 2023 [15]. Mean daily iron intakes for women aged 19 to 64 years were 9.8 mg/day in 2008 to 2010 and 8.6 mg/day in 2019 to 2023 [15].

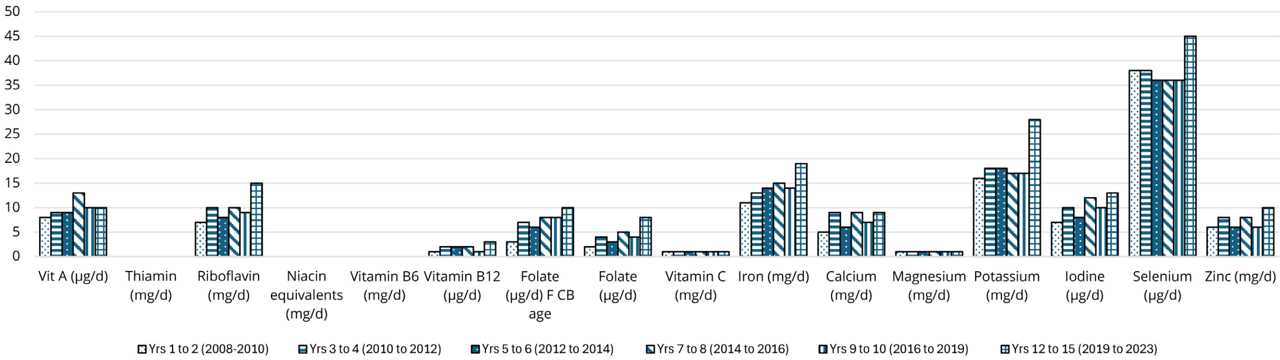

Figure 4. Percentage of adults aged 19 to 64 years with vitamins & mineral intakes below the LRNI (from 2008 to 2023).

4.4. 65 Years and Beyond

As demonstrated in Figure 5, data from the latest UK NDNS (2019 to 2023) shows that over time the percentage of adults below the LRNI for iron, calcium, potassium, selenium and zinc has increased since 2008 to 2010. In 2008 to 2010, amongst adults aged 65 - 74 years intakes below the LRNI for iron, calcium, potassium, selenium and zinc were:

- 0% below the LRNI-iron;
- 2% below the LRNI-calcium;
- 9% below the LRNI-potassium;
- 29% below the LRNI-selenium;
- 3% below the LRNI-zinc.

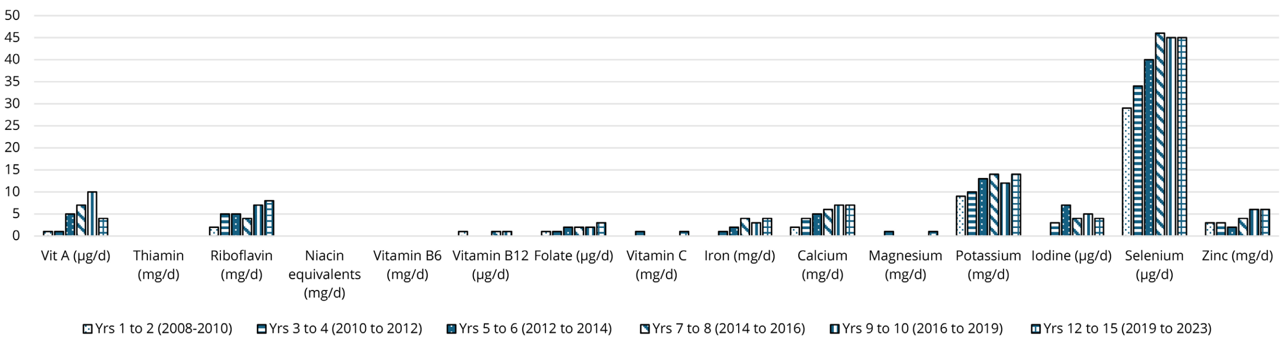

Figure 5. Percentage of adults aged 65 to 74 years with vitamins & mineral intakes below the LRNI (from 2008 to 2023).

These intakes below the LRNI increased by 2019-2023, respectively [15] rising to:

- 4% below the LRNI-iron;
- 7% below the LRNI-calcium;
- 14% below the LRNI-potassium;
- 45% below the LRNI-selenium;
- 6% below the LRNI-zinc.

