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Dietary surveys indicate vitamin intakes below recommendations are common in representative Western countries

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Abstract

Vitamins play a crucial role in health, but modern lifestyles may lead to suboptimal intakes even in affluent countries. The aim of the present study is to review vitamin intakes in Germany, the UK, The Netherlands and the USA and to compare them with respective national recommendations. Data on adults from the most recently published national dietary intake surveys for the first three countries and data for adults from the US National Health and Nutrition Examination Survey from 2003 to 2008 for the USA were used as a basis for the analysis. The proportions of the populations with intakes below recommendations were categorised as <5, 5–25, >25–50, >50–75 and >75 % for each vitamin. The data generated are presented in a 'traffic light display', using colours from green to red to indicate degrees of sufficiency. The trends found were compared with the results from the European Nutrition and Health Report 2009, even though in that report, only information on mean intakes in the different countries was available. We showed that, although inter-country differences exist, intakes of several vitamins are below recommendations in a significant part of the population in all these countries. The most critical vitamin appears to be vitamin D and the least critical niacin. The variation between the countries is most probably due to differences in recommendations, levels of fortification and local dietary habits. We show that a gap exists between vitamin intakes and requirements for a significant proportion of the population, even though diverse foods are available. Ways to correct this gap need to be investigated.

Key words: Vitamin intakes: Nutrition: Dietary surveys

The clinical features of overt vitamin deficiency and its relationship to dietary components have been recognised for centuries (e.g. vitamin A and blindness), but it was only in 1912 that Casimir Funk introduced the term 'vitamine' for substances, a deficiency of which would result in beriberi, scurvy and pellagra[1]. Since then researchers have discovered the importance of vitamins for many biological functions at the molecular and cellular level, and today it is recognised that vitamins have an important role to play in promoting human health[2]. Consequently, daily intake recommendations for the thirteen vitamins have been established in many countries. Although the concept of intake recommendations is widely recognised, national dietary reference values vary considerably in terminology and value[3–6]. However, the underlying concept of these dietary intake recommendations is similar: previously defined to prevent overt deficiencies, nowadays, dietary reference intakes aim to define the intake at which health, including the reduction of chronic diet-related diseases, is optimal for the majority of individuals (generally 97·5 %) of a given population or group. Despite the existence of these intake recommendations, it is not fully clear how good the nutritional status in Western populations is. On the one hand, a variety of different kinds of foods is available and is accessible for everybody. On the other hand, changed lifestyles, reduced physical activity, indoor living and an increase in fast and convenience food with a low micronutrient density may have an impact on the quality of a person's daily diet and hence on their nutritional status[7,8]. National surveys try to answer this question and can be seen as a snapshot of the populations' health and nutritional status. To further investigate and compare the current vitamin status in industrialised countries, large population-based surveys from Germany, the UK, The Netherlands and the USA were selected. The purpose of the present study was to assess and compare the dietary intakes as published in these surveys and to present the vitamin status relative to the respective national dietary reference intakes in a visual way. We chose a 'traffic light display', as it allows for a comparison of vitamin

Abbreviations: IOM, Institute of Medicine; NHANES, US National Health and Nutrition Examination Survey.

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status in different populations taking into account local and national dietary habits and cultural specifics of countries and presents a tool to assess the pattern of the vitamin status in a visual way.

Experimental methods

Included cohorts and dietary surveys

The German Nutritional Intake Study (Nationale Verzehrsstudie II) 2008[9], the US National Health and Nutrition Examination Survey (NHANES) from 2003 to 2008[10–12], the British National Diet and Nutrition Survey 2003[13] and the Dutch National Food Consumption Survey 2007–10[14] were selected for the assessment. These surveys were chosen as they provide a higher level of detail than most other surveys published in industrialised countries. The three European surveys all published either the percentage of a given population below recommendations or the 5th, 25th, 50th and 75th percentiles for vitamin intakes, which is the information the 'traffic light display' is based on. The NHANES is unique as the complete datasets are publicly available for download and analysis, allowing the calculation of the required statistics.

