VITAMIN INTAKE AND STATUS IN ELDERLY EUROPEANS

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Proefschrift

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STELLINGEN

1. Oudere Europeanen die tijdens de zomermaanden blootstelling aan zonlicht schuwen, hebben een verhoogd risico op vitamine D deficiëntie tijdens de wintermaanden.
Dit proefschrift.

2. Ouderen met een lage energie-inneming ('kleine eters') compenseren dit niet door het kiezen van voedingsmiddelen met een hoge micronutriënten-dichtheid en hebben derhalve een hoger risico op micronutriënten-deficiënties dan ouderen met een hoge energie-inneming.
Dit proefschrift.

3. Anders dan voor vitamine D is er geen enkele aanleiding het gebruik van supplementen met wateroplosbare vitamines aan te bevelen voor de gehele populatie ouderen.
Dit proefschrift.

4. Een belangrijke reden van een inadequate nutriëntenvoorziening in verpleeghuizen is een onvoldoende spreiding van de maaltijden over de dag.

5. Het creëren van een entourage die uitnodigt tot meer eten zal de voedingstoestand van ouderen in verpleeghuizen verbeteren.

6. In de Nederlandse situatie is de term welvaartsziekten in tegenspraak met de bevinding dat kanker en hart- en vaatziekten meer voorkomen bij personen met een lagere sociaal economische status.

7. De aanbeveling in het advies "Richtlijnen goede voeding" van de Voedingsraad om maximaal 10 procent van de energie als verzadigd vet te consumeren is binnen het Nederlandse voedingspatroon niet realistisch.

8. Ervaring in het verzamelen van onderzoeksgegevens is een vereiste om de praktische haalbaarheid van onderzoeksvoorstellen te kunnen beoordelen.

9. Gebruik van het woord 'gezond' in de benaming 'broodje gezond' is misleidend.

10. Vele handen maken licht werk geldt uitsluitend indien alle neuzen in dezelfde richting wijzen.

11. Bij de werving van studenten voor de Landbouwuniversiteit Wageningen zou meer nadruk gelegd moeten worden op de unieke wijze waarop ontwikkelingen ten aanzien van produktie en consumptie van voedsel, alsmede de effecten hiervan op de gezondheid worden geïntegreerd binnen één wetenschappelijke organisatie.

12. 'Time waits for no one, and it won't wait for me'.
The Rolling Stones (Jagger M, Richards K), 1974.

Stellingen behorend bij het proefschrift

Vitamin intake and status in elderly Europeans

Reggy P.J. van der Wielen
Wageningen, 5 september 1995

voor mijn ouders

Abstract

Vitamin intake and status in elderly Europeans

PhD thesis by Reggy P.J. van der Wielen, Department of Human Nutrition, Wageningen Agricultural University, Wageningen, the Netherlands. September 5, 1995.

Ageing is associated with a decrease in food intake, which may lead to concurrent nutrient inadequacies and consequently enhance health deterioration. This thesis describes the adequacy of dietary intake and biochemical status of selected water-soluble vitamins and vitamin D in groups of elderly people.

Using a modified dietary history method, a comparison study in groups of Dutch elderly people with different levels of physical fitness showed that, although the groups had similar dietary patterns, the inactive group (nursing home residents) had a significantly lower energy intake than the very active elderly people. In addition, about half of the inactives had dietary intakes below the mean minimum requirement for at least one of the vitamins thiamin, riboflavin, vitamin B_6 or vitamin C, whereas the actives had virtually no dietary inadequacies.

Results of the SENECA study (a Survey in Europe on Nutrition and the Elderly, a Concerted Action) showed that in about 2600 apparently healthy elderly, aged 70-75 years, a high prevalence of biochemical deficiency was present for the vitamins B_6 (22% of both males and females) and D (36% of the males and 47% of the females). For vitamin B_6 this was mainly due to low intakes of this vitamin. For vitamin D, surprisingly, lowest mean (winter-time) levels were found in southern European study sites. Low levels could partly be explained by avoidance of sunlight exposure and inability to perform activities of daily living.

In nursing home residents with a poor nutritional status, dietary enrichment with a physiological dose (25% of the recommendations) of water-soluble vitamins for 12 weeks, significantly improved the status of the vitamins B_1, B_6 and C.

In conclusion, the main reason for an inadequate dietary intake of water-soluble vitamins is a reduced energy intake. Stimulation of physical activity in elderly people and/or consumption of nutrient dense products, may help to ensure dietary adequacy of water-soluble vitamins. In winter, vitamin D fortification seems to be necessary in elderly people who are less mobile and/or who avoid exposure to sunlight.

Contents

CHAPTER 1

Introduction

The population of elderly people, here defined as people aged 65 years and older, is growing in westernized societies, both in absolute terms and as a proportion of the total population. In the Netherlands, for example, in 1994 about 1.16 million people (7.6%) were aged 65-74 years and about 848 thousand (5.5%) were aged 75 years or more.[1] In 1980 these figures were 984 thousand (7.0%) and 631 thousand (4.5%) respectively.[2] It is estimated that in the year 2010 about 2.5 million (14.7%) people will be aged 65 years and older.[1]

Ageing has been defined as 'a process that converts healthy individuals into frail ones, with diminished reserves in most physiological systems and an exponentially increasing vulnerability to most diseases and to death'.[3] Thus, a growing population of elderly people inevitably leads to an increased demand for health care for this human population segment.

One of the factors essential to keep a good health status is to maintain an adequate nutritional status. Furthermore, an inadequate nutritional status may accelerate already existing health problems. Food (and therefore energy) intake reduces in the process of ageing.[4,5] Possible underlying causes for this reduction may be health problems (reduction in physiological functions, acute and chronic disease, institutionalization, absorption problems due to atrophic gastritis or use of medication),[6-9] a decline in the senses of smell and taste,[10,11] social isolation (loss of partner, mobility problems), problems to budget food and chewing problems.[12,13] Also dietary energy need may be reduced by several age-related changes like reduced physical activity (living a more sedentary lifestyle, reduced capacity to perform activities of daily living),[4,8,14,15] and a decrease in resting metabolic rate as a result of a decreased lean body mass.[16-18]

Since reduced food intake may lead to an inadequate intake of micronutrients, the dietary pattern still should be balanced and nutrient densities of the foods eaten should be high enough to meet the dietary needs. Especially body stores of water-soluble vitamins are relatively low, and if the daily needs for these vitamins are not covered, the risk of biochemical vitamin deficiency is substantial.[19] For fat-soluble vitamins the body stores are higher. However, for these vitamins the body is also dependent on dietary availability at the longer term. For vitamin D, which main source is its formation in the human skin under the influence of sunlight exposure, the dietary needs may even increase in elderly people since the capacity of the skin to produce this vitamin decreases with ageing.[20]

Keeping a good health and nutritional status for as long as possible during the process of ageing, will contribute to the quality of life and will temper the rising costs of health care for the elderly. Therefore, it is important to evaluate the adequacy of the diet and nutritional status of elderly people, in order to come with advices to change dietary habits where needed.

The aim of this thesis is to expand the available knowledge of the nutritional situation of elderly people, with emphasis on selected water-soluble vitamins and vitamin D, and to come with recommendations of how the nutritional status of vulnerable groups from a nutritional point of view may be improved. The adequacy of dietary intake and biochemical status of these vitamins in elderly people, and associations of dietary intake, life-style characteristics, and indicators of physical condition with vitamin status are evaluated. Some aspects need to be taken into consideration first, i.e. the heterogeneity of the group of elderly people as a whole and the standardization of the used methodology in order to be able to make comparisons between results of different studies.

Heterogeneity of the elderly population

Since each individual is to a different extent exposed to several aspects of ageing and has a different genetic predisposition to the ageing process, the pace of the ageing process will differ from person to person. This makes the elderly population very diverse, and therefore it is hard to judge the nutritional status of elderly people in general. One possibility to partly overcome this problem is to classify elderly people in strata of chronological age, and to assess dietary intakes and status per stratum. However, using this chronological age approach alone is a poor selection criterion since it does not take into account the increase in physiologic heterogeneity of the population with increasing age.[8] Therefore, Rowe and Kahn[21] suggested that it may be better to differentiate between usual ageing (associated with a variety of chronic medical conditions and disabilities) and successful ageing (little or no loss in physiological functioning with age) when studying factors that determine functional changes with advancing age. According to Harris and Feldman,[22] a third category of high risk or accelerated ageing, which refers to elderly people who carry the heaviest burden of chronic disease and disability, should be added.

Examples of different categories of ageing, within the same age stratum could be for example: elderly people who are still undertaking regular sport activity (successfully aged), elderly people who live a more sedentary life but who are still able to perform activities of daily living without much difficulty (normally aged), and residents of institutions for chronical care and rehabilitation of somatic and/or psycho-geriatric disabled elderly (accelerated aged). To give an impression of the size of the latter category in the Netherlands, at the beginning of 1994, about 3.5% of the people aged 65-84 years and about 33% of those aged 85 years and older were living in retirement homes. Furthermore, about 3% of the people aged 65 years and older were living in nursing homes in the Netherlands.[1] This means that about 9% (180 thousand persons) of the people aged 65 years and older are institutionalized. Hospitalized elderly people are not included in this percentage.

Comparability of results

Even when study results of similar 'categories of ageing' are described, comparison of dietary or biochemical data from different studies is often hampered by differences in methodology, or by differences in used reference values for inadequacy or deficiency.

Dietary assessment.
There is not one standard dietary assessment method. The dietary history, 24-hour recall, (weighed) record for several days and the food frequency questionnaire are the four basic methods used to estimate dietary intake.[23] Each method has its own advantages and disadvantages, and the choice of the method depends on the design and purpose of the study, and on the target population. To judge the adequacy of the diet, most countries have their own Recommended Dietary Allowances (RDA) to compare the nutrient intakes with.[24-26] These recommendations are established by expert committees, who interpret the scientific knowledge to date and integrate and reflect the results to age specific dietary needs. This means that in different studies, the judgement of dietary adequacy can be based on different cut-off limits. In *Chapter 2* these differences in dietary assessment techniques and allowances are discussed in more detail.

Biochemical analysis techniques.

Vitamin status can be measured as the concentration of the vitamin itself or its active component in metabolism (in whole blood, plasma, serum, cells, biopsies), as excretion determination in urine, or as enzyme activity measurements.[27,28] One of the problems with the latter method is that fresh blood is needed, which is sometimes not achievable in an epidemiological study setting. Reference values (cut-off values for biochemical deficiency) are often based on the 2.5 percentile of the distribution in a healthy adult population, with the assumption that there are no age-specific differences in adequate nutritional status. People who fall outside the range of adequacy are considered to be at risk for nutrient deficiency. Functional capacity problems or clinical signs are more defined outcomes of serious deficiency. When biochemical data are presented in this thesis, reference values are described for each parameter.

Studies included in this thesis

Results of three different studies were compared in this thesis in order to (a) describe the nutritional situation of elderly people, (b) to be able to characterize vulnerable groups with respect to nutrient inadequacies, and (c) to come with recommendations to improve the nutritional situation of these vulnerable groups where needed. In each study the same modified dietary history was used to assess dietary intake and adequacy of the different categories of ageing.[29]

'Normal agers'.

