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NHANES Data indicates that adequate vitamin intake remains a challenge for a large part of the elderly even in affluent societies

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Abstract

Background and aims: Demographic changes lead to an increased number of elderly, which has a dramatic impact on health care cost. One factor driving up this cost is the widespread malnutrition in elderly, especially in patients, already before entering the health care system. The aim of this paper was to analyze the adequacy of vitamin intakes in older people based on data from the US National Health and Nutrition Examination Survey (NHANES) 2003 to 2008.

Methods: Vitamin intake for the US elderly aged >70 years was determined based on information collected during NHANES 2003-2008. The proportions of elderly with intakes below the Estimated Average Requirement (EAR) and the correlation with household incomes were calculated for each vitamin.

Results: >50% US elderly do not reach the EAR for vitamin D, E and K and 35-40% for vitamin C and A, while for the B-vitamins, the proportion ranges from 1-30% and vitamin intakes correlated with household incomes.

Conclusions: Even in an affluent country such as the US, a high number of elderly do not get enough vitamins from their diets. Affordable solutions to supply them with necessary vitamins are needed to counter possible adverse effects on health and wellbeing.

Abbreviations: AI: Adequate Intake; CDC: Center for Disease Control and Prevention; EAR: Estimated Average Requirement; NCHS: National Center for Health Statistics; NCI: National Cancer Institute; NHANES: National Health and Nutrition Examination Survey; USDA: United States Department of Agriculture

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Introduction

In aging societies health care cost puts an increasing burden on national budgets and finding ways to reduce them are high on the list of governments' priorities. One area that is getting increasing attention is the cost of malnutrition in health care settings as well as nursing homes for the elderly and infirm. It was estimated that the annual cost of managing patients at risk of disease-related malnutrition in the United Kingdom in 2003 was £7.3 billion[1]. If these figures are extrapolated to Europe, the cost increases to €170 billion per year[2]. Already in 2003, two thirds of this money was spent on the care of individuals aged >65 years[1]. This age group is expected to increase from 506 million or 7% of the world's population in 2008 to 1.3 billion or 14% in 2040[3], which will have an enormous impact on the cost linked to their care.

A recent survey in hospitals showed that while malnutrition as defined by the Malnutrition Universal Screening Tool was generally high in all persons, the older ones had a 40% higher risk compared to the ones younger than 65 years[4]. Moreover, it is thought that 25% of patients admitted to hospitals have a poor nutritional status at arrival[2]. A recent study in the USA found that malnourished elderly or older people at risk of malnutrition were more likely to need health care services and to visit hospitals

and emergency rooms[5]. Consequently, the risk of malnutrition should already be addressed before the person enters into the care system due to disease, disability or injury.

So far, the focus of malnutrition screening assessment has largely been on protein-energy malnutrition. However, inadequate vitamin intakes have recently been reported to be widespread in Western countries in the population aged 20 to 50 years of age[6]. Therefore, our aim was to assess the vitamin intakes of population aged >70 years surveyed during the United States National Health and Nutrition Examination Survey (NHANES) for 2003 to 2008 to gain insight into the adequacy of vitamin intake in the elderly population before they enter the care system. The NHANES data is to our knowledge the only such data set for the age group of >70 years available to such an extent to the public. However, the conclusions drawn from this analysis may be relevant for other affluent Western countries, even though differences exist between the nutritional habits and food intakes in the US and Europe as well as between different European countries.

Methods

Study population

We focused and used the dataset from NHANES 2003–2008 for people aged >70 years as reference. This survey uses a complex, multistage probability sampling design to obtain a sample representative of the civilian non-institutionalized household population of the United States[7-9]. In this part of the survey data are selected for all adult participants with complete and reliable dietary records in the age ranges >70 years (n= 2'545). The NHANES data are collected by the National Center for Health Statistics (NCHS) of the Centers for Disease Control and Prevention (CDC). All participants or proxies provided written informed consent, and the Research Ethics Review Board at the NCHS approved the survey protocol. Information on dietary intakes were collected during an in-person examination using a 24-hour recall, while demographic data, such as age, gender and household income were collected through a computer-assisted personal interview. A second 24-h dietary recall was collected via telephone around 3 to 10 days later. The measures used to estimate portion sizes are described elsewhere[10]. To be able to assess the quality of the diet alone, the vitamin intakes from dietary sources and fortification excluding dietary supplements were used.