Older women (aged 65- to 74-years) appeared to have particularly low selenium intakes—40% had intakes below the LRNI in 2008 to 2010, but 54% by 2019 to 2023 [15]. Seventeen percent of older males (65 to 74 years) had selenium intakes below the LRNI in 2008 to 2010 and 35% by 2019 to 2023 [15].

Interestingly, amongst older men aged 65- to 74-years, intakes of oily fish (data includes non-consumers) have declined too, from 19 g/day in 2008-2010 to 6 g/day in 2019 to 2023 [15]. Adults aged 75 years and older (**Figure 6**), vitamin and mineral intakes have fluctuated up and down somewhat between 2008 to 2010 and 2019 to 2023 [15]. As a result, there has been no clear dietary improvements.

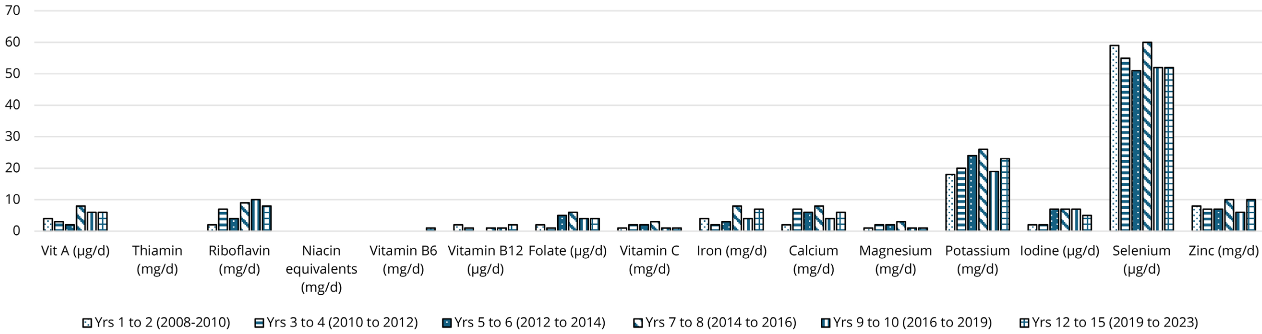

Figure 6. Percentage of adults aged 75 years+ with vitamins & mineral intakes below the LRNI (from 2008 to 2023).

5. Knowledge, Understanding and Barriers to Intake

A Perspectus Global Omnibus survey was completed by n = 1505 UK respondents [12]. Seventy-eight percent of the survey population were carnivorous, 6% were pescatarian and 5% were vegan. Over two-thirds (67%) reported that they sometimes or often think about which nutrients could be missing from their diet. On a day-to-day basis around one-third of consumers reported that vitamins C (31%) and D (27%) were the most important vitamins for health, with 36% detailing iron and 30% noting calcium as vital minerals too.

Figure 7 shows how important consumers feel certain nutrients are for health, with selenium, copper, and iodine regarded as being less important when it comes to wellbeing needs. More than 50% felt that they understood the role(s) or vitamin C, B vitamins (general), vitamin B12, vitamin D, folate/folic acid, calcium, iron, magnesium, and omega-3 fatty acids in the human body. Less than 50% clearly understood the role(s) of vitamin E, vitamin K, iodine (only 38%), copper (only 33%), riboflavin (only 32%), and selenium (only 31%) in the human body. Around three-quarters (73%) were concerned that they may not be getting all the nutrients that they needed from their diet. Around one-third (35% - 36%) had tried to consciously increase their vitamin C or D intakes, but less so for other nutrients, for example, only 5% and 4% had tried to deliberately increase their intakes of selenium and iodine/copper.

In terms of general insights, most people (58%) said they would try to improve their diet to be healthier, whilst only 21% would make improvements to avoid a specific health condition. Just under half (48%) felt that healthy eating was important throughout life. Similarly, 49% experienced tiredness as a common health and wellbeing problem. Forty-one percent, 34% and 30% reported low energy levels, sleeplessness, and low mood respectively, as affecting health and wellbeing. Only 15% were concerned about developing osteoporosis. In addition, twenty-two percent reported that they planned to take GLP-1 medications. Emerging research shows that GLP-1 medications have an impact on people's vitamin and mineral status, and as a result, consumers taking GLP-1 medications will not have all the essentials nutrients needed daily for their health and wellness needs.