In 1988, a European multicentre study was initiated, called the SENECA study (a Survey in Europe on Nutrition and the Elderly: a Concerted Action).[30] The study was designed to explore cross-cultural differences in dietary patterns of elderly people, living in different countries of the European Community, and to study associations with lifestyle factors affecting health and performance. For this purpose, 2586 elderly subjects, born between 1913 and 1918 were studied in 19 towns in 12 European countries between October 1988 and March 1989. Although subjects were not selected as people from a specific category of ageing, non-responders analysis showed that the participants were in general apparently healthy free living individuals[31]. Selecting elderly people aged 70 – 75 years enabled the research group to examine the nutrition and health status before the period of rapid health deterioration and increased mortality. A strictly standardized modified dietary history method was used in all study towns to assess intake of foods and nutrients.[29] Dietary intake of nutrients was calculated using the country specific nutrient composition tables.[32,33] Furthermore, a fasting blood sample was drawn and biochemical analyses took place in central laboratories.[34] With the exception of the vitamin D status, descriptive results of the baseline measurements are described in a supplement of the European Journal of Clinical Nutrition.[35] In the spring of 1993 a follow up study was carried out in a subsample of the SENECA study.

'Successful agers'.

In July 1993, a study on physical activity, exercise capacity and health was carried out in elderly participants in the annual four days long distance march in Nijmegen. The SENECA protocol (including the same modified dietary history method) was used as part of this study. In total 32 females and 34 males, aged 70 years and older, who were able to walk 30 or 40 kilometres on four consecutive days participated in the food consumption part of the study. In this thesis only results of the dietary assessment are described. The other results of this '4-day marches' group will be published elsewhere.[36]

'Accelerated agers'.

Between October 1992 and December 1993, 10 males and 11 females who admitted institutions for chronical care and rehabilitation of somatic disabled elderly (here referred to as a nursing home), participated in a study to examine the nutritional situation in the month previous to institutionalization. Furthermore, the effect of 12 weeks supplementation with a physiological dose of water-soluble vitamins on the nutritional status was studied in 40 females who already lived in a nursing home for at least three months. In this study, the SENECA modified dietary history was also used. The biochemical analyses were performed at other laboratories than in the SENECA study.

Outline of the thesis

In this thesis, the adequacy of the diet in representants of the different categories of ageing is studied, with emphasis on selected water-soluble vitamins and vitamin D. In *Chapter 2,* an overview is presented of studies published between 1980 and 1993, which have assessed dietary intakes of the vitamins thiamin, riboflavin, B_6, folic acid, B_{12} and C, in both free-living and institutionalized elderly people living a Western lifestyle. In *Chapter 3,* differences in dietary intakes of energy and the vitamins thiamin, riboflavin, B_6, and C, between the above described studies are reported. Since one of the results of the SENECA baseline study was a high and widespread prevalence (23%) of biochemical vitamin B_6 deficiency,[34] an in depth analysis was conducted to examine combined associations of vitamin B_6 status with dietary vitamin B_6 intake, other dietary factors, indicators of physical condition and lifestyle factors in the SENECA population, as reported in *Chapter 4.* In *Chapter 5* the geographical distribution of vitamin D status in the SENECA study is described. *Chapter 6* describes the effect of 12 weeks supplementation with fruit juice, enriched with a physiological dose of water-soluble vitamins, on the nutritional status of female nursing home residents. This category of elderly people was chosen for the intervention because it was expected that the nutritional status of these people would be inadequate. Finally, in *Chapter 7* the results are summarized, methodological problems are discussed, general conclusions are drawn and implications for health policy are discussed.

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CHAPTER 2

Dietary intake of water-soluble vitamins in elderly people living in a Western society (1980 - 1993)

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ABSTRACT

In this article dietary intakes of the water-soluble vitamins thiamin, riboflavin, B_6, folate, B_{12} and C in both free-living and institutionalized elderly persons living a Western lifestyle are reviewed. In total 37 studies on elderly people (aged 60 years and over) which were published between 1980 and 1993 are discussed with a view to the dietary assessment methods used, dietary recommendations and blood biochemistry. Dietary intakes of thiamin, riboflavin and vitamin B_{12} in general are found to be adequate. Vitamin B_6 intake was found to be most frequently below the recommendations. A substantial proportion of the elderly had dietary folate intakes below two-thirds of the country specific recommendations in several studies. Vitamin C intakes seem to be adequate in free-living elderly but tend to be low in institutionalized elderly. The use of water-soluble vitamin supplements is not recommended for elderly people in general. More data are needed on optimal as well as safe levels of intake to allow for specific advice with respect to supplement use of vulnerable groups of elderly people.

INTRODUCTION

Together with the increase in the proportion of elderly people in Western Societies, interest in the nutrition and health of this age group is growing. Elderly people are considered a vulnerable group with respect to nutritional risks for multiple reasons such as reduced intakes of foods, disturbances in digestion, drug-nutrient interactions, and chronic disease. As food intake declines with advancing age, the dietary pattern of older people should be well balanced to meet the dietary needs of macro- as well as micro-nutrients. Malnutrition might worsen patho-physiological processes of ageing, and as a result of that reduce the quality of life. Since body stores of water-soluble vitamins are rather low, covering the daily dietary needs of these vitamins is very important.

The aim of this paper is to review the dietary intakes of the water-soluble vitamins thiamin, riboflavin, B_6, folate, B_{12} and C in both free-living and institutionalized elderly persons, living a Western lifestyle in different continents of the world. The adequacy of the diet to fulfil the needs for these vitamins will be discussed in view of the dietary assessment methods used, dietary recommendations and blood biochemistry. Dietary intakes of the other water-soluble vitamins (niacin, biotin, pantothenic acid) are not discussed in this review. The dietary needs for niacin are normally met in part by the conversion of dietary tryptophan to niacin.[1] Dietary intakes and biochemical deficiencies of biotin and pantothenic acid are hardly ever reported.

SELECTION OF THE LITERATURE

Studies of elderly (aged 60 years and over) which were published in international journals between 1980 and 1993, and in which vitamin intake from the diet is given for males and females separately, were selected for this review. Subgroups with less than 25 subjects have been excluded. Food consumption of elderly people studied and reported before 1980, have been discussed in other reviews.[2-4] In total, 32 studies are described in which free-living elderly subjects are involved.[5-36] Four of these studies also include institutionalized elderly.[7,19,21,31] In another five studies dietary intakes of institutionalized elderly only are presented.[37-41]

CHARACTERISTICS OF THE REPORTED STUDIES

To make a meaningful comparison of the results reported and for the evaluation of the adequacy of the dietary intake data, it is necessary to consider some study characteristics. Firstly the characteristics of the populations under study, secondly the validity of the dietary assessment methods, thirdly the background of the recommended intakes and fourthly the relation with blood biochemistry. Therefore these issues will be discussed first.

Characteristics of the populations

Table 1 describes the study characteristics with respect to sampling frame, population size, response rate, age and method of dietary assessment. Three studies consisted of a nationwide random sample of free-living elderly people.[18,24,30] The other studies in free-living elderly (n = 29) have been carried out at restricted study sites, using different selection criteria. Within these particular sampling frames, thirteen of these studies involved a random study sample. Studies conducted in institutionalized elderly people have not been very clear in reporting selection criteria.

Twenty-one of the presented studies in free-living elderly, and all except one of the studies in institutionalized elderly present the dietary intake results for an age range of at least twenty years. In fact the majority of studies did not present the results for separate age groups and therefore cover an age range of between five and about forty years. The maximum age range is about half a lifespan.

Table 1. Studies which reported dietary intakes of water-soluble vitamins in elderly people, living a Western lifestyle.

Authors	Reference	Sampling frame	n males	n females	Response (%)	Age	Dietary method[a]
Free-living elderly:							
Baghurst and Record, 1987	(5)	randomly selected (from electoral roll) elderly residents of Adelaide, Australia	195	136	82	65-75	S
Bianchetti et al., 1990	(6)	all elderly inhabitants of a restricted area in the center of *Brescia, Italy*	386	815	92	70-75	H
Boston Nutritional Status Survey, 1992	(7)	healthy elderly (recruited by local media and presentations), 'Boston Nutritional Status Survey', USA	100 97 42	158 177 117	nd	60-69 70-79 80⁺	R3
Contaldo et al., 1986	(8)	healthy elderly, selected from a random group, Naples, *Italy*	70	66	nd	65-69	D
Fidanza et al., 1984	(9)	pensioners in Perugia (not random), 5th year follow-up, Italy	41 60	54 52	nd	65-70 70⁺	D
Fidanza et al., 1991	(10)	pensioners in Perugia (not random), 11th year follow-up, Italy	46	47	nd	mean 76.8 & 75.8	D
Garry et al., 1982	(11)	healthy elderly (not random),'New Mexico longitudinal study of nutrition and aging, Albuquerque, USA	125	145	nd	60⁺	R3
Gray et al., 1983	(12)	residents of retirement community (random selection of a cohort of 11,500 subjects), Southern California, USA	19	32	82	58-95	D
Herbeth et al., 1989	(13)	subsample of a survey on a self sufficient urban population, France	139	152	20	60-82	R7
Horwath, 1989	(14)	randomly selected (State electoral rolls) group of elderly, Adelaide, Australia	919	1102	77	65⁺	S
Horwath et al., 1992	(15)	*all free-living elderly (registered with health center)*, Mosgiel, New Zealand	255	457	85	70⁺	S
Koehler et al., 1992	(16)	healthy participants in New Mexico Aging Process Study (follow up Garry et al.), USA	97	122	nd	60⁺	R3
Kohrs et al., 1980	(17)	people in participation areas of congregate hot-meal *programs (part. groups: 0, 1, or 2-5 times/week) in* Missouri, USA	31 68 46	76 (0) 143 (1) 81 (2-5)	60	59-99	D
Löwik et al., 1989	(18)	nationwide random sample (municipal registers) of apparently healthy elderly, The Netherlands	269	269	53	65-79	D
Löwik et al., 1992	(19)	free-living elderly women (respondents to newspaper *announcement), control group nursing home study*, Amsterdam, The Netherlands	-	52	nd	74 ± 6	D

- continued -

Authors	Reference	Sampling frame	n males	n females	Response (%)	Age	Dietary method[a]
Manore et al., 1989	(20)	free-living low-income elderly people (not random), Phoenix, USA	60	138	nd	60⁺	R3
Marazzi et al., 1990	(21)	free-living elderly (not random), Rome, Italy	-	65	nd	60-90	R3
Mensink and Arab, 1989	(22)	randomly selected (resident registration lists), categorized as active and less active, 3 cities, Germany	48 82	44 (act.) 124 (l. act.)	nd	65-75	R7
Millen Posner et al., 1987	(23)	homebound elderly with home medical care (randomly selected from care listings), Boston, USA	17	34	65	63-99	H
NHANESII, 1983	(24)	nationwide random sample of elderly citizens, NHANESII 1976-'80, USA	1199	1416	62	65-74	H
Nordström et al., 1988	(25)	stratified systematic sample of all 70, 75 and 79 year old, Umeå, Sweden	94	89	79	70, 75, and 79	D
O'Hanlon et al., 1983	(26)	random selection of participants in nutrition programs, central Missouri, USA	145	300	nd	60-96	D
Payette and Gray-Donald, 1991	(27)	healthy free living subjects (random selection from municipal electoral list), Sherbrooke, Canada	35	47	41	65-89	R7
Porrini et al., 1987	(28)	free-living elderly (selection not described), Stradella, North Italy	52 59	75 65	nd	60-69 70⁺	R7
Räsänen et al., 1992	(29)	males (follow up of subsample seven countries study), Finland	227	-	43	70-89	D
Ryan et al., 1992	(30)	Ross Lab. Elderly Dietary Survey, RLEDS, nationwide representative sample modelled after USDA's continuing Survey of Food Intakes by Individuals, USA	115 65	178 116	74	65-74 74⁺	H
Scaccini et al., 1992	(31)	elderly, both free-living and inhabitants of retirement homes (not representative for age and sex structure), Italy	449	497	32	60-99	W7
SENECA investigators, 1991	(32)	elderly citizens, from European countries (random samples of towns' residents, stratified by age and sex), SENECA:					D
		Hamme; Belgium (H/B)	120	100	55	70-76	
		Roskilde; Denmark (R/DK)	96	98	46	70-76	
		Haguenau; France (H/F)	110	110	51	70-76	
		Romans; France (R/F)	116	103	34	70-76	
		Anogia, Archanes; Greece (AA/GR)	31	45	81	74-76	
		Padua; Italy (P/I)	97	93	51	70-76	
		Fara Sabina, Magliano Sabina, Poggio Mirteto; Italy(FMP/I)	32	32	69	74-76	
		Culemborg; Netherlands (C/NL)	114	124	37	70-76	
		Elverum; Norway (E/N)	32	28	56	74-76	
		Vila Franca de Xira; Portugal (V/P)	111	111	62	70-76	
		Betanzos; Spain (B/E)	86	116	58	70-76	
		Yverdon; Switzerland (Y/CH)	117	124	49	70-76	
		Burgdorf; Switzerland (Bu/CH)	30	30	40	74-76	
		Bellinzona; Switzerland (Be/CH)	30	30	57	74-76	