Nutrients from foods

The NHANES total diet files report combined intakes of vitamins in food consumed by NHANES participants as analyzed by CDC/ US Department of Agriculture (USDA) using various USDA databases (The Food and Nutrient Database for Dietary Studies was used for NHANES 2003-2004 (version 2.0), 2005-2006 (version 3.0), and 2007-2008 (version 4.0)) to determine the vitamin content of NHANES foods.

Analyses of NHANES 2003-2008 Dataset

Intake data from both 24-h recalls were used to estimate usual intake and percentiles of intake from foods using the National Cancer Institute (NCI) method[11]. The balanced repeated replication approach was implemented in conjunction with NCI method to develop standard errors and confidence intervals. Covariates in the usual intake models included day of the week of dietary recall (weekend/weekday) and interview sequence of the dietary recall (in person vs. via telephone). The population was stratified by gender and was grouped by age for all NCI runs.

Adequacy of vitamin intake

US Dietary Reference Intakes distinguish between two levels of intakes: The Estimated Average Requirement (EAR), which is defined as the intake that covers the needs of 50% of the respective age and gender group and the Recommended Daily Allowance, which are thought to cover the needs of 97.5% of that population group[12-15]. If insufficient evidence is available to arrive at such values (E.g. for vitamin K), Adequate Intakes (AI) are defined instead[12]. The EAR (or AI in the case of vitamin K) for each vitamin (Table 1)[12-15] were used to quantify the potential gap in vitamin intakes in the US elderly according to the cut-point method that defines intakes below the EAR as inadequate[16]. As the revised recommendations for vitamin D had not been published when the data was analyzed, but it was clear that the review was underway, it was decided not to use the previous recommendations[17]. Instead, the adequacy of intake was established by comparing the new RDA[14] with the percentiles of vitamin D intake in this population.

Table 1: Estimated Average Requirements (EAR) for men (n= 1'274) and women (n=1'271) in the United States for the age group of >70 years[12-15] and proportion of male and female seniors (>70 years) in the NHANES cohort 2003 to 2008 with vitamin intakes below the age-specific EAR

		EAR		<EAR	
Vitamin	Unit/d	Men	Women	Men	Women
Vitamin A	µg RE	625	500	69.9%	66.8%
Vitamin D	µg	10	10	>90.0%[1]	>90.0%[1]
Vitamin E	mg TE	12	12	99.1%	99.7%
Thiamine	mg	1.0	0.9	14.4%	30.3%
Riboflavin	mg	1.1	0.9	5.6%	9.8%
Niacin	mg	12	12	11.3%	22.4%
Vitamin B_6	mg	1.4	1.3	31.2%	48.3%
Vitamin B_{12}	µg	2.0	2.0	2.4%	11.0%
Folic acid	µg	320	320	19.5%	41.7%
Vitamin C	mg	75	60	50.6%	47.1%
Vitamin K*	µg	120	90	82.2%[3]	66.0%[3]

RE, retinol equivalent; TE, tocopherol equivalent. the 90th percentile of Vitamin D intakes were found to be clearly below the revised EAR for this vitamin, [2]The Institute of Medicine concluded that insufficient evidence was available to arrive at an EAR for vitamin K and therefore only defined an Adequate Intake

Impact of income on vitamin intake

The data was stratified by household income to assess the impact of available budget on vitamin intakes. The proportion with vitamin intakes below the EAR were then compared between individuals with yearly household incomes <$25'000, $25'000 to $75'000 and >$75'000. For this, the Cochran-Armitage trend test, a modified Chi-squared test for ordered categorical data, was used[18]. P values <0.05 were considered significant.

Results

The sample contained 1'274 men and 1'271 women aged >70 whose data on dietary intake was collected during 2003 to 2008. Table 1 shows the proportion of elderly men and women in the US with vitamin intakes below the EAR. While some small differences between the genders are evident, the results show that more than half of the people do not reach the EAR for vitamin D, E and K and 35% to 40% for vitamin C and A. The situation is a bit better for the B-vitamins, with levels of inadequate intake varying from ~1% for vitamin B12 in men to ~30% for vitamin B6 in women. There is a significant trend towards reduced intakes of vitamins with lower household income in the elderly in the US (Table 2).