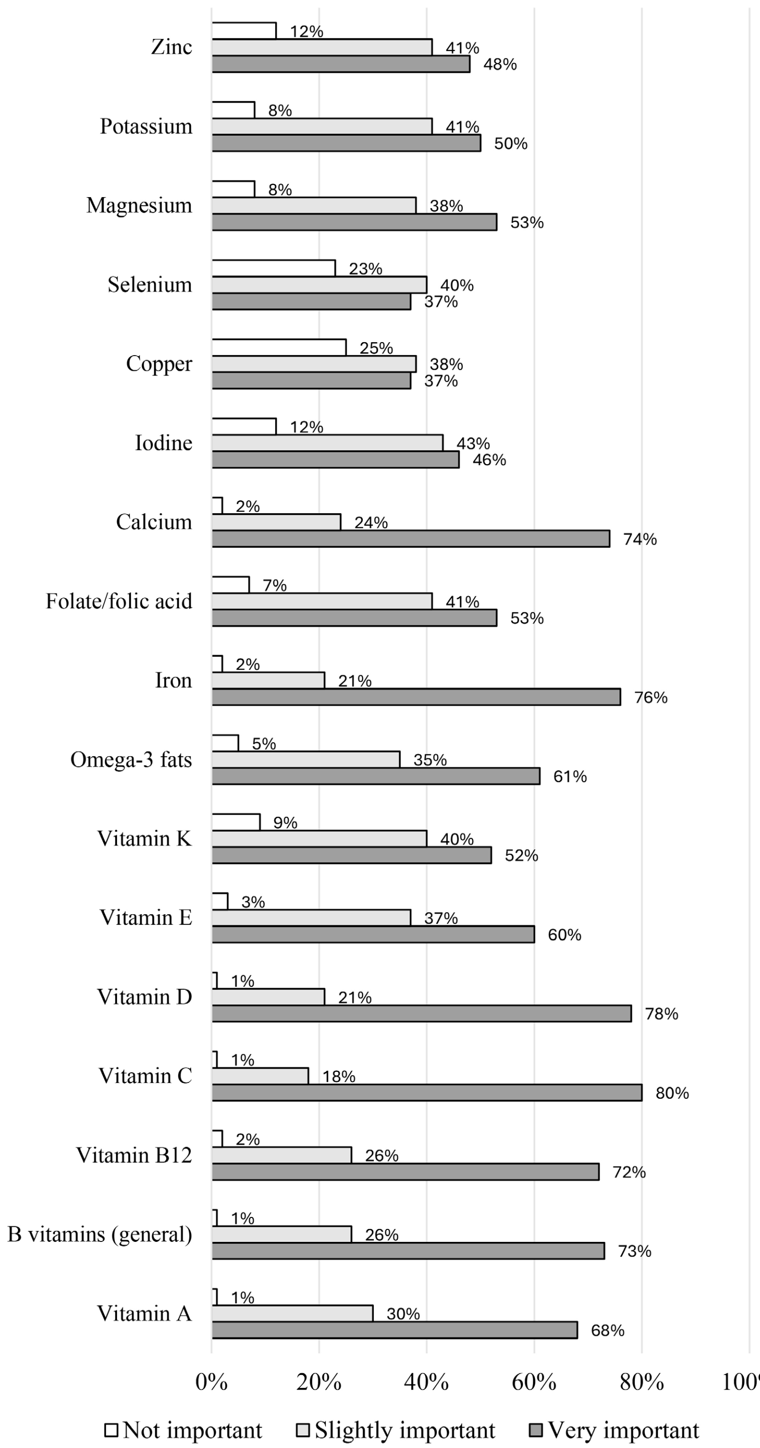

Figure 7. Thinking of the following nutrients, how important do you think they are for health? Perspectus survey data (n = 1505).

Regarding public health guidance, 61% made the most effort to eat 5-a-day fruit and vegetables. Ninety-three percent reported that their diet/food choices could be healthier. A third (34%) felt that healthy foods and ingredients were too expensive, and this acted as a barrier to healthier eating. In the last 5 years, 59% of consumers reported that busy lifestyles, time needed to spend cooking, and the inconvenience of preparing foods were obstacles to healthy eating compared with 5 years ago. Sixty-one percent reported that the "cost of living crisis" had affected their food choices to some extent or a great extent. Fifty percent would be most likely to review their diet if a healthcare professional told them to, or 41% would if they had a serious illness.