The study details and dietary assessment methods for the four nutritional surveys have been described in detail elsewhere[9,10,13,14]. For the German, British and Dutch surveys, data as published in the respective report were used. For the US data, we employed the Food and Nutrient Database for Dietary Studies (version 2.0 for the NHANES 2003–4, version 3.0 for 2005–6 and version 4.0 for 2007–8) to determine the vitamin content of foods collected during the NHANES. Intake data from the two 24 h recalls were used to estimate usual intake and percentiles of intake from foods using the National Cancer Institute method[15]. Intakes for males and females in the 19–50-year age range were selected to achieve matching age groups for adults from Germany, the USA and The Netherlands. For the UK, only the 19–49-year age group was available and therefore used. This age group was also chosen as for each vitamin, country and sex, with a few exceptions, it is covered by a single recommendation. The vitamins listed in Table 1 were selected, as information was available for all surveys with the exception of niacin for the Dutch National Food Consumption Survey. To maximise comparability between the surveys, the vitamin intakes from dietary sources and, where available, fortification excluding dietary supplements were used. For the Dutch and British surveys, where estimates for intakes from the diet with fortification alone as well as total dietary intake were available, the impact of vitamin supplements on categorisation according to the 'traffic light display' was evaluated.

Traffic light display

To take into account differences in habits and population characteristics, country-specific recommendations estimated to cover the needs of 97·5 % of a specific age group and sex were used (Table 1)[16–26]. The population at risk of inadequate vitamin intakes was defined as the proportion with intakes below these recommendations. The vitamin intake data from the surveys were grouped into <5, 5–25, >25–50, >50–75 and >75 % of a population having inadequate intakes. Based on these adequacy-of-intake groups, the data are presented in a 'traffic light display', using colours from green for the <5 % group (very good status) to red for the >75 % group (poor status) (Fig. 1).

Skewness of intake distribution

It is frequently assumed that vitamin intakes are normally distributed and that, consequently, the mean intake represents the intake met by 50 % of the population. Therefore, we calculated the relative difference between the mean and the median for each vitamin from the British National Diet and Nutrition Survey, as in that survey both values were available. The magnitude of the difference between these two values was used as an indicator for skewness of intake distribution.

Table 1. Recommended intakes for men and women in the USA[20–23], Germany[19,25], the UK[24] and The Netherlands[16–18,26] for the age group from 19 to 50 years

		USA		Germany		UK		The Netherlands	
Vitamins	Unit/d	Men	Women	Men	Women	Men	Women	Men	Women
Vitamin A	mg RE	0·9	0·7	1·0	0·8	0·7	0·6	0·9	0·7
Vitamin D	μg	15	15	20	20	NA	NA	2·5*†	2·5*†
Vitamin E	mg TE	15	15	14–15*	12*	NA	NA	0·67‡	0·67‡
Thiamin	mg	1·2	1·1	1·2–1·3	1·0	1·0	0·8	1·1	1·1
Riboflavin	mg	1·3	1·1	1·4–1·5	1·2	1·3	1·1	1·5	1·5
Niacin	mg	16	14	16–17	13	17	13	17	17
Vitamin B_6	mg	1·3	1·3	1·5	1·2	1·4	1·2	1·5	1·5
Vitamin B_{12}	μg	2·4	2·4	3·0	3·0	1·5	1·5	2·8	2·8
Folic acid	mg	400	400	400	400	200	200	300	300
Vitamin C	mg	90	75	100	100	40	40	70	70

RE, retinol equivalent; NA, not available; TE, tocopherol equivalent.
* Average nutrient requirement/approximation.
† 5 μg/d without exposure to sun.
‡ mg TE/g PUFA.