Table 2: Proportion of population with vitamin intakes below the Estimated Average Requirement (EAR) by household budget

	Low income[1]		Medium income[2]		High income[3]		P-value	Δ [%][4]
	% <EAR	SE	% <EAR	SE	% <EAR	SE		
Vitamin A	40.5	1.9	34.1	2.0	30.0	5.2	<0.001	25.9
Thiamine	12.7	1.4	9.1	1.1	3.8	1.6	<0.001	70.1
Riboflavin	4.2	0.5	2.7	0.4	1.4	0.7	<0.001	66.7
Niacin	7.9	1.4	4.7	0.8	1.0	0.7	<0.001	87.3
Vitamin B6	31.1	2.2	23.1	1.9	13.7	3.2	<0.001	55.9
Folic Acid	19.0	1.7	12.7	1.3	9.5	2.6	<0.001	50.0
Vitamin B_{12}	5.6	1.3	2.2	0.6	2.4	1.5	<0.001	59.3
Vitamin C	39.1	2.2	33.1	1.9	22.9	3.3	<0.001	41.4
Vitamin D[5]	na	na	na	na	na	na	na	na
Vitamin E	98.4	0.5	96.3	0.8	91.8	2.5	<0.001	6.7
Vitamin K[6]	75.3	1.7	71.6	2.2	56.7	8.0	<0.001	24.7

[1]Household income < $25'000/ year, n= 1151, [2]Household income $25'000 to $75'000 per year, n= 1011, [3]Household income > $75'000 per year, n= 204, [4] Relative difference in the proportion of persons below recommendations in the highest and the lowest income group,[5]This value could not be calculated as the Dietary Reference Values for vitamin D were under revision when the data was analysed, [6]The Institute of Medicine concluded that insufficient evidence was available to arrive at an EAR for vitamin K and therefore only defined an Adequate Intakena: not available

Discussion

The information collected in the dietary intake survey as part of NHANES 2003-2008 indicates that the majority of elderly people in the United States do not met the EAR for at least one vitamin: >50% US elderly do not reach the EAR for vitamin D, E and K and 35 to 40% for vitamin C and A, while for the B-vitamins, the proportion ranges from 1 to 30%(Table 1). The results from the European Nutrition and Health Report indicate that the situation of the elderly in the general population is similar in Europe[19]: Average intakes of vitamin D and folate for the elderly in most of the 15 countries included in the report were found to be below recommendations, while vitamin E and C were below recommendations in around half of them[19]. In an Austrian cohort of non-institutionalized persons aged 70 to 90 years, inadequate plasma levels were found in a significant proportion of the cohort for various vitamins[20]. A multi-centre study in various European countries identified vitamin D and B12 as particularly critical in their elderly cohort[21]. It is also in agreement with a survey that classified around 50% of community dwelling elderly in Europe as at risk for malnutrition[22].

Intake are clearly improved by the use of nutritional supplements: The risk to have vitamin intakes below the EAR was four times lower in elderly persons who regularly used supplements of one or more micronutrients[23]. In elderly men, the prevalence of vitamin A, E and folate intakes below the EAR decreased from 53% to 4%, from 93% to 14% and from 75% to 7%, respectively with the use of supplements[23]. However, only around 3% of elderly persons in German nursing homes were taking vitamin supplements[24]. In comparison, more than 35% of people aged 60 or more in the US were reported to be taking them[25]. A similar situation probably exists for micronutrients supplied by fortification and enrichment, as these provide a significant source for vitamins and minerals in the US[26], but not in Europe[27].

The NHANES survey did not collect information on institutionalized elderly; however, data collected in Germany shows that the situation of elderly in German institutions is worse in such a cohort: Vitamin intakes for more than 80% of institutionalized elderly in Germany are inadequate for vitamin C, D, E, and folic acid as well as for thiamine in women[24]. With the exception of niacin in men, the intakes for all the other vitamins assessed in this study were found to be inadequate for 25% to 75%. While distinct differences can be expected between the nutritional situation in Germany and the US, comparison with the non-institutionalized German seniors[28] shows that the situation is clearly worse for those in care settings[24]. Even though the controlled environment of a hospital or care home would be ideal for improving nutrition, this opportunity has so far been not been taken due to lack of awareness of the problem not just in the general public, but also among health care professionals and decision makers[2]. Consequently, it has been postulated that nutrition took a more prominent role in the training of physicians and other health care professionals[29].

Old age and the accompanying pathologies result in a multitude of physiological and social changes. Older people tend to eat alone more often, which was shown to result in decreased food intakes[30]. Due to physical disabilities, dementia, depression or other psychological factors, they are less capable of preparing meals for themselves[31]. A recent study showed that disability and chronic illness significantly increased the odds of a diet characterised by low variability[32]. Moreover, decreased effectiveness to detect and react to hunger further increases the risk of malnutrition[30]. Appetite tends to decrease due to declining taste and smell sensitivities, various pathological conditions or medications and impaired chewing due to ill-fitting dentures[33]. Reduced secretion of saliva in the elderly or the intake of certain drugs makes swallowing more difficult[34].