- continued -

Authors	Reference	Sampling frame	n		Response	Age	Dietary
			males	females	(%)		method[a]
Smidt et al., 1991	(33)	Healthy elderly women (random selection from medical registration lists), Cork City, Ireland	-	80	nd	65-92	H
Somogyi and Kopp, 1983	(34)	apparently healthy, free-living elderly (selection not reported), Zürich, Switzerland	24	67	nd	63-83	nd
Walker and Beauchene, 1991	(35)	recruited, independently living individuals (selection not reported), Tennessee, USA	7	54	nd	60-94	R3
Yearick et al., 1980	(36)	apparently healthy elderly (non random sample), Oregon, USA	25	75	nd	63-96	R3
Institutionalized elderly:							
Boston Nutritional Status Survey, 1992	(7)	mentally competent elderly from 15 long-term care facilities (not random), 'Boston Nutritional Status Survey', USA	11 45 35 12	14 44 79 26	nd	60-69 70-79 80-89 90+	R3
Ferro-Luzzi et al., 1988	(37)	light and heavier drinking (LD & HD) apparently healthy elderly in retirement homes throughout Italy	98 90	126 (LD) 79 (HD)	54	65+	W7
Gonzalez-Gross et al., 1991	(38)	institutionalized elderly (selection not reported), Autonomic Community of Madrid, Spain	20	52	nd	68-95	W5
Guilland et al., 1984	(39)	nursing home patients (random selection), Dijon, France	31	29	nd	60-98	W5
Löwik et al., 1992	(19)	mentally competent nursing home (NH) patients or residents of service flats (SF), all >3 months resident, Amsterdam, The Netherlands	-	54 (NH) 29 (SF)	65 56	83 ± 8 81 ± 6	D
Marazzi et al., 1990	(21)	institutionalized elderly (>3 months resident), Rome, Italy	-	64	nd	60-90	R3
Suboticanec et al., 1989	(40)	residents (without acute disease) of 2 elderly homes, Zagreb, Yugoslavia	50	50	nd	65-80	R3
Testolin et al., 1986	(41)	inst. elderly (selfsufficient, no serious pathology), Northern Italy	28	57	nd	70+	W10

nd = not defined.
[a] D = dietary history; H = 24-hour recall; Rx = diet record (x = number of days); S = semi-quantitative food frequency questionnaire; Wx = weighed record (x = number of days).

Assessment of dietary intakes

Different techniques can be used in assessing dietary intakes. In this review, the methods most often used to collect information on nutrient intakes are dietary histories, 24-hour recalls, food records and food frequency questionnaires. Each method has its own advantages and drawbacks.[42] It is difficult to draw general conclusions from papers in which validity and reproducibility of dietary assessment methods in elderly subjects have been studied since purpose, design, target population, the estimation of portion sizes, reference method and time frame are different for most studies.

A 24-hour recall gives information in a simple and fast way in younger adults, but the results are not representative of the usual consumption of individuals. When studying large groups of people, this method gives an estimation of the usual dietary intake on an aggregate level, but no reliable information on the distribution of usual intake within groups.[43,44] It seems that due to a decline in short term memory with age, the 24-hour recall is an unreliable method in elderly people.[45] A dietary history, a food frequency questionnaire or a (seven day) weighed record seem to lead to more valid results.[46-49] When dietary records are used, the subject has to be highly motivated, willing and able to report accurate and detailed information.[48] Participants might change their dietary pattern during the record period to simplify the recording process. The weighed record seems to be the most accurate method for current food consumption measurement. For practical reasons this method is not often used in larger studies. A dietary history, including a food frequency check list, is a tedious and difficult interview and requires well trained interviewers. On the other hand, the regular food pattern can be measured in an accurate way.[48,50,51] There are indications however, that the dietary history method tends to overestimate food intakes compared to dietary records.[52]

From estimated food intakes, information on nutrient intakes can be calculated using food composition tables. Many Western countries have their own food composition tables, on the basis of which dietary nutrient intakes are calculated. The main advantage of country specific tables is that these include traditional dishes and products. As far as water-soluble vitamins are concerned, food composition tables are often incomplete. Most databases contain complete information with respect to thiamin, riboflavin and vitamin C content of foods. Fewer databases contain (complete) information with respect to vitamin B_6, folate or vitamin B_{12}.

In most studies where food consumption is measured, mean nutrient intakes are presented. However, the distribution of micronutrient intakes is often skewed to the right. This means that, although the intake might be adequate at a group level, it is possible that a substantial number of subjects have insufficient intakes of certain nutrients. Median intakes and percentile distributions give more insight into percentages of the people with intakes below the recommendations. Due to the large within subject day-to-day variation in dietary intake, the use of a one day observation period results in a greater apparent variation between subjects than would be observed if a longer observation period were used. Furthermore, the 24-hour recall tends to underestimate dietary intakes. Therefore dietary intake data, gathered by means of a 24-hour recall cannot be used to estimate percentages of people having adequate or inadequate levels of nutrient intakes.[53-55] Data reported as such are not included in this review.

Recommended dietary allowances

At a group level, the calculated nutrient intakes can be compared with dietary standards. In most Western countries dietary recommendations, most often referred to as Recommended Dietary Allowances (RDAs), have been published. RDAs for nutrients are based on the available scientific knowledge and are considered as the mean nutritional requirement of healthy persons plus two standard deviations (SDs) to cover the needs of most (98 per cent) individuals. They are presented by sex and age categories. Expanding knowledge of dietary needs of specific categories of people, has lead to changes in RDAs over time. Furthermore, most countries have their own expert committees which often results in country specific dietary recommendations.[1,56-63]

The RDAs for older people are most often extrapolations of the recommendations for healthy young adults. The main reason for that is that relatively few studies on nutritional needs of elderly people have been conducted. Thus comparison with RDAs alone is not sufficient to evaluate the adequacy of nutrient intakes.

Blood biochemistry

Biochemical measurements are indispensable in judging the adequacy of vitamin nutriture of people, although these values often do not reflect recent intakes. Factors like body stores, disease and medications also have an impact on blood values of the various nutrients. Analysis techniques are available to measure either blood concentration of the vitamin itself or to carry out functional tests (e.g. activity stimulation tests to judge the state of thiamin or riboflavin deficiency). The methodology for assessing vitamin nutriture has been described by others.[64-66]

Adequate intakes of nutrients do not necessarily imply an optimal nutritional status. Bioavailability problems, drug-nutrient interactions and underlying disease might cause biochemical or clinical deficiency despite adequate intakes.[67-70]

As for the RDAs, reference values of biochemical parameters are often based on values found in samples of healthy adults.[65] Therefore prevalence of low biochemical status needs to be interpreted with care.

RESULTS AND INTERPRETATION

In the following paragraphs the different dietary standards for each vitamin are presented, and the ability of the diet to meet nutritional needs is discussed for free-living as well as for institutionalized elderly people. Associations with the biochemical status parameters of the described vitamins are also discussed. Dietary intakes of thiamin, riboflavin, vitamin B_6, folate, vitamin B_{12} and vitamin C are presented in **Tables 2-7**.

Thiamin intake

Dietary standards

Recommendations for thiamin intake are often expressed as caloric densities. The 1989 RDA for thiamin intake in the USA[1] is unchanged compared to the 1980 edition[62] and is 0.5 mg/1000kCal for people aged 65 and over, with a minimum absolute intake of 1.2 mg/day for males and 1.0 mg/day for females who consume less than 2000 kCal per day. The Australian RDA is slightly lower (0.9 mg/day for males aged 65 years and over and 0.7 mg/day for females aged 54 years and over).[57-59] In Europe, the RDA ranges from 0.7 mg/day in Spanish elderly females, to 1.5 mg/day in elderly males and females in Greece and Belgium.[56]

Prevalence of dietary inadequacy

In **Table 2**, dietary thiamin intakes are presented. Mean dietary thiamin intake usually ranged from 1.1 to 2.0 mg/day in men, with the exception of all Italian studies where mean dietary intakes far below the recommendations were found.[6,8-10,28,31,32,41] For women the mean dietary thiamin intake ranged from 1.0 to 1.4 mg/day in most of the presented studies. As for males, the intakes were much lower in the Italian studies.[6,8-10,28,31,32,41] Löwik et al. found low mean intakes in apparently healthy women[18] as well as in female nursing home and service flat residents[19], but not as low as the Italian figures. Smidt et al.[33] also reported relatively low mean thiamin intakes (0.9 mg/day) in healthy Irish women. With the exception of two studies[6,33] in which the 24-hour recall was used, all of the studies which reported low mean thiamin intakes used either a dietary record with a recording period of at least seven days[28,31,41] or a dietary history[8-10,18,19,32] for dietary assessment. Reported median intakes tended to be slightly lower for both men and women in all studies where both mean and median intakes were presented.[5,8-10,12,14,24,27,28,71,72]

Table 2. Dietary thiamin intakes (mg/day) and dietary adequacy.

Author	Reference	Sub-sample	Sex	Mean	SEM	p10	p50	p90	Dietary adequacy[a]
Free-living elderly:									
Baghurst and Record, 1987	(5)	-	M	1.37	nd	nd	1.20	nd	11% < RDA[b]
			F	1.16			1.08		6% < RDA
Bianchetti et al., 1990	(6)	-	M	nd	nd	nd	nd	nd	96% < ⅔RDA[c]
			F						92% < ⅔RDA
Boston Nutritional Status Survey, 1992	(7,71)	60-69yrs	M	1.60	0.06	nd	1.59	nd	4% < ⅔RDA[c]
			F	1.19	0.03		1.13		5% < ⅔RDA
		70-79yrs	M	1.49	0.05		1.42		2% < ⅔RDA
			F	1.17	0.03		1.09		5% < ⅔RDA
		80⁺yrs	M	1.44	0.07		1.36		5% < ⅔RDA
			F	1.20	0.04		1.13		4% < ⅔RDA
Contaldo et al., 1986	(8)	-	M	0.7	0.03	0.40	0.65	1.1	nd
			F	0.57	0.02	0.30	0.55	0.80	