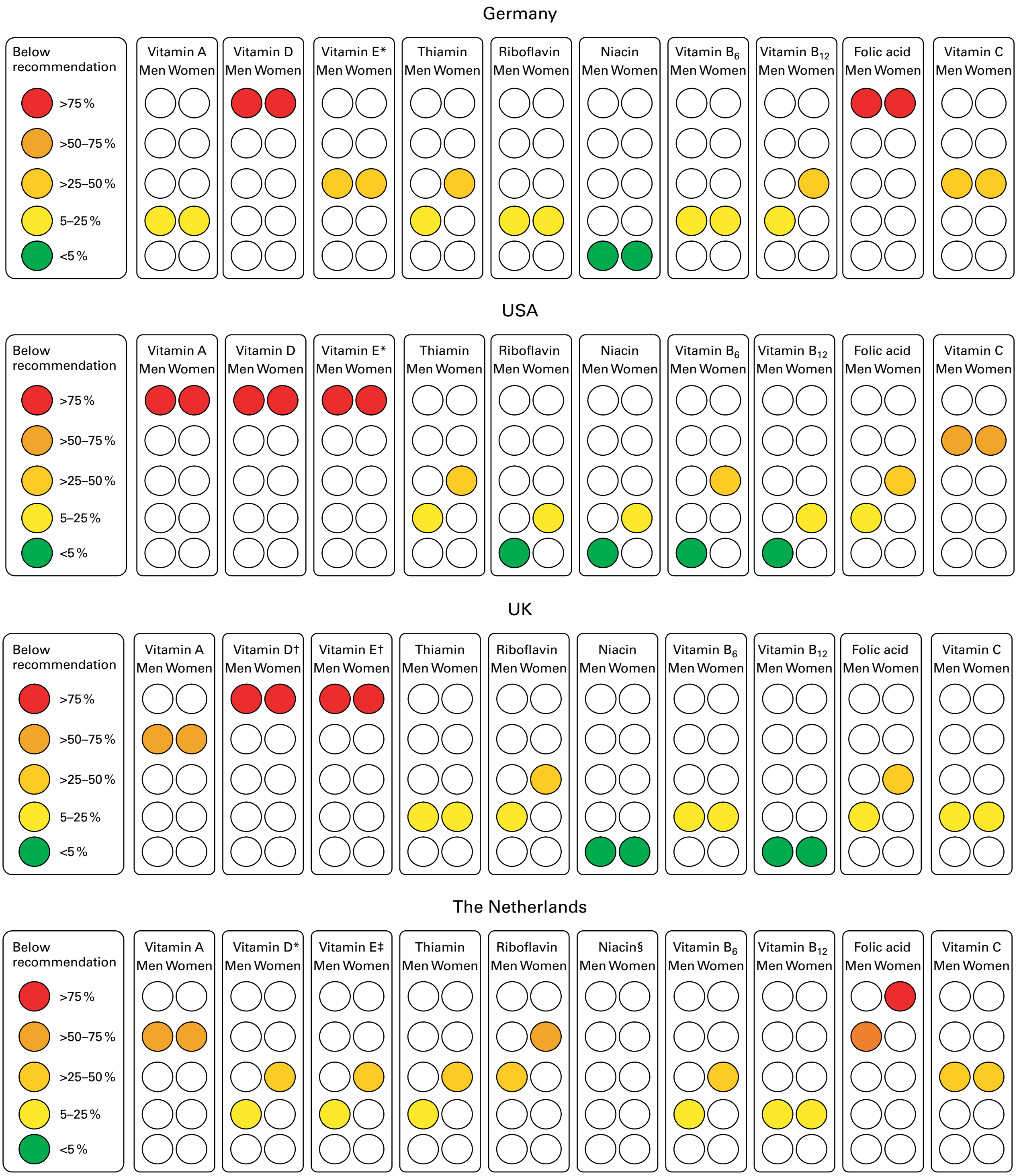

Fig. 1. Population with intakes below the specific recommended reference value for the country[16–26]. The level of recommendation covering the needs of 97·5 % of the population was used where it existed. * Average nutrient requirement/approximation. † No references exist, therefore, the Institute of medicine reference was used. ‡ > 25–50 % for men aged 19–30 years. § Data not available.

Results

The Nationale Verzehrsstudie sample contained 3270 men and 4176 women, the British National Diet and Nutrition Survey 580 men and 632 women and the Dutch National Food Consumption Survey 704 men and 698 women in the relevant age group. For the NHANES, data from the cycles 2003–4, 2005–6 and 2007–8 were combined, resulting in a dataset of 3944 men and 3641 women. The percentage of a population below the recommended intake levels for men and women in the four countries assessed according to the 'traffic light display' is displayed in Fig. 1. The current recommended intakes of the respective countries are met in more than 95 % of the population in Germany for niacin and in the UK for niacin and vitamin B_{12}. In the USA, more than 95 % of men meet the recommendations for riboflavin, niacin, vitamin B_6 and B_{12}. Conversely, more than 75 % of the population do not receive recommended intakes of vitamin D and folate in Germany, vitamins A, D and E in the USA, vitamins D and E in the UK and folate in women in The Netherlands. The intakes of the remaining vitamins show varying degrees of inadequacy within and between the different countries. The impact of vitamin supplements on the categorisation of vitamin intakes according to the 'traffic light display' is summarised in Table 2. The relative difference between the mean and the median is between 1·6 and 25·3 % and for all vitamins analysed, the median is lower than the mean, indicating a deviation from normality for the intake distribution (Table 3).