However, inadequate vitamin status is often not only caused by decreased intakes, but also impaired absorption. As an example, the intakes of vitamin B12 were reported to be mostly above the EAR (Table 1) even without intakes from supplements. However, data collected in NHANES 1999 to 2004 showed that 5 to 25% of people aged 60 or more had low serum vitamin B12 levels[35]. In Germany, were intakes are lower still, vitamin B12 deficiency can be expected to be even more common. It is thought that around two thirds of cases of cobalamin

deficiency in the elderly are due to malabsorption[36,37]. Given the relative size of cobalamin stores, a large time lag exists between the onset of the malabsorption and the development of the deficiency[38]. Even subclinical deficiency is an indicator of insufficient absorption of dietary cobalamin and oral supplementation with daily doses of at least 1000 μg was proposed for elderly people at risk of malabsorption[39,40].

Changes in body composition as part of the aging process are associated with an increased risk for malnutrition as they lead to decreased energy requirements[41] while requirements for micronutrients remain the same[12,13,15] or, for vitamin D, increase[14]. A study in healthy elderly found intakes below EAR for most people for vitamin D and calcium and for around half for vitamin B6, folate, magnesium and zinc, while energy intake corresponded with the recommendations[42]. This highlights the importance of nutrients dense foods for population groups with low levels of activity and therefore reduced energy intakes[43]. However, a study comparing recommendations with actual eating behaviour showed that among the >70 years, recommended intakes for fruits, vegetables and whole grains were not meet by ~70%, >80% and >90% of individuals, respectively[44]. It has also been shown that nutrient density decreased in parallel with the household budget available for food[45]. Given the often reduced budgets of the elderly, this adds a further difficulty to achieving a balanced diet with sufficient micronutrients. This relationship between household budget and vitamin intake was confirmed in our data (Table 2).

The relevance of these vitamin inadequacies for life quality and health care cost has been studied in most detail for the case of vitamin D[46-50]. Among the patients in a medical intensive care unit, vitamin D deficiency at admission was as high as 78% and 25-hydroxy vitamin D levels were found to correlate with mortality after ≥2 days in the hospital[51-54]. Vitamin D status was inversely related to hospital stay and 25-hydroxy vitamin D levels were found to decrease further during the stay at the surgical intensive care unit[55]. As a consequence of the increased time spent at the hospital, treatment cost more than doubled for people with severe vitamin D deficiency[55].

Data from such large-scale dietary intake surveys are considered to provide the most accurate data on populations currently available, as validated biomarkers with generally accepted cut-off points only exist for a few vitamins. Comparison between countries has its limitations, as, although the concept of intake recommendations is widely recognized, national dietary reference values vary considerably in terminology and recommended level[56-59]. Moreover, day-to-day variance in nutrient intake typically results in large within-individual variability when conducting dietary surveys using methods such as the 24-hour recall. However, some of this bias can be eliminated by using the NCI method to estimating usual intakes based on data from at least two interviews per person[60]. The method has been shown to provide a good approximation of usual intake, especially given to relatively large sample size[61]. To assess adequacy of intake from such data, the Institute of Medicine recommends to use the proportion of a population with intakes below the EAR, as individual requirements are normally not known[16,62]. When different cut-offs (RDA, 0.66 RDA, 0.50 RDA and EAR) were compared with more comprehensive analyses, defining inadequacy of intake as intakes lower than the EAR gave the most accurate estimates[63]. Still, one limitation of the paper is that dietary surveys do not provide a direct measure of an individual's nutrient status, but such data is still missing for large-scale cohorts.

Conclusion

The data presented shows that intakes are critically low in the elderly in the US for various vitamins. Given the importance of adequate vitamin intakes and the problems achieving them from the diet alone, specific fortified foods and supplements targeted at the elderly, both healthy and frail, need to be developed and tested. It has been shown that the addition of an oral nutrient supplement containing vitamins and additional energy to the diet of acutely ill elderly patients led to an increase in nutritional status[64] and quality of life[65] combined with a decrease in hospital re-admission[66] and depressive symptoms[67]. Given the complexity of the physiological and metabolic changes inherent to the aging process, more research is warranted to gain a better understanding of the effects of vitamin inadequacies on aging and the capacity of nutritional interventions to slow this process.

Competing Interests

The authors are employed by DSM Nutritional Products Ltd., a bulk supplier of vitamins.

Authors' Contributions

BT, PW and ME defined the scope of the paper; BT analysed the data; BT and PW wrote the paper; BT, PW and ME had primary responsibility for the final content; all authors read and approved the final manuscript.

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