- continued -

Author	Reference	Sub-sample	Sex	Mean	SEM	p10	p50	p90	Dietary adequacy[a]
Fidanza et al., 1984	(9)	65-70yrs	M	0.93	0.04	0.60	0.82	nd	nd
			F	0.76	0.03	0.45	0.74		
		70^{+} yrs	M	0.88	0.05	0.47	0.80		
			F	0.71	0.03	0.48	0.67		
Fidanza et al., 1991	(10)	-	M	0.83	0.04	0.55	0.78	1.04	nd
			F	0.75	0.03	0.44	0.74	1.05	
Garry et al., 1982	(11)	-	M	nd	nd	nd	nd	nd	27% < RDA[c]
			F						47% < RDA
Gray et al., 1983	(12)	-	F	1.24	0.07	nd	1.16	nd	0% < ⅔RDA[c]
Herbeth et al., 1989	(13)	-	M	1.17	0.02	nd	nd	nd	nd
			F	1.02	0.02				
Horwath, 1989	(14)	-	M	1.23	0.01	nd	1.20	nd	2% < ⅔RDA[b]
			F	1.15	0.01		1.10		1% < ⅔RDA
Horwath et al., 1992	(15)	-	M	1.22	0.02	nd	nd	nd	1% < ⅔RDA[b]
			F	1.14	0.02				1% < ⅔RDA
Koehler et al., 1992	(16)	-	M	1.5	nd	nd	nd	nd	nd
			F	1.2					
Kohrs et al., 1980	(17)	participate congregate hot-meal programs (0,<2, 2-5 times/wk)	M (0)	1.26	0.08	nd	nd	nd	± 50% of all participants < RDA[d]
			M (<2)	1.40	0.06				
			M (2-5)	1.35	0.07				
			F (0)	1.03	0.05				
			F (<2)	1.01	0.03				
			F (2-5)	1.11	0.04				
Löwik et al., 1989	(18)	-	M	1.11	0.01	nd	nd	nd	nd
			F	0.93	0.01				
Löwik et al., 1992	(19)	-	F	1.06	0.03	nd	nd	nd	nd
Mensink and Arab, 1989	(22)	phys. act.	M	1.11	0.04	nd	nd	nd	nd
			F	1.01	0.04				
		less active	M	1.13	0.03				
			F	1.00	0.03				
Millen Posner et al., 1987	(23)	-	F	1.1	0.17	nd	nd	nd	62% < RDA[c]
NHANESII, 1983	(24)	-	M	1.33	0.03	0.61	1.13	2.25	nd
			F	0.99	0.02	0.45	0.85	1.58	
Nordström et al., 1988	(25)	-	M	1.6	0.05	nd	nd	nd	nd
			F	1.3	0.04				
O'Hanlon et al., 1983	(26)	-	M	nd	nd	nd	nd	nd	8% < ⅔RDA[d]
			F						13% < ⅔RDA

- continued -

Author	Reference	Sub-sample	Sex	Mean	SEM	p10	p50	p90	Dietary adequacy[a]
Payette and Gray-Donald, 1991	(27)	-	M	1.55	0.12	nd	1.56	nd	9% < ⅔RDA[e]
			F	1.20	0.07		1.12		11% < ⅔RDA
Porrini et al., 1987	(28)	60-69 yrs	M	0.72	0.04	0.43	0.68	1.02	nd
			F	0.60	0.02	0.34	0.57	0.90	
		70⁺ yrs	M	0.71	0.04	0.40	0.65	0.98	
			F	0.56	0.02	0.36	0.55	0.75	
Räsänen et al., 1992	(29)	-	M	2.00	0.04	nd	nd	nd	nd
Ryan et al., 1992	(30)	65-74 yrs	M	1.6	0.1	nd	nd	nd	16% < ⅔RDA[f]
			F	1.4	0.1				13% < ⅔RDA
		74⁺ yrs	M	1.5	0.1				12% < ⅔RDA
			F	1.2	0.1				16% < ⅔RDA
Scaccini et al., 1992	(31)	-	M	0.77	0.01	nd	nd	nd	6% < ⅔RDA[g]
			F	0.66	0.01				2% < ⅔RDA
SENECA investigators, 1991	(32)	H/B	M	nd	nd	0.82	1.18	1.65	9% < RDA[h]
			F			0.77	1.04	1.39	5% < RDA
		R/DK	M			0.90	1.20	1.60	4% < RDA
			F			0.60	1.00	1.30	10% < RDA
		H/F	M			0.75	1.10	1.67	17% < RDA
			F			0.53	0.92	1.61	19% < RDA
		R/F	M			0.74	1.18	1.98	13% < RDA
			F			0.67	0.88	1.43	15% < RDA
		AA/GR	M			0.83	1.27	2.13	10% < RDA
			F			0.50	0.83	1.13	31% < RDA
		P/I	M			0.52	0.84	1.22	44% < RDA
			F			0.47	0.71	1.12	48% < RDA
		FMP/I	M			0.68	1.06	1.48	22% < RDA
			F			0.55	0.82	1.12	38% < RDA
		C/NL	M			0.87	1.24	1.60	3% < RDA
			F			0.71	0.94	1.29	7% < RDA
		E/N	M			0.85	1.11	1.34	6% < RDA
			F			0.75	0.91	1.09	0% < RDA
		V/P	M			0.68	1.25	1.97	19% < RDA
			F			0.44	0.80	1.38	37% < RDA
		B/E	M			0.85	1.31	1.96	8% < RDA
			F			0.81	1.21	2.11	4% < RDA
		Y/CH	M			0.61	0.90	1.30	37% < RDA
			F			0.59	0.76	1.13	36% < RDA
		Bu/CH	M			0.81	1.21	1.53	10% < RDA
			F			0.67	0.98	1.32	17% < RDA
		Be/CH	M			0.64	0.91	1.35	30% < RDA
			F			0.57	0.82	1.34	23% < RDA
Smidt et al., 1991	(33)	-	F	0.91	0.11	nd	nd	nd	nd
Somogyi and Kopp, 1983	(34)	-	F	1.2	0.05	nd	nd	nd	nd
Walker and Beauchene, 1991	(35)	-	F	1.08	0.06	nd	nd	nd	nd

- continued -

Author	Reference	Sub-sample	Sex	Mean	SEM	p10	p50	p90	Dietary adequacy[a]
Yearick et al., 1980	(36)	-	M F	1.33 1.16	0.1 0.1	nd	nd	nd	12% < ⅔RDA[d] 17% < ⅔RDA
Institutionalized elderly:									
Boston Nutritional Status Survey, 1992	(7,72)	age groups combined	M F	1.5 1.3	0.04 0.02	nd	1.4 1.3	nd	2% < ⅔RDA[c] 4% < ⅔RDA
Ferro-Luzzi et al., 1988	(37)	light-drinking	M F	nd	nd	nd	0.71 0.63	nd	nd
		heavier drinking	M F				0.70 0.66		
Löwik et al., 1992	(19)	nurs. home service flat	F F	0.65 0.85	0.02 0.03	nd	nd	nd	nd
Suboticanec et al., 1989	(40)	-	M F	1.1 1.0	0.06 0.06	nd	nd	nd	nd
Testolin et al., 1986	(41)	-	M F	0.66 0.56	0.03 0.02	0.48 0.37	0.67 0.56	0.96 0.72	nd

nd = not defined.
a Several versions of the RDA have been used as reference, see other footnotes.
b Australian NHMRC RDA for men (0.9 mg/day) and women (0.7 mg/day) 65⁺ years, 1982.[67,68]
c United States NRC RDA for men (1.2 mg/day) and women (1.0 mg/day) 51⁺ years, 1980.[62]
d United States NRC RDA for men (1.2 mg/day) and women (1.0 mg/day), 1974.
e Canadian RDA 0.8 mg/day for both men and women, 1990.[63]
f United States NRC RDA for men (1.2 mg/day) and women (1.0 mg/day) 51⁺ years, 1989.[1]
g LARN, Italian RDA, 1989.
h Reference used 0.8 mg/day for males and 0.7 mg/day for females.

Although in general the mean intakes were found to be adequate, a number of studies reported that a substantial part of the study population had dietary thiamin intakes below the recommendations. Garry et al.[11] used a three day dietary record and concluded that 27 per cent of the men and 47 per cent of the women had dietary thiamin intakes below the 1980 USA recommendations, but no absolute figures were presented. Kohrs et al.[17] reported that over 50 per cent of the total population had dietary thiamin intakes below the USA 1974 recommendations. In the SENECA study, low dietary thiamin intakes were reported for both men and women living in mediterranean towns - with the exception of the Spanish men and women and the Greek men -, as well as in the elderly people living in two of the Swiss towns studied.[32] In the SENECA study the intakes were compared with the lowest dietary recommendations in Europe, which are 0.8

mg/day for males and 0.7 mg/day for females.

To relate thiamin intakes to nutritional status, in ten studies erythrocyte transketolase (ETK) activity was reported as a measure of thiamin status.[8,10,13,22,28,33,34,40,41,72-74] With the exception of the free-living population in the Boston Nutritional Status Survey[74], in which a significant relationship between thiamin intake and the ETK activity coefficient was found, no significant correlations between thiamin intake and thiamin status were found in the reported studies. Two studies[33,75] reported the thiamindiphosphate effect (TPP%) thiamin status indicator. The mean ETK activity coefficients range from 1.02[41] to 1.17[34] and were found to be normal for most subjects. An activity coefficient of 1.17 is often used as an upper cut-off value for slight biochemical deficiency. In two Italian studies[28,41] ten per cent of the subjects had an ETK activity coefficient above 1.17 and in one Italian study[8] this was the case in twenty per cent of the subjects. Another Italian study[75] reported 25 per cent of the subjects as being mildly to severely thiamin deficient (TPP% > 15). Smidt et al. reported that almost half of the subjects exhibited a deficient thiamin status.[33] Somogyi and Kopp even concluded that 40 per cent of their study population were slightly thiamin deficient.[34] Although only in one study significant correlations with intake were found, it seems that studies in which a high prevalence of biochemical thiamin deficiency was observed, also showed a high percentage of people having inadequate dietary intakes of thiamin. According to one of the research groups, a possible explanation for absence of correlation between dietary intake figures and biochemical status might be the limited range of thiamin intakes, small sample size or inaccuracy of nutrient composition tables.[73]

From these studies we conclude that in general thiamin intakes seem to be adequate in most of the older people. Lower intake figures have been found for the Italian elderly, and in homes for the elderly. Biochemical figures are in line with this conclusion.

Riboflavin intake

Dietary standards

In the USA, a riboflavin intake of at least 1.4 mg/day for males and 1.2 mg/day for females aged 51 years and over is recommended.[1,62] The Australian recommendations are 1.3 mg/day for males aged 64 years and over and 1.0 mg/day for females aged 54 years and over.[57-59] In Europe, the RDA for riboflavin ranges between 1.0 mg/day for elderly females in Spain and 1.8 mg/day for elderly males in France.[56] Most riboflavin recommendations for elderly Europeans aged 65 years and over are slightly higher than the USA recommendations.[56]

Prevalence of dietary inadequacy

Dietary riboflavin intakes are listed in **Table 3.** Relatively few of the studied elderly people had low riboflavin intakes. Mean dietary riboflavin intakes of free-living elderly men exceeded 1.5 mg/day in 14 of the 23 studies. As for thiamin intake, five Italian studies reported much lower mean intakes (ranging from 0.95 to 1.33 mg/day).[8-10,28,31] A study in Germany also showed lower mean intakes (1.42 and 1.32 mg/day for physically active and less active men respectively).[22] In the SENECA study, relatively low median dietary intakes ranging from 1.33 to 1.43 mg/day were found for men in towns in Belgium, Greece, Italy and Switzerland.[32]

In most of the free-living elderly women studied mean intakes ranged from 1.2 to 2.1 mg/day. As for the Italian men, Italian women had lower mean intakes, ranging from 0.88 to 1.16 mg/day.[8-10,28,31] Median intakes below 1.2 mg/day were reported in the SENECA study for women in towns in Belgium, Greece and Portugal.[32]

Table 3. Dietary riboflavin intakes (mg/day) and dietary adequacy.