Discussion

To assess the nutritional status of a nation is a challenge, and large-scale dietary intake surveys, albeit far from ideal, are considered to provide the most accurate data on populations currently available. Based on studies from Germany, the USA, the UK and The Netherlands, the percentage of the population not meeting the recommended intakes was displayed according to the 'traffic light display' to provide a visual profile of the vitamin status. This shows that, for an appreciable number of vitamins, more than three-quarters of the population do not achieve the recommended intakes. The fat-soluble vitamins and folate show the most pronounced inter-country variation. This is most probably due to differences in national recommendations, local dietary habits and fortification programmes. The Dutch recommendations propose to use 2·5 μg/d vitamin D in general and 5 μg/d for people without exposure to sun. Using the higher levels,

Table 2. Change in categorisation according to the 'traffic light display' if total intake including supplements is used and the estimated average requirements (EAR) is used as a cut-off point for adequacy of vitamin intake*

	Total intake including vitamin supplements				EAR cut-off	
	UK		The Netherlands		USA	
	Men	Women	Men	Women	Men	Women
Vitamin A	0	0	+1†	+1†	+1	+1
Vitamin D	0	0	0	0	0	0
Vitamin E	0	0	0	+1†	0	0
Thiamin	0	0	0	0	+1	+1
Riboflavin	0	0	+1	+1	0	+1
Niacin	0	0	NA	NA	0	+1
Vitamin B_6	0	0	0	+1	0	+1
Vitamin B_{12}	0	0	0	0	0	0
Folate	0	0	+1†	+1	+1	+1
Vitamin C	0	0	+1	+1	+1	+1

NA, not available.

* 0: no difference in categorisation, +1: prevalence of inadequate intake for the vitamin is one category lower if the contribution of vitamin supplements is included or if the EAR is used as a cut-off point.

† Difference only exists for the age group 31–50 years, but not for 19–30 years.

which are still well below the Germany, Austria and Switzerland (DACH) and Institute of Medicine (IOM) levels, more than 75 % of the Dutch adults would be categorised as having inadequate intakes. The DACH very recently increased their recommendations from 5 to 20 μg vitamin D/d with the rationale that these amounts are needed to achieve optimal 25-hydroxyvitamin D serum concentrations[25]. For vitamin E, the authors of the Dutch National Food Consumption Survey propose to use the IOM recommendations as the Dutch reference value has not been reviewed since 1989[14]. This would shift the level of inadequacy from 25 to 50 % for men and >75 % for women.

Inadequate intake prevalence and deficiency for folate is common in the European countries, but less so in the USA[5,27]. The high prevalence of inadequate intakes in the UK is masked by significantly lower recommendations (Table 1). The IOM recommendation for women of childbearing age is 400 μg/d of folic acid, as congenital malformations occur before most women know they are pregnant. Periconceptional folic acid supplementation has been shown to reduce the incidence of neural tube defects by 20–60 %[28–31]. In Europe, the mean intakes for women are less than 300 μg/d[32] and approximately 4500 babies or fetuses are affected by neural tube defects every year[33]. The incidence of neural tube defects in Germany is even higher still[29], and although two-thirds of pregnancies are reportedly planned, only about 4 % use an adequate prophylaxis[34]. Fortification increased the average woman's intake by 100 μg/d in the USA, and it has been reported that countries with mandatory folic acid fortification achieved a significant decrease in the prevalence of neural tube defects[35–38]. The hypothesis that very high folic acid intake might promote the growth of pre-neoplastic lesions has not been proven by consistent study findings. In addition, the masking of pernicious anaemia, which has concerned people, has not been observed in countries with mandatory folate fortification[39].

Germany is at the upper and the USA at the lower end of intakes for total vitamin A and β-carotene compared with other western countries[32]. The differences are partially due to the conversion factor of 1:12 used for β-carotene in the USA[20] and 1:6 used in Germany, The Netherlands and the UK[9,13,14]. This is due to different interpretations of the evidence for the relative absorption of provitamin A and its conversion by β-carotene mono-oxygenase[19,20,24]. There are no official recommendations for β-carotene intakes, but 2–4 and 3–6 mg/d were proposed as advisable by the Nationale Verzehrsstudie II and IOM, respectively[9,21]. Given the small contribution of preformed retinol even in affluent countries, levels of 7 mg/d have been suggested elsewhere[40]. While a significant proportion of German adults have β-carotene intakes in the range of these proposed recommendations[9], in the USA, most people are even below the lowest level of 2 mg/d (data not shown). This highlights the importance of the contribution of β-carotene to the overall vitamin A status. The situation in the UK is similar to the USA[13], while in the Dutch survey, information on β-carotene intakes was not available[14]. As only a small proportion of vitamin A is taken up as preformed retinol, even individuals at the high end of intakes

Table 3. Difference between mean and median intake in the British National Diet and Nutrition Survey[13]