The majority would take advice from a general practitioner (62%), nutritionist/dietician (44%), a nurse (30%), or pharmacist (21%) for advice related to diet. Sixty-three percent reported sometimes or often being confused about what to eat for a healthy, nutritious diet. Seventy-one percent reported taking a multivitamin and multimineral supplement, 26% a daily vitamin D supplement, 24% a vitamin C supplement, 12% a calcium supplement, and 17% an omega-3 supplement. Around one-quarter (25%) said that they did not know which supplements to take.

6. Health Ramifications of Nutrient Shortfalls

6.1. Younger Children

Health ramifications of nutrient shortfalls can be far-reaching. For children aged 1.5 to 10 years, vitamin A, iron, iodine, and zinc shortfalls were most common (**Figure 1** and **Figure 2**). Vitamin A is important for the maintenance of epithelial cells (those forming protective layers lining organs, body cavities, and structures) and for the maintenance of healthy immune responses [22]. In the early years, mild to moderate iron deficiency anaemia may present itself as poor appetite, fatigue, lethargy, dizziness, irritability, and lassitude, while severe iron deficiency may present itself as shortness of breath, tachycardia, poor capillary refilling and diaphoresis (excessive sweating) [23]. If severe and prolonged, iron deficiency anaemia may lead to neurodevelopmental and cognitive defects that can become challenging to reverse [23]. Iodine shortfalls are also well recognised as a main driver of developmental impairment [24]. Zinc shortfalls, especially amongst young children, have been linked to growth retardation, cognitive impairment and cell-mediated immune dysfunction [25] [26].

6.2. Pre-Teen and Teens

For older children aged 11- to 18-years, vitamin A, riboflavin, folate, iron, calcium, potassium, iodine, selenium, and zinc shortfalls were apparent. A substantial proportion of young people had intakes of these nutrients below the LRNI (**Figure 3**). Other research has similarly found that intakes of vitamins A, D, folate, calcium, iron, zinc and potassium in teenagers are generally low compared to advised recommendations and that there is little risk of excessive micronutrient intakes based on present dietary patterns [27]. Young people are growing up during a time of unprecedented change when it comes to food environments [28]. Nutrition is fundamentally important during this life-stage, which aligns with puberty, with implications for adult muscle, height, fat mass accrual and non-communicable disease risk in later life [28]. Before 18 years of age, around 95% of the skeletal size and bone and muscle mass is acquired making this a crucial time to build a strong musculoskeletal system [29]. Reductions in potassium intakes coupled with high sodium intakes may also contribute to low-grade metabolic acidosis, which can have a bone-wasting effect [30]. This is particularly concerning given that one-third (32%) of UK 11- to 18-year-olds had potassium intakes below the LRNI [15]. With teenage girls, vitamin A and iron shortfalls may increase the risk of menorrhagia (heavy menstrual bleeding) and poor growth, including that of the pelvis which can cause cephalopelvic disproportion [31]. Iodine is a non-metallic trace element mostly concentrated in the thyroid that plays a key role in thyroid hormonogenesis and is important for every phase of life, including adolescence [32]. Regarding selenium, some research has found a non-linear inverse U-shaped association between selenium status and bone mineral density in children and teens, indicating that insufficient intakes could have ramifications for bone health [33]. Zinc is an essential trace element and plays key roles in cell functions, including the metabolism of neurotransmitters, melatonin, and prostaglandins [34]. Shortfalls of zinc (and iron) have been linked to poor memory, impulsiveness, inattentiveness, fussy appetite, mood changes and altered levels related to the aggravation and progression of ADHD [34].