Author	Reference	Sub-sample	Sex	Mean	SEM	p10	p50	p90	Dietary adequacy[a]
Free-living elderly:									
Baghurst and Record, 1987	(5)	-	M	2.18	nd	nd	1.94	nd	4% < RDA[b]
			F	1.91			1.80		4% < RDA
Boston Nutritional Status Survey, 1992	(7,71)	60-69yrs	M	2.04	0.07	nd	1.95	nd	3% < ⅔RDA[c]
			F	1.58	0.04		1.50		3% < ⅔RDA
		70-79yrs	M	1.98	0.08		1.81		2% < ⅔RDA
			F	1.59	0.05		1.46		3% < ⅔RDA
		80+ yrs	M	1.96	0.08		1.92		0% < ⅔RDA
			F	1.60	0.05		1.45		2% < ⅔RDA

- continued -

Author	Reference	Sub-sample	Sex	Mean	SEM	p10	p50	p90	Dietary adequacy[a]
Contaldo et al., 1986	(8)	-	M	1.2	0.04	0.70	1.1	1.6	nd
			F	1.05	0.04	0.60	1.0	1.6	
Fidanza et al., 1984	(9)	65-70yrs	M	0.95	0.05	0.58	0.90	nd	nd
			F	0.94	0.05	0.52	0.89		
		70⁺ yrs	M	0.96	0.05	0.51	0.85		
			F	0.88	0.04	0.52	0.83		
Fidanza et al., 1991	(10)	-	M	0.99	0.05	0.55	0.96	1.46	nd
			F	0.99	0.06	0.54	0.89	1.59	
Garry et al., 1982	(11,76)	-	M	1.86	0.06	nd	1.70	nd	16% < RDA[c]
			F	1.58	0.06		1.39		29% < RDA
Gray et al., 1983	(12)	-	F	1.66	0.11	nd	1.56	nd	9% < ⅔RDA[c]
Herbeth et al., 1989	(13)	-	M	1.49	0.03	nd	nd	nd	nd
			F	1.29	0.04				
Horwath, 1989	(14)	-	M	2.16	0.03	nd	2.10	nd	2% < ⅔RDA[b]
			F	2.05	0.02		2.00		2% < ⅔RDA
Horwath et al., 1992	(15)	-	M	1.73	0.04	nd	nd	nd	4% < ⅔RDA[c]
			F	1.62	0.03				2% < ⅔RDA
Koehler et al., 1992	(16)	-	M	2.0	nd	nd	nd	nd	nd
			F	1.5					
Kohrs et al., 1980	(17)	participate congregate hot-meal programs (0,<2, 2-5 times/wk)	M (0)	2.19	0.15	nd	nd	nd	± 15% of all participants < RDA[d]
			M (<2)	2.24	0.11				
			M (2-5)	2.28	0.10				
			F (0)	1.90	0.11				
			F (<2)	1.74	0.06				
			F (2-5)	2.02	0.10				
Löwik et al., 1989	(18)	-	M	1.70	0.03	nd	nd	nd	nd
			F	1.51	0.03				
Löwik et al., 1992	(19)	-	F	1.91	0.05	nd	nd	nd	nd
Mensink and Arab, 1989	(22)	phys. act.	M	1.42	0.05	nd	nd	nd	nd
			F	1.37	0.06				
		less active	M	1.32	0.04				
			F	1.22	0.03				
Millen Posner et al., 1987	(23)	-	F	1.4	0.22	nd	nd	nd	62% < RDA[c]
NHANESII, 1983	(24)	-	M	1.84	0.04	0.76	1.56	3.03	nd
			F	1.36	0.04	0.54	1.13	2.26	
Nordström et al., 1988	(25)	-	M	2.0	0.06	nd	nd	nd	nd
			F	1.7	0.05				

- continued -

Author	Reference	Sub-sample	Sex	Mean	SEM	p10	p50	p90	Dietary adequacy[a]
O'Hanlon et al., 1983	(26)	-	M	nd	nd	nd	nd	nd	6% < ⅔RDA[d]
			F						3% < ⅔RDA
Payette and Gray-Donald, 1991	(27)	-	M	1.53	0.08	nd	1.53	nd	14% < ⅔RDA[e]
			F	1.20	0.05		1.16		21% < ⅔RDA
Porrini et al., 1987	(28)	60-69 yrs	M	1.33	0.08	0.75	1.24	1.97	nd
			F	1.16	0.06	0.66	1.06	1.90	
		70+ yrs	M	1.26	0.08	0.70	1.17	1.86	
			F	1.08	0.05	0.57	1.00	1.67	
Räsänen et al., 1992	(29)	-	M	3.0	0.07	nd	nd	nd	nd
Ryan et al., 1992	(30)	65-74 yrs	M	1.9	0.1	nd	nd	nd	18% < ⅔RDA[f]
			F	1.6	0.1				10% < ⅔RDA
		74+ yrs	M	1.8	0.2				12% < ⅔RDA
			F	1.4	0.1				13% < ⅔RDA
Scaccini et al., 1992	(31)	-	M	1.27	0.02	nd	nd	nd	7% < ⅔RDA[g]
			F	1.08	0.02				4% < ⅔RDA
SENECA investigators, 1991	(32)	H/B	M	nd	nd	0.86	1.34	1.93	38% < RDA[h]
			F			0.82	1.17	1.59	22% < RDA
		R/DK	M			1.40	2.00	2.80	2% < RDA
			F			1.10	1.70	2.50	5% < RDA
		H/F	M			1.03	1.58	2.67	24% < RDA
			F			0.99	1.49	3.20	13% < RDA
		R/F	M			1.14	1.69	3.20	12% < RDA
			F			0.96	1.47	3.03	12% < RDA
		AA/GR	M			0.95	1.43	2.44	29% < RDA
			F			0.50	0.88	1.52	56% < RDA
		P/I	M			1.00	1.42	2.27	24% < RDA
			F			0.87	1.30	2.10	23% < RDA
		FMP/I	M			0.96	1.63	2.20	25% < RDA
			F			0.86	1.26	1.88	31% < RDA
		C/NL	M			1.13	1.73	2.26	16% < RDA
			F			1.01	1.52	2.11	9% < RDA
		E/N	M			1.17	1.65	2.05	16% < RDA
			F			1.10	1.37	1.78	4% < RDA
		V/P	M			0.81	1.57	2.46	24% < RDA
			F			0.61	1.11	2.15	40% < RDA
		B/E	M			1.15	1.73	2.59	10% < RDA
			F			1.05	1.67	2.54	9% < RDA
		Y/CH	M			0.97	1.48	2.16	25% < RDA
			F			0.78	1.25	1.71	23% < RDA
		Bu/CH	M			1.20	1.72	2.31	10% < RDA
			F			1.15	1.52	2.22	3% < RDA
		Be/CH	M			1.05	1.33	2.00	23% < RDA
			F			0.83	1.35	1.92	27% < RDA
Somogyi and Kopp, 1983	(34)	-	F	1.7	0.05	nd	nd	nd	nd

- continued -

Author	Reference	Sub-sample	Sex	Mean	SEM	p10	p50	p90	Dietary adequacy[a]
Walker and Beauchene, 1991	(35)	-	F	1.51	0.01	nd	nd	nd	nd
Yearick et al., 1980	(36)	-	M F	2.12 1.51	0.14 0.07	nd	nd	nd	12% < ⅔RDA[d] 17% < ⅔RDA
Institutionalized elderly:									
Boston Nutritional Status Survey, 1992	(7,72)	age groups combined	M F	2.1 1.9	0.05 0.04	nd	2.1 1.9	nd	0% < ⅔RDA[c] 1% < ⅔RDA
Ferro-Luzzi et al., 1988	(37)	light-drinking heavier drinking	M F M F	nd	nd	nd	1.31 1.16 1.34 1.11	nd	nd
Gonzalez-Gross et al., 1991	(38)	-	M F	1.55 1.61	0.10 0.06	nd	nd	nd	nd
Löwik et al., 1992	(19)	nurs. home service flat	F F	1.37 1.62	0.07 0.09	nd	nd	nd	nd
Suboticanec et al., 1989	(40)	-	M F	1.7 1.5	0.08 0.07	nd	nd	nd	nd
Testolin et al., 1986	(41)	-	M F	1.82 1.50	0.07 0.05	1.34 0.94	1.87 1.47	2.29 2.07	nd

nd = not defined.
[a] Several versions of the RDA have been used as reference, see other footnotes.
[b] Australian NHMRC RDA for men (1.3 mg/day) and women (1.0 mg/day) 65$^+$ years, 1982.[57,58]
[c] United States NRC RDA for men (1.4 mg/day) and women (1.2 mg/day) 51$^+$ years, 1980.[62]
[d] United States NRC RDA for men (1.2 mg/day) and women (1.0 mg/day), 1974.
[e] Canadian RDA 1.0 mg/day for both men and women, 1990.[63]
[f] United States NRC RDA for men (1.4 mg/day) and women (1.2 mg/day) 51$^+$ years, 1989.[1]
[g] LARN, Italian RDA, 1989.
[h] Reference used 1.0 mg/day for both men and women.

With the exception of Ferro-Luzzi et al.[37] who found a median dietary riboflavin intake below 1.5 mg/day in men and below 1.2 mg/day in women, all studies among institutionalized elderly men showed satisfactory mean dietary intakes.

When compared to the dietary recommendations, a few studies reported a relatively high prevalence of low dietary riboflavin intakes.[11,27,32,36,76] One of the worst situations was reported in a study in Canada[27], where 14 per cent of the men and 21 per cent of the women were found to have riboflavin intakes below two-thirds of the Canadian RDA.[63] The recommendations for riboflavin intakes in

Canada (1 mg/day for both males and females) are lower than the RDA in the USA.[1] In the SENECA study[32], dietary riboflavin intakes in 8 of the 14 larger study samples were below 1.0 mg/day in 24 to 38 per cent of the elderly men. In these centres, with the exception of a town in France (H/F), the prevalence of elderly women consuming less than 1.0 mg riboflavin per day from diet alone ranged from 22 to 56 per cent. Garry et al.[11] reported that 16 per cent of the males and 29 per cent of the females had dietary riboflavin intakes below the USA 1980 RDA. Yearick et al.[36] found dietary intakes below the USA 1974 RDA (1.5 and 1.1 mg/day for males and females respectively) in 20 per cent of the males and 29 per cent of the females. In the latter two studies a three day dietary record was used, which may lead to under-reporting unless the population is highly motivated.

The erythrocyte glutathione reductase (EGR) activity, which is a commonly used biochemical measure of riboflavin nutriture, was reported in 14 studies.[8,10,13,22,28,34,37,38,40,41,72,73,75-78] The mean activity coefficients range from 1.00 in elderly German women[22] to 1.32 in institutionalized elderly men in former Yugoslavia.[40] Using an activity coefficient of 1.20 as a cut-off point, in eight studies ten to twenty per cent of the people under study were found to be at risk for riboflavin deficiency.[8,19,28,37,38,41,73,75] In four studies the riboflavin status was found to be adequate in all participants.[22,34,72,78] Garry et al.[76] used an EGR activity coefficient of 1.35 as cut-off point and concluded that only three subjects had a poor riboflavin nutriture.

Significant correlations between riboflavin intake and the EGR activity coefficient were found in women by Fidanza et al.[10,73](r = -0.22 at the fifth year follow up and r = -0.33 at the eleventh year follow up) and by Herbeth et al.[13] in the total population (r = -0.21). Garry et al.[76] found that 28 per cent of the variability in EGR activity coefficient could be accounted for by total daily riboflavin intake. In the Boston Nutritional Status Survey[77] a 3.5-fold increase in the riboflavin intake was found to be associated with a 0.05 decrease in the EGR activity coefficient for free-living subjects and for institutionalized females. A 74 per cent increase in the riboflavin intakes of institutionalized males resulted in and equivalent decrease in the EGR activity coefficient.