		Men*			Women*		
Vitamins	Unit/d	Mean	Median	Δ (%)†	Mean	Median	Δ (%)†
Vitamin A	mg RE	809·1	604·2	25·3	611·5	521·4	14·7
Vitamin D	μg	3·5	3·1	11·4	2·6	2·1	19·2
Vitamin E	mg TE	10·5	9·9	5·7	8·0	7·5	6·2
Thiamin	mg	1·97	1·77	10·1	1·52	1·38	9·2
Riboflavin	mg	2·06	1·92	6·8	1·54	1·46	5·2
Niacin	mg	44·8	44·0	1·8	30·3	29·7	2·0
Vitamin B_6	mg	2·9	2·7	6·9	2·0	1·9	5·0
Vitamin B_{12}	μg	6·1	5·3	12·7	4·4	4·0	9·1
Folic acid	mg	336·3	316·9	5·8	243·4	239·4	1·6
Vitamin C	mg	78·6	64·7	17·7	75·5	62·9	16·7

* Aged 19–49 years.
† Difference between the mean and the median as a proportion of mean intake.

in Germany are below the upper intake still regarded as safe by the IOM[9,20]. A similar conclusion was reached by an evaluation of retinol intakes in adults from food and, where information was available, fortification and supplementation in various European countries[41].

Vitamin intakes are comparable in other European countries as reported in the European Nutrition and Health Report 2009[32]. However, that report only compares mean intakes with the respective RDA, an approach thought to underestimate the number of individuals with low intakes[42]. Still, the majority of the countries do not reach even this low threshold for a number of vitamins. The comparison of mean and median from the UK survey shows that the intakes are not normally distributed as is often assumed, resulting in a further underestimation of the problem (Table 3). One limitation of the present study is that the cut-offs used to define adequacy could not be chosen freely, but according to availability for all four surveys. While the US and Dutch recommendations define cut-offs for 50 % (i.e. estimated average requirements) and 97·5 % of the population (i.e. RDA), the former is not stated in the British and DACH recommendations. The IOM recommends the use of estimated average requirements as a basis to calculate the proportion of a population with inadequate vitamin intakes according to the cut-point method[42,43]. When this technique combined with different cut-offs was compared with more comprehensive analyses, the estimated average requirement was found to give the best estimate of the prevalence of inadequate intake, while the RDA tended to overestimate it[44]. However, categorising the NHANES data using both cut-offs showed that the difference is at most one category (Table 2). As the ‘traffic light display’ aims at profiling the vitamin status of countries and to highlight areas of concern, the message remains the same with either cut-off, and consequently, we used the one that maximised comparability between the countries.

Except for the NHANES, we had no access to raw data from the surveys and depended on previously published information. The included nutritional surveys were conducted with different study designs and methodologies, which are likely to influence the comparability of results. The analysis is limited to sex and age as data on socio-economic status or cultural habits were not available for all surveys. Furthermore, information on food availability between the countries could not be taken into account. Finally, it should be mentioned that the initial data came from the results of dietary questionnaires. In cases of data validity, it is recommended to have additional measurements of dietary intake, for example nutritional biomarker measurements. Nutritional biomarkers can have less error than dietary data, as they take into account, for example, combination of foods eaten together, food storage and preparation that influence nutrient content and absorption, and inter-individual differences in metabolism[45].

We decided to evaluate intake data excluding dietary supplements to assess the quality of the diet. Yet, the use of vitamin supplements has increased over the last decades[46] and consequently its effect has to be considered. While dietary supplements decreased the number of individuals not achieving the recommended intakes in the USA, a significant proportion still had insufficient intakes for vitamins A, C, D, E and K[47]. Supplement use in Europe is less common and, in addition, there is a strong north-to-south gradient, with 40 and 5 % users, respectively[5]. This corresponds with the range of 25–50 % reported in the three European surveys evaluated. Interestingly, re-categorising the intake data with supplements had no noticeable impact on the ‘traffic light display’ score for the UK data, but showed a slight shift towards lower prevalence for the Dutch survey (Table 2). The German report did not include the impact of the supplements on total intake[9].

Besides the ones used in the present study, most surveys do not publish sufficiently detailed data to allow evaluation of vitamin intake based on the cut-point method recommended by the IOM[42]. Therefore, a more accurate picture will only be available once data on nutrient intakes are evaluated with more accurate methods, linking them to functional indicators or biomarkers of vitamin status. Nevertheless, the available data clearly show that a gap exists between vitamin intakes and requirements for a significant proportion of the population even in the most affluent countries – a fact that is surprising and a call to action 100 years after the term ‘vitamine’ was coined.

British Journal of Nutrition

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