6.3. Adults Aged 19 to 64 Years

For adults aged 19- to 64-years, vitamin A, riboflavin, folate, iron, calcium, potassium, iodine, selenium and zinc were the most common nutritional shortfalls (**Figure 4**). Vitamin A, D and zinc are important nutrients for a well-functioning immune system, so shortfalls could have wider implications for immune health [35]. The World Health Organisation and most countries advise a healthy diet and folic acid supplementation of 400 μg/d periconceptionally for neural tube defect prevention [36]. Despite this, in the UK 10% of women have folate intakes below the LRNI and only 19% of women of childbearing age report taking supplements [15]. Over one-third (34%) women aged 19 - 64 years had iron intakes under the LRNI [15]. Iron dietary shortfalls can lead to iron deficiency and over time, iron-deficiency anaemia which can be asymptomatic or present itself as tiredness, fatigue, light-headedness, challenges concentrating, depression, restless leg syndrome and exercise-intolerance [37]. Potassium from the diet is associated with blood pressure reduction in adults, which in turn influences the risk of coronary heart disease and stroke [38]. There is also growing evidence that suitable dietary potassium intakes can prevent age-related bone loss and reduce the risk of kidney stones [38]. Selenium is integrated into selenoproteins and is known to have anti-oxidant and anti-inflammatory effects, reinforce fertility, immune function, and prevent cognitive decline with health effects tending to follow a U-shaped curve in relation to selenium status indicating that a balance intake is most beneficial [39]. In the UK, 18% of women in the latest NDNS (2019 to 2023) had iodine intakes below the LRNI which is an increase from 9% in 2008 to 2010 [15]. Iodine is a mineral that is particularly important for brain development in children and adults, especially neurodevelopment, which makes it a particularly important nutrient across the childbearing years and pregnancy [40]. Indeed, iodine deficiency has been described as a leading cause of preventable impaired mental function worldwide [41]. In the human body, most zinc is found in bone and skeletal muscle and 70% is bound to albumin in the circulation [42]. In particular, zinc plays a key role in bone tissue's normal development and is involved in the synthesis of the collagen matrix, bone turnover, and mineralization [43].

6.4. Older Adults

With adults aged 65 years and beyond, selenium and potassium deficits were particularly common alongside some vitamin A, riboflavin, calcium, iodine and zinc shortfalls (**Figure 5** and **Figure 6**). Selenium is an essential trace element with an umbrella review of meta-analyses concluding that selenium intakes may be associated with a reduced risk of all-cause mortality, depression, digestive system cancers, and Keshan disease (a condition that affects heart muscle) [44]. As previously mentioned selenium is well recognised as an important bone nutrient and suboptimal intakes may be associated with reduced bone mineral density and increased risk of hip fractures [45]. For those adults in their ageing years, a range of minerals have been found to be important for the prevention and treatment of sarcopenia (low muscle strength, mass, and function) which includes selenium alongside magnesium and calcium [46]. Adequate intakes of potassium appear to be important for blood pressure regulation, with meta-analytical findings suggesting that an adequate potassium intake is vital to achieve a lower blood pressure level, particularly for those already with hypertension [47] [48]. Other meta-analytical research found that higher potassium intakes were associated with a 24% reduced risk of stroke [48]. Subsequently, shortfalls of these minerals could have wider implications for bone health, blood pressure, and stroke risk.

7. Discussion

The present review of latest UK NDNS data shows that certain vitamins, but particularly mineral shortfalls, remain to be common across various population groups from early childhood to older age. In addition, the real-world research results also demonstrate that due to nutrient misunderstandings and a lack of awareness, the health and wellness roles of vitamins and minerals such as folate/folic acid, iodine, selenium, and copper continue to remain overlooked by the UK population, leading to nutrient gaps in the daily diet. Across the population groups, young people (especially those aged 11 to 18 years) and females/women/ those of childbearing age appear to be most vulnerable to certain micronutrient shortfalls. Vitamins and minerals are essential to humans as they facilitate energy-yielding metabolism, DNA synthesis, oxygen transport, and neuronal functions which translates into important physiological processes underpinning muscular function, brain function and cognition [49]. They are important across the life course, and shortfalls could increase the risk and severity of infections with vitamins A, C, D, E, B2, B6, and B12, folic acid, iron, selenium, and zinc being particularly relevant to immunocompetence [50].

Minerals such as selenium and magnesium are important for the prevention and treatment of sarcopenia, particularly in older age [51]. Conditions such as sarcopenia can have high economic, social, and personal costs which can be implicated with a higher risk of frailty, functional decline, hospitalization and death [52]. Declines in intakes of nutrients such as iodine are apparent in the UK but also in other countries [15] [53]. For example, in the US, declines in iodine intake across women has been attributed to declines in milk consumption [53].