In general it can be concluded that, with the exception of a few studies with a high prevalence of low intakes, the dietary riboflavin intake is satisfactory for free-living as well as for institutionalized elderly people in Western society. The low incidence of biochemical riboflavin deficiency supports this conclusion.

Vitamin B_6 intake

Dietary standards

In the ninth edition (1980) of the USA dietary recommendations vitamin B_6 minimum intakes of 2.2 mg/day and 2.0 mg/day were recommended respectively for males and females aged 51 years and over.[62] In the tenth edition, these recommendations have been lowered to 2.0 and 1.6 mg/day respectively for males and females in this age category.[1] The latter recommendations are based on a figure of 0.016 mg/g protein compared to the 0.020 mg/g protein used in the previous edition. However, it was concluded by the subcommittee working on the vitamin B_6 recommendations that the latter figure was higher than could be justified by requirement studies.[1] The Australian dietary recommendations for vitamin B_6 are presented as a range, 1.0 - 1.5 mg/day for males aged 65 years and over and 0.8 - 1.1 mg/day for females aged 54 years and over, based on 0.02 mg/g dietary protein.[57-59] In a review by Trichopoulou and Vassilakou[56], no information has been reported with respect to vitamin B_6 recommendations in Europe. In the Netherlands, 0.02 mg/g protein is recommended in both elderly males and females, with a minimum of 1.2 mg/day for males and 1.0 mg/day for females aged 65 years and over.[60]

Prevalence of dietary inadequacy

In 16 studies vitamin B_6 intakes were reported. In these studies, listed in **Table 4**, mean intakes in elderly men ranged from 1.04 (male nursing home residents, studied by Guilland et al.) to 1.9 mg/day (men aged 65-74 years, studied by Ryan et al. and men aged 60 years and over, studied by Manore et al.). In women, the intakes ranged from 0.82 (women living in a nursing home, studied by Löwik et al.) to 1.7 mg/day (women aged 65-74 years, studied by Ryan et al.).[19,20,30,39] The 'younger' elderly women in the study of Ryan et al.[30] were the only group with a mean vitamin B_6 intake above the 1989 USA recommendations. However, since data on the vitamin B_6 content of many foods are not available in some of the present nutrient databases, the dietary intake results need to be interpreted with some reservation.

In the SENECA study[32] median dietary vitamin B_6 intakes in elderly Europeans aged 70-75 years ranged from 1.07 to 1.71 mg/day in men and from 0.75 to 1.48 mg/day in women. The highest prevalence of vitamin B_6 intakes below the lowest RDA in Europe (1.0 and 0.8 mg/day respectively for males and females) were found in two towns in Switzerland (40 and 33 per cent), and one town in Greece (32 per cent) for males, and in two towns in Switzerland (23 and 13 per cent) and one town in Denmark (11 per cent) for females.

Table 4. Dietary vitamin B_6 intakes (mg/day) and dietary adequacy.

Author	Reference	Sub-sample	Sex	Mean	SEM	p10	p50	p90	Dietary adequacy[a]
Free-living elderly:									
Baghurst and Record, 1987	(5)	-	M	1.43	nd	nd	1.32	nd	20% < RDA[b]
			F	1.37			1.25		9% < RDA
Bianchetti et al., 1990	(6)	-	M	nd	nd	nd	nd	nd	93% < ⅔RDA[c]
			F						93% < ⅔RDA
Boston Nutritional Status Survey, 1992	(7,71)	60-69 yrs	M	1.42	0.07	nd	1.26	nd	63% < ⅔RDA[c]
			F	1.13	0.05		0.98		70% < ⅔RDA
		70-79 yrs	M	1.35	0.06		1.22		67% < ⅔RDA
			F	1.09	0.03		0.99		75% < ⅔RDA
		80^+ yrs	M	1.19	0.06		1.11		74% < ⅔RDA
			F	1.08	0.05		1.04		74% < ⅔RDA
Garry et al., 1982	(11)	-	M	nd	nd	nd	nd	nd	94% < RDA[c]
			F						97% < RDA
Herbeth et al., 1989	(13)	-	M	1.68	0.04	nd	nd	nd	nd
			F	1.42	0.03				
Horwath, 1989	(14)	-	M	1.29	0.01	nd	1.30	nd	3% < ⅔RDA[b]
			F	1.26	0.01		1.20		2% < ⅔RDA
Horwath et al., 1992	(15)	-	M	1.32	0.02	nd	nd	nd	1% < ⅔RDA[b]
			F	1.27	0.02				0% < ⅔RDA
Löwik et al., 1989	(18)	-	M	1.38	0.02	nd	nd	nd	nd
			F	1.15	0.02				
Löwik et al., 1992	(19)	-	F	1.44	0.04	nd	nd	nd	nd
Manore et al., 1989	(20)	-	M	1.9	0.08	nd	nd	nd	18% < ⅔RDA[c]
			F	1.5	0.06				36% < ⅔RDA
Mensink and Arab, 1989	(22)	phys. act.	M	1.5	0.05	nd	nd	nd	nd
			F	1.4	0.05				
		less active	M	1.5	0.04				
			F	1.3	0.03				

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Author	Reference	Sub-sample	Sex	Mean	SEM	p10	p50	p90	Dietary adequacy[a]
NHANESII, 1983	(94)	white	M	1.57	0.03	nd	1.36	nd	81% < RDA[c]
		black	M	1.19	0.09		0.98		92% < RDA
		white	F	1.13	0.02		0.98		94% < RDA
		black	F	0.98	0.07		0.81		90% < RDA
Payette and Gray-Donald, 1991	(27)	-	M	1.45	0.08	nd	1.35	nd	0% < ⅔RDA[d]
			F	1.28	0.06		1.26		0% < ⅔RDA
Ryan et al., 1992	(30)	65-74 yrs	M	1.9	0.1	nd	nd	nd	38% < ⅔RDA[e]
			F	1.7	0.1				28% < ⅔RDA
		74⁺ yrs	M	1.8	0.2				31% < ⅔RDA
			F	1.5	0.1				38% < ⅔RDA
SENECA investigators, 1991	(32)	H/B	M	nd	nd	1.02	1.48	2.14	9% < RDA[f]
			F			0.89	1.24	1.69	1% < RDA
		R/DK	M			1.00	1.40	1.90	8% < RDA
			F			0.70	1.10	1.50	11% < RDA
		H/F	M			1.23	1.71	2.25	3% < RDA
			F			1.03	1.48	2.20	3% < RDA
		R/F	M			1.17	1.68	2.40	4% < RDA
			F			0.94	1.31	1.85	2% < RDA
		AA/GR	M			0.83	1.13	1.96	32% < RDA
			F			0.48	0.75	1.02	2% < RDA
		C/NL	M			1.21	1.71	2.28	2% < RDA
			F			0.96	1.33	1.83	3% < RDA
		V/P	M			1.07	1.67	2.45	9% < RDA
			F			0.81	1.23	1.90	1% < RDA
		B/E	M			0.78	1.46	2.13	20% < RDA
			F			0.75	1.35	2.32	1% < RDA
		Y/CH	M			0.79	1.07	1.46	40% < RDA
			F			0.64	0.95	1.24	3% < RDA
		Bu/CH	M			0.86	1.22	1.56	33% < RDA
			F			0.73	0.96	1.41	23% < RDA
		Be/CH	M			0.86	1.25	1.79	23% < RDA
			F			0.76	1.13	1.82	13% < RDA
Institutionalized elderly:									
Boston Nutritional Status Survey, 1992	(7,72)	age groups combined	M	1.3	0.05	nd	1.2	nd	72% < ⅔RDA[c]
			F	1.2	0.03		1.2		73% < ⅔RDA
Guilland et al., 1984	(39)	-	M	1.04	0.01	nd	nd	nd	100% < RDA[c]
			F	1.02	0.01				100% < RDA
Löwik et al., 1992	(19)	nurs. home	F	0.82	0.03	nd	nd	nd	nd
		service flat	F	1.13	0.05				

nd = not defined.

[a] Several versions of the RDA have been used as reference, see other footnotes.

[b] Australian NHMRC RDA (lower end of the range) for men (1.0 mg/day) and women (0.8 mg/day) 65⁺ years, 1982.[57,58]

[c] United States NRC RDA for men (2.2 mg/day) and women (2.0 mg/day) 51⁺ years, 1980.[62]

[d] Canadian RDA 0.015 mg/g protein for both men and women, 1990.[63]

[e] United States NRC RDA for men (2.0 mg/day) and women (1.6 mg/day) 51⁺ years, 1989.[1]

[f] Reference used 1.0 mg/day for both men and women.

The biochemical status of vitamin B_6 is often measured by its coenzymatically active form pyridoxal-5-phosphate (PLP) or by measuring the activity coefficients of erythrocyte aspartate aminotransferase (EAST), formerly referred to as EGOT (glutamic oxaloacetic transaminase). Ten of the here presented studies reported at least one of these biochemical indicators of vitamin B_6 status.[10,13,20,28,39,40,72,78-81] Although the incidence of an inadequate biochemical vitamin B_6 status was rather high in most studies, which is consistent with the relatively low dietary intakes, positive associations between dietary intakes of vitamin B_6 and PLP concentrations were reported only by Löwik et al.[80]($r=0.32$ among female nursing home patients and $r=0.27$ among independently living women). Herbeth et al.[13] found a negative correlation between intake of vitamin B_6 and EGOT activity coefficient ($r=-0.17$). A recent study by Bode et al.[82] showed that vitamin B_6 body pools in healthy rats are redistributed during ageing. This may be an age related physiological process and as a result it was concluded that plasma PLP levels observed in healthy elderly cannot be checked against normal ranges for young adults to assess vitamin B_6 status. Readjustment of the RDA for this vitamin for elderly people should therefore probably not be based on low plasma PLP levels compared to those of young adults.[82]

This review shows that in most studies mean or median vitamin B_6 intakes are below the most recent country specific dietary recommendations and indicate that a substantial proportion of the free-living as well as the institutionalized elderly subjects may have a marginal vitamin B_6 intake from diet alone. Further studies are required to determine the 'normal' PLP levels in elderly as compared to young adults and also to study the health implications at present intakes.

Folate intake

Dietary standards

In the USA, the recommendations for folate intake are 200 μg/day and 180 μg/day respectively for males and females aged 51 years and over.[1] This means a reduction of fifty per cent in comparison with the 1980 RDA (400 μg/day for both elderly males and females aged 51 years and over).[62] The reason for lowering the folate RDA is based on studies which show that diets containing half as much folate as the 1980 RDA maintain adequate folate status.[1,83] In Australia 200 μg folate per day is recommended for all age categories.[57-59] The RDA in Europe for folate have not been reported in the review by Trichopoulou and Vassilakou.[56] In the Netherlands, 200-300 μg/day is recommended for both elderly males and females aged 65 years and over.[60]

Table 5. Dietary folate intakes (μg/day) and dietary adequacy.

Author	Reference	Sub-sample	Sex	Mean	SEM	p10	p50	p90	Dietary adequacy[a]
Free-living elderly:									
Baghurst and Record, 1987	(5)	-	M	292	nd	nd	255	nd	28% < RDA[b]
			F	277			256		30% < RDA
Boston Nutritional Status Survey, 1992	(7,71)	60-69 yrs	M	282	13.7	nd	245	nd	56% < ⅔RDA[c]
			F	239	7.9		216		70% < ⅔RDA
		70-79 yrs	M	278	12.1		263		52% < ⅔RDA
			F	230	6.9		211		74% < ⅔RDA
		80$^+$ yrs	M	260	19.6		244		60% < ⅔RDA
			F	242	11.0		218		69% < ⅔RDA
Garry et al., 1982	(11)	-	M	nd	nd	nd	nd	nd	86% < RDA[c]
			F						91% < RDA
Horwath, 1989	(14)	-	M	193	2.1	nd	187	nd	16% < ⅔RDA[b]
			F	189	2.0		182		21% < ⅔RDA
Horwath et al., 1992	(15)	-	M	233	4.3	nd	nd	nd	4% < ⅔RDA[b]
			F	227	3.0				5% < ⅔RDA
Millen Posner et al., 1987	(23)	-	M	162	26.8	nd	nd	nd	nd
			F						
Payette and Gray-Donald, 1991	(27)	-	M	177	10.1	nd	173	nd	40% < ⅔RDA[d]
			F	165	9.0		150		28% < ⅔RDA
Ryan et al., 1992	(30)	65-74 yrs	M	277	22.0	nd	nd	nd	22% < ⅔RDA[e]
			F	268	17.8				15% < ⅔RDA
		74$^+$ yrs	M	248	31.7				21% < ⅔RDA
			F	228	18.6				27% < ⅔RDA
Institutionalized elderly:									
Boston Nutritional Status Survey, 1992	(7,72)	age groups combined	M	271	9.0	nd	265	nd	52% < ⅔RDA[c]
			F	239	5.0		244		65% < ⅔RDA

nd = not defined.

[a] Several versions of the RDA have been used as reference, see other footnotes.

[b] Australian NHMRC RDA 200 μg/day for both men and women aged 65$^+$ years, 1982.[57,58]

[c] United States NRC RDA 400 μg/day for both men and women aged 51$^+$ years, 1980.[62]

[d] Canadian RDA for men (205 μg/day) and women (190 μg/day), 1990.[63]

[e] United States NRC RDA for men (200 μg/day) and women (180 μg/day) aged 51$^+$ years, 1989.[1]

Prevalence of dietary inadequacy

During the reference period eight studies reported about the dietary folate intakes of elderly people (**Table 5**). In most of the larger studies, mean folate intakes were found to exceed the recommendations for folate intake as stated in the 1989 version of the NRC RDA.[1,5,15,30,71,72] Baghurst et al.[5] reported the highest dietary folate intakes in their population of 65-75 years old elderly residents of Adelaide, Australia (292 and 277 μg/day for men and women respectively). Mean dietary intakes below 200 μg/day have been reported in three studies.[14,23,27] Lowest mean intakes were found for women in the vulnerable group of homebound elderly with home medical care in Boston (162 μg/day).[23]

In the New Mexico longitudinal study of nutrition and aging[11] as well as in the Boston Nutritional Status Survey[7,71,72], prevalences of inadequate folate intakes of 50 per cent and more were reported. However, in these studies the ninth edition of the United States NRC RDA (400 μg) was used as a dietary standard which is twice as high as the current recommendations in most countries. Mean and median folate intakes were in the same order as found in the other studies and in the Boston Nutritional Status Survey[84] six per cent of both males and females had dietary intakes of folate below two-thirds of the current RDA of 200 μg for males and 180 μg for females.

Biochemical folate status was measured in nine of the reviewed studies.[10,27,37,40,72,73,75,78-80,85] In general, the incidence of biochemical deficiency ranged from adequate status (free-living and institutionalized elderly)[72,79] to 28 per cent deficiency (female nursing home residents).[80] Ferro-Luzzi et al.[37] found that 51 per cent of the heavy drinking retirement home residents showed biochemical malnutrition. Although in two studies folate intake (including supplements) was positively associated with folate status[27,85], the information is too limited to verify dietary intakes of folate with biochemical data in this review.

It may be concluded that, although dietary folate intakes of apparently healthy elderly are adequate on a group level in most studies, the proportion of people with intakes below the current recommendations is rather high. As a consequence of that folate is a vitamin at risk with respect to inadequate dietary intakes.

Vitamin B_{12} intake

Dietary standards

Vitamin B_{12} recommendations in the USA have been decreased from 3.0 μg/day in the 1980 RDA to 2.0 μg/day in the 1989 RDA, both for elderly males and females aged 51 years and over.[1,62] According to the subcommittee, this recommendation still allows for normal serum concentrations and substantial body stores. The Australian recommendations for vitamin B_{12} intake are 2.0 μg/day for all age categories.[57-59] As for vitamin B_6 and folate, vitamin B_{12} recommendations for elderly in Europe have not been reviewed by Trichopoulou and Vassilakou.[56] In the Netherlands, 2.5 μg/day is recommended for elderly people aged 65 years and over.[60]

Adequacy of dietary intake

In ten studies dietary vitamin B_{12} intakes have been calculated (**Table 6**). In general, intakes were found to be adequate. Mean intakes ranged between 3.84 and 9.37 μg/day for men and between 2.50 and 7.49 μg/day for women.[5,27] Three studies concluded that a substantial part (12 to 34 per cent) of the population studied had dietary intakes below two-thirds of the RDA.[6,11,71] The reason for these relatively high prevalence however, is that they used 3 μg/day as RDA. Using the most recent RDA (1989) of 2 μg, three per cent of the free-living elderly males and 12 per cent of the free-living elderly females in the Boston Nutritional Status Survey[84] had dietary vitamin B_{12} intakes below two-thirds of this RDA. In this survey, vitamin B_{12} intakes in institutionalized elderly people were also measured. Although the used database for calculating the nutrient intakes might be incomplete with respect to vitamin B_{12}, it was found that the dietary intake of this vitamin was adequate (4.6 and 4.0 μg/day for males and females respectively).[72]

Eight studies reported vitamin B_{12} concentrations in plasma.[10,22,40,72,73,78-80,86] The biochemical status of vitamin B_{12} was judged to be adequate in all of these studies. However, in the Boston Nutritional Status Survey more than five per cent of the free-living males and females in the age category 90^+ had plasma vitamin B_{12} values <74 pmol/l.[86] Using 111 pmol/l plasma as a cut-off value of vitamin B_{12} deficiency, the prevalence of biochemical deficiency in the SENECA study ranged from 1.5 to 10 per cent in half of the centres.[79]

Table 6. Dietary vitamin B_{12} intakes (µg/day) and dietary adequacy.

Author	Reference	Sub-sample	Sex	Mean	SEM	p10	p50	p90	Dietary adequacy[a]
Free-living elderly:									
Baghurst and Record, 1987	(5)	-	M	9.37	nd	nd	6.20	nd	3% < RDA[b]
			F	7.49			5.31		10% < RDA
Bianchetti et al., 1990	(6)	-	M	nd	nd	nd	nd	nd	31% < ⅔RDA[c]
			F						34% < ⅔RDA
Boston Nutritional Status Survey, 1992	(7,71)	60-69 yrs	M	4.31	0.31	nd	3.44	nd	18% < ⅔RDA[c]
			F	3.31	0.26		2.37		32% < ⅔RDA
		70-79 yrs	M	5.34	0.70		3.35		20% < ⅔RDA
			F	4.21	0.39		2.81		30% < ⅔RDA
		80^{+} yrs	M	4.91	0.49		3.54		12% < ⅔RDA
			F	4.08	0.44		2.68		30% < ⅔RDA
Garry et al., 1982	(11)	-	M	nd	nd	nd	nd	nd	42% < RDA[c]
			F						65% < RDA
Horwath, 1989	(14)	-	M	6.31	0.20	nd	3.90	nd	2% < ⅔RDA[b]
			F	5.40	0.19		3.20		5% < ⅔RDA
Horwath et al., 1992	(15)	-	M	4.87	0.16	nd	nd	nd	2% < ⅔RDA[b]
			F	4.35	0.11				3% < ⅔RDA
Koehler et al., 1992	(16)	-	M	5.2	nd	nd	nd	nd	nd
			F	4.1					
Mensink and Arab, 1989	(22)	phys. act.	M	6.46	0.62	nd	nd	nd	nd
			F	5.34	0.78				
		less active	M	5.88	0.34				
			F	4.63	0.29				
Payette and Gray-Donald, 1991	(27)	-	M	3.84	0.60	nd	2.85	nd	3% < ⅔RDA[d]
			F	2.50	0.20		2.24		15% < ⅔RDA
Ryan et al., 1992	(30)	65-74 yrs	M	7.1	1.7	nd	nd	nd	9% < ⅔RDA[e]
			F	7.1	2.2				20% < ⅔RDA
		74^{+} yrs	M	4.2	0.5				15% < ⅔RDA
			F	3.8	0.9				17% < ⅔RDA
Institutionalized elderly:									
Boston Nutritional Status Survey, 1992	(7,72)	age groups combined	M	4.6	0.18	nd	4.3	nd	2% < ⅔RDA[c]
			F	4.0	0.14		3.7		8% < ⅔RDA

nd = not defined.

[a] Several versions of the RDA have been used as reference, see other footnotes.

[b] Australian NHMRC RDA 2.0 µg/day for both men and women aged 65^{+} years, 1982.[57,58]

[c] United States NRC RDA 3.0 µg/day for both men and women aged 51^{+} years, 1980.[62]

[d] Canadian RDA 2.0 µg/day for both men and women, 1990.[63]

[e] United States NRC RDA 2.0 µg/day for both men and women aged 51^{+} years, 1989.[1]

A positive association between intake and biochemical status was reported in the Boston Nutritional Status Survey.[86] The vitamin B_{12} needs are low and relatively easy to cover by a non-vegetarian diet. In case of atrophic gastritis, which is often found in elderly, vitamin B_{12} absorption problems might occur, but even then it may take several years before vitamin B_{12} deficiency is seen because of large body stores.

It is concluded that in the reported studies dietary vitamin B_{12} intake in free-living elderly seems to be adequate. Biochemical data from other studies endorse these findings.

Vitamin C intake

Dietary standard

The country specific dietary recommendations for vitamin C intake show great differences, depending on the criteria of adequacy. When the aim is to prevent scurvy 30 mg/day is recommended, whereas higher intakes are needed to assure some degree of storage or tissue saturation. The USA 1989 RDA for vitamin C is 60 mg/day for both elderly men and women and has not been changed in comparison with the 1980 version.[1,62] The Australian recommendations are much lower, 40 mg/day for elderly males, and 30 mg/day for elderly females.[57-59] In Europe, the recommendations range between 30 mg/day in the United Kingdom and 80 mg/day in France for elderly people aged 65 years and over.[56]

Prevalence of dietary inadequacy

In most of the studies presented in **Table 7**, mean dietary vitamin C intakes were found to be adequate. The lowest mean vitamin C intakes in free-living elderly were found in four Italian studies[6,9,10,28] and in one Swedish study[25], ranging between 48 and 71 mg/day.

For institutionalized elderly, lowest mean vitamin C intakes were found by Löwik et al.[19] in female nursing home residents (54 mg/day) and in residents of Yugoslavian retirement homes by Suboticanec et al. (61 and 56 mg/day for men and women respectively).[40]

Vitamin C concentrations in plasma or serum have been measured in eleven studies.[10,13,21,27,34,36,40,72,73,75,80,87,88] Payette and Gray-Donald[27] reported that 37 per cent of the variance of serum vitamin C could be explained by vitamin C intake and gender. Yearick et al.[36] and Marazzi et al.[21] found correlations with dietary intake of 0.37 and 0.23 respectively. Garry et al.[87] fitted a linear regression model to plasma ascorbic acid and the logarithm of daily ascorbic acid intake and found that 33 per cent of the variation in plasma ascorbic acid concentration could be explained by this model. In the free-living elderly of the Boston Nutritional Status Survey[88] a 1.3 fold increase in vitamin C intake was associated with a 10 μmol/l increase in plasma ascorbate. Institutionalized elderly in the same study showed a 10 μmol/l increase in plasma ascorbate when intakes were increased by 0.5 fold for males or 0.8 fold for females. The highest incidence of biochemical deficiency was found by Löwik et al.[80](38 per cent of the female nursing home residents) and Suboticanec et al. (65 and 59 per cent of institutionalized males and females respectively).[40] These latter figures are consistent with the relatively low intakes of vitamin C reported in these studies.

Table 7. Dietary vitamin C intakes (mg/day) and dietary adequacy.

Author	Reference	Sub-sample	Sex	Mean	SEM	p10	p50	p90	Dietary adequacy[a]
Free-living elderly:									
Baghurst and Record, 1987	(5)	-	M	138	nd	nd	114	nd	5% < RDA[b]
			F	148			131		4% < RDA
Bianchetti et al., 1990	(6)	-	M	nd	nd	nd	nd	nd	41% < ⅔RDA[c]
			F						46% < ⅔RDA
Boston Nutritional Status Survey, 1992	(7,71)	60-69yrs	M	145	7.8	nd	134	nd	6% < ⅔RDA[c]
			F	136	6.2		125		6% < ⅔RDA
		70-79yrs	M	153	7.9		145		3% < ⅔RDA
			F	137	4.3		132		3% < ⅔RDA
		80⁺yrs	M	116	9.4		113		12% < ⅔RDA
			F	133	6.6		122		7% < ⅔RDA
Fidanza et al., 1984	(9)	65-70yrs	M	55	4.2	26	52	nd	nd
			F	56	3.5	29	47		
		70⁺ yrs	M	62	3.9	32	57		
			F	58	3.6	27	54		
Fidanza et al., 1991	(10)	-	M	65	5.3	27	61	100	nd
			F	71	4.8	32	64	111	
Garry et al., 1982	(11,87)	-	M	142	6.2	nd	137	nd	7% < RDA[c]
			F	137	6.1		132		10% < RDA

- continued -

Author	Reference	Sub-sample	Sex	Mean	SEM	p10	p50	p90	Dietary adequacy[a]
Gray et al., 1983	(12)	-	F	183	11.0	nd	184	nd	0% < ⅔RDA[c]
Herbeth et al., 1989	(13)	-	M	128	4.2	nd	nd	nd	nd
			F	125	4.0				
Horwath, 1989	(14)	-	M	88	2.0	nd	76	nd	3% < ⅔RDA[b]
			F	101	2.0		88		2% < ⅔RDA
Horwath et al., 1992	(15)	-	M	109	4.3	nd	nd	nd	0% < ⅔RDA[b]
			F	121	3.4				0% < ⅔RDA
Kohrs et al., 1980	(17)	participate congregate hot-meal programs (0,<2, 2-5 times/wk)	M (0)	132	11.9	nd	nd	nd	< 10% of all participants < RDA[d]
			M (<2)	145	9.9				
			M (2-5)	134	9.1				
			F (0)	129	11.7				
			F (<2)	130	6.6				
			F (2-5)	134	6.9				
Löwik et al., 1989	(18)	-	M	94	2.6	nd	nd	nd	nd
			F	101	2.6				
Löwik et al., 1992	(19)	-	F	132	6.1	nd	nd	nd	nd
Marazzi et al., 1990	(21)	-	F	102	8.4	nd	nd	nd	nd
Mensink and Arab, 1989	(22)	phys. act.	M	82	4	nd	nd	nd	nd
			F	79	3				
		less active	M	70	6				
			F	75	3				
Millen Posner et al., 1987	(23)	-	F	149	21.3	nd	nd	nd	29% < RDA[c]
NHANESII, 1983	(24)	-	M	100	3.5	11	79	212	nd
			F	105	2.9	13	90	220	
Nordström et al., 1988	(25)	-	M	71	4.2	nd	nd	nd	nd
			F	71	4.7				
O'Hanlon et al., 1983	(26)	-	M	nd	nd	nd	nd	nd	3% < ⅔RDA[d]
			F						3% < ⅔RDA
Payette and Gray-Donald, 1991	(27)	-	M	91	7.9	nd	79	nd	6% < ⅔RDA[e]
			F	99	8.8		94		2% < ⅔RDA
Porrini et al., 1987	(28)	60-69 yrs	M	62	5.5	24	44	116	nd
			F	54	4.5	13	41	109	
		70^+ yrs	M	50	4.4	13	42	89	
			F	48	4.3	14	38	85	
Räsänen et al., 1992	(29)	-	M	100	4.2	nd	nd	nd	nd

- continued -

Author	Reference	Sub-sample	Sex	Mean	SEM	p10	p50	p90	Dietary adequacy[a]
Ryan et al., 1992	(30)	65-74 yrs	M	106	8.4	nd	nd	nd	23% < ⅔RDA[f]
			F	112	6.4				20% < ⅔RDA
		74$^+$ yrs	M	100	13.6				22% < ⅔RDA
			F	101	8.8				28% < ⅔RDA
Scaccini et al., 1992	(31)	-	M	100	2.7	nd	nd	nd	5% < ⅔RDA[g]
			F	87	2.2				6% < ⅔RDA
SENECA investigators, 1991	(32)	H/B	M	nd	nd	46	92	nd	1% < RDA[h]
			F			45	96		2% < RDA
		R/DK	M			28	60		12% < RDA
			F			31	60		9% < RDA
		H/F	M			34	66		6% < RDA
			F			43	74		4% < RDA
		R/F	M			53	98		1% < RDA
			F			56	94		1% < RDA
		AA/GR	M			93	158		0% < RDA
			F			32	102		9% < RDA
		P/I	M			54	102		3% < RDA
			F			46	89		4% < RDA
		FMP/I	M			73	154		0% < RDA
			F			59	120		3% < RDA
		C/NL	M			70	122		1% < RDA
			F			70	124		2% < RDA
		E/N	M			46	79		0% < RDA
			F			37	76		0% < RDA
		V/P	M			49	108		4% < RDA
			F			35	83		7% < RDA
		B/E	M			53	130		1% < RDA
			F			82	174		1% < RDA
		Y/CH	M			53	98		0% < RDA
			F			60	105		2% < RDA
		Bu/CH	M			43	105		3% < RDA
			F			56	84		0% < RDA
		Be/CH	M			46	98		3% < RDA
			F			54	114		0% < RDA
Somogyi and Kopp, 1983	(34)	-	F	92	4.5	nd	nd	nd	nd
Walker and Beauchene, 1991	(35)	-	F	113	9.0	nd	nd	nd	nd
Yearick et al., 1980	(36)	-	M	107	9.6	nd	nd	nd	4% < ⅔RDA[d]
			F	102	7.3				1% < ⅔RDA
Institutionalized elderly:									
Boston Nutritional Status Survey, 1992	(7,72)	age groups combined	M	134	5.7	nd	133	nd	3% < ⅔RDA[c]
			F	130	4.4		128		6% < ⅔RDA
Löwik et al., 1992	(19)	nurs. home	F	54	3.7	nd	nd	nd	nd
		service flat	F	97	10.2				

- continued -

Author	Reference	Sub-sample	Sex	Mean	SEM	p10	p50	p90	Dietary adequacy[a]
Marazzi et al., 1990	(21)	-	F	88	5.2	nd	nd	nd	nd
Suboticanec et al., 1989	(40)	-	M	61	8.2	nd	nd	nd	nd
			F	56	7.4				

nd = not defined.
[a] Several versions of the RDA have been used as reference, see other footnotes.
[b] Australian NHMRC RDA 30 mg/day for both men and women aged 65 + years, 1982.[57,58]
[c] United States NRC RDA 60 mg/day for both men and women aged 51 + years, 1980.[62]
[d] United States NRC RDA 45 mg/day for both men and women, 1974.
[e] Canadian RDA for men (40 mg/day) and women (30 mg/day), 1990.[63]
[f] United States NRC RDA 60 mg/day for both men and women aged 51 + years, 1989.[1]
[g] LARN, Italian RDA, 1989.
[h] Lowest European RDA 30 mg/day for both men and women.

In general it can be concluded that the dietary intake of vitamin C in apparently healthy, free-living elderly in Western societies on a group level seems to be sufficient. For institutionalized elderly extra attention might be needed to ensure adequate vitamin C intakes.

GENERAL DISCUSSION AND CONCLUSIONS

In this review, 37 studies in which dietary intakes of elderly people are measured have been discussed with respect to intakes of the vitamins thiamin, riboflavin, B_6, folate, B_{12} and C. It was concluded that in general the dietary intakes of thiamin, riboflavin and vitamin B_{12} are adequate (**Tables 2, 3 and 6**). Dietary vitamin B_6 intakes are low compared to the recommendations (**Table 4**) and therefore as such might be a vitamin at risk for deficiency. Although dietary folate intakes are on average in the same order as the recommendations (**Table 5**), a substantial proportion of the elderly has intakes below two-thirds of the dietary recommendations in several studies. According to the recommendations vitamin C intakes are adequate in free-living elderly but tend to be low in institutionalized elderly people (**Table 7**).

In most of the studies in which dietary vitamin intakes of Italian elderly were presented, the intakes of thiamin, riboflavin and vitamin C in general were rather low.[8-10,21,28,31,32,37,41,75] The mean energy intakes in these studies (range 7.8 - 11.0 MJ/day for males and 6.2 - 8.1 MJ/day for females) were not different from the other studies (range 7.4 - 11.5 MJ/day for males and 5.4 - 9.8 MJ/day for females). Although in general correlations with biochemical status were absent, a relatively high prevalence of inadequate status of these vitamins were reported in these studies in Italy. Dietary habits (low consumption of fresh fruit and vegetables in combination with a high level of alcohol consumption) might be a reason for these findings in the Italian elderly.[89] The intakes of the vitamins B_6, folate and B_{12} were not reported in most of these studies.

As stated earlier, there are a number of methodological issues which complicate the comparison of the study results and their interpretation. These issues will be discussed below.

Characteristics of the populations

The reviewed studies cover different groups of elderly people which is reflected by selection criteria and response rate. Although 16 of the presented studies consisted of random samples, the response rates ranged from 34 to 92 per cent and most of these samples were based on a selective group of people.[5,6,8,12,14,15,18,22-27,30,32,39] People who refuse to participate in studies are probably not representative of the participating group which implies that generalization of the conclusions to the total reference population is often difficult, if not impossible. Health reasons for example, might lead to non-participation, which can result in an underestimation of the prevalence of dietary inadequacy. Therefore it is important to evaluate the possible occurrence of selectivity in participation and to give attention to this aspect in the subjects description paragraph. In fifteen studies which were carried out in free-living elderly, response rates were not reported.[8-11,16,19-22,26,28,34-36,71] Three of these studies did not describe the selection procedures[21,28,34], whereas in two studies participants were recruited by advertisements.[19,71]

Six papers consisted of either baseline or follow-up descriptive data from longitudinal studies.[9-12,16,29] Due to mortality and non-participation in the follow-up studies the groups will be too selective to draw conclusions about adequacy of the diet of the original target population. On the other hand, these studies are more informative in assessing dietary changes in time during the process of ageing.

When selectivity has occurred, weighting factors can be included in the statistical analysis to correct for this selection bias. In the baseline part of the SENECA study, which has a mixed-longitudinal design, a detailed non-participation analysis was carried out to estimate selection bias. It was concluded that in general the participants covered the more healthy part of the target population.[90]

The category of people, referred to as the elderly covers both a broad chronological and biological age range. However, in most studies, people aged 65 years and over are all grouped together under this denominator. Four studies presented intake data for different age strata within their study and although the differences are not statistically significant in most of the presented figures, there is a clear trend that intakes of all six reported vitamins in general reduce with advancing age.[9,28,30,71]

Only 8 studies reported dietary intakes of water-soluble vitamins in groups of at least 20 institutionalized elderly males and females.[19,21,37-41,72] Large differences in health status exist between elderly people living in different types of institutions and also within the institutions differences can be substantial. To come to more well-founded pronouncements with respect to the dietary needs of different categories of institutionalized elderly people, dietary intakes as