Electrolyte minerals, which include potassium, magnesium and calcium are fundamental for the wellbeing of the cardiovascular system [54]. Alongside calcium and vitamin D, magnesium, potassium, vitamin C and vitamin K are also important for bone health [55], yet several of these are lacking from UK diets. It has been estimated that around 7.6 million people in the UK have cardiovascular disease and about 25% of deaths in people under the age of 75 years are attributed to cardiovascular disease. In the UK, direct medical costs due to fragility fractures were around £1.8 billion in 2000 with a potential projection to £3.3 billion by 2025, with most of these costs being for hip fracture care [56]. It has been estimated further that by 2030, fragility fractures could rise further to £5.89 billion [57]. It is well recognised that the achievement of optimal peak bone density in adolescence from dairy foods, fortified foods, or supplements alongside weight-bearing exercise may help osteoporosis prevention [58] [59]. Potentially, observed shortfalls in calcium, potassium, and selenium could exacerbate the risk of failing to achieve this.

B vitamins are important for optimal brain physiological and neurological functioning [60]. Fish is one of the most predominant dietary sources of omega-3 PUFA with higher intakes being linked to reduced risk of depression, adult psychiatric and neurodegenerative illnesses, acute coronary syndrome, and protection against cardiovascular morbidity and mortality and liver cancer whilst reinforcing childhood learning and behaviour [61]-[63]. In the latest UK NDNS, riboflavin was lacking across those aged 11 to 64 years. Oily fish consumption was under-consumed among all population groups, and children aged 11- to 18-years where consumption levels appear to have declined since 2008 [11] [15]. A previous secondary analysis of the UK NDNS (years 2008-2016) also found that younger people and women of childbearing age were at particular risk of oily fish and omega-3 shortfalls [64]. This is concerning given that a further £117.9 billion of the UK economy is spent on mental health problems, which is approximately 5% of the UK's GDP [65]. While the cause-and-effect relationships can be challenging to determine, the observed latest NDNS shortfalls in oily fish consumption could be contributing to some of these mentioned health ramifications.

Nearly half (49%) of girls aged 11- to 18-years had iron intakes below the LRNI, and 34% of women aged 19 - 64 years [15]. This can have extended health implications. For example, amongst university students, recent research showed that across women there were associations between iron intake, serum ferritin levels and total Intelligence Quotient, with lower iron intakes being associated with reduced intellectual ability [66]. In Sweden, a study exploring dietary patterns in teenage girls revealed that plant-based diets could be contributing to higher prevalence rates of iron deficiency—vegetarians/vegans (69 and 49%) were significantly more likely to be iron deficient compared to omnivores (31%) [67].

There could be many plausible explanations for such shortfalls. The EAT-Lancet planetary plate limits the intake of highly processed foods and animal source foods globally. However, due to concerns for vitamin B12, calcium, iron and zinc intakes, some modifications to the original planetary health diet have been made which include raising the amount of animal-derived foods and reducing foods high in phytate which could reduce the bioavailability of some of these nutrients [68]. Confusions over such dietary transitions and food movements could be impacting on present micronutrient intakes, as observed in Swedish adolescent girls in the case of iron [67]. The expense of food could be another explanation. UK research calculating the price (£/100 kcal) for food items showed that:

- bread, rice, potatoes, and pasta were cheapest (£0.12/100 kcal)
- less healthy food cost around £0.33/100 kcal while healthier food is priced at £0.81/100 kcal
- fruit and vegetables were the most expensive (£1.01/100 kcal) [69].

Social media engagement could also theoretically affect food choices in young adults by influencing body image perceptions [70]. Data from the 2008/9-2018/19 NDNS shows that adolescents living in North England from lower socioeconomic backgrounds, were most likely to have higher intakes of ultra-processed foods which could impact on micronutrient intakes [71]. Perpetuation of misinformation can also confuse and diminish support for evidence-based science food and nutrition policies [6]. Changes in dietary assessment methods within the UK NDNS (please refer to limitations section) may also have contributed to some lower nutrient intakes. It should, however, be recognised that low intake or biomarker values indicate potential, not clinically proven deficiency [72]. The monitoring of micronutrient levels is important for metabolic, mitochondrial, immune, and inflammatory functions [72]. Finally, moving forward, it is imperative to consider the nutrient-density of foods within public health guidance. There has been much focus on plant-based diets and ultra-processed foods recently, and this fundamental element has been overlooked. There is also scope to better utilise health claims that relate to the specified vitamin and mineral gaps, so that health associations can be better made and understood by public sectors.

8. Limitations

Whilst the UK NDNS measures total fat intake and intakes of n-3 PUFA, it does not specifically measure eicosapentaenoic acid (EPA) nor docosahexaenoic acid (DHA) intakes. Also, while total iron intake is derived, heme and non-heme iron intakes, are not derived and bioavailability of nutrients such as iron is not derived. Probiotic intakes are also not recorded, and where there is some data on supplement use, it may not fully capture the types and dosages of all the specific types of supplements.

Within the NDNS, there was a small shortfall in recalls completed on a Saturday and Sunday which may be attributed to some participants being reluctant to complete recalls during weekends [11]. Around 10% of recalls also had at least 1 food reported by the individual as missing from the diet and nutrition analysis software and 31% of recalls were completed in less than 10 minutes [11]. Bias from over- and underreporting should also be considered from dietary assessment methods [73]. Finally, while the UK NDNS may infer trends through dietary data, it does not directly track or assess health outcomes such as obesity, heart disease, or diabetes and it is a cross-sectional survey so does not determine cause-and-effect. It should be considered that data collection was suspended between March and October 2020 due to the COVID pandemic, but any recordings just before or after this period may not have been representative of standard diets. Equally, the transition to the web-based automated Intake-24 software from the traditional paper-based 4-day food diaries may have potentially affected reported food intakes.

In the U.S., it is being advised that vitamin K and magnesium Dietary Reference Intakes (DRIs) should be updated and DRIs should be compiled for EPA, DHA and lutein [74]. In the UK, Dietary Reference Values were published in 1991 (more than three decades ago) [14] and whilst Government Dietary Recommendations were republished in 2016, many of the 1991 data values remain to be used, thus there is a need to consider a modern update to UK dietary recommendations [75]. Subsequently, there is a need to update these and consider new nutrients of interest such as choline, EPA, and DHA in the future.

9. Conclusions

The present review and analysis of the latest UK NDNS data shows that vitamin, mineral and omega-3 shortfalls continue to exist. In 2016, vitamin D, calcium, iron and iodine shortfalls were most common and it was predicted that these micronutrients of concern would remain similar 10 years on [9]. That prediction is largely correct. Today, we are continuing to see a demise in public health nutrition, with poor consumption levels of vitamin D and calcium (especially for those 11 to 18 years), iron, folate, and iodine dietary levels (particularly amongst girls and women), alongside selenium and potassium intakes (ages 11 years+) and low oily fish consumption. For the future, if nutrient levels continue to be poor and below the recommended levels, the future health and wellness of the nation could be at risk.

It should be considered that inadequate intakes of key nutrients such as folate/folic acid, iron, and iodine among women of childbearing years can have extended implications across the next generation, for example, potentially affecting neurodevelopment [41] [76]. Given the ongoing insufficient intakes for bone nutrients such as vitamin D and calcium, osteomalacia (bone softening), osteoporosis, and fragility fractures, conditions traditionally associated with old age may begin to be seen more frequently in younger generations if vitamin D metabolism is disrupted as a result [77]. It should also be considered that low levels of oily fish consumption in the UK and subsequently low habitual omega-3 intakes could have wider implications for conditions such as depression, attention deficit hyperactivity disorder, Alzheimer's disease, and the prevention of cognitive decline [78].

It is important to maintain adequate vitamin intakes, and especially mineral intakes, through a balanced diet and guided supplementation. In instances where there are large gaps between habitual dietary intakes and recommendations (iron in girls, folate in women of childbearing age, oily fish/omega-3 intakes), supplementation-specific strategies may be advised. Public health interventions and education about dietary sources of specific vitamins and minerals are now central to ensuring optimal health and wellbeing across populations, especially young girls. If such nutrition policies are not implemented, along with fairer food costs for healthy foods, the NHS is likely to experience greater strains, resulting in higher costs from treating the health consequences of poor-quality diets [79]. Optimising nutrient intakes through dietary sources or bridging dietary gaps with a multivitamin and multimineral supplement, as well as an omega-3/fish oil supplement may help to augment health and wellbeing and reduce UK healthcare costs that could in part be attributed to dietary micronutrient and omega-3 shortfalls.

Ethics Statement

This was secondary research and did not require ethical approval.

Data Availability

All data used in this study are publicly available and can be accessed from the sources cited in the manuscript.

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Conflicts of Interest

The review was written by the authors alone and HSIS had no role in writing the publication. The authors declare no competing interests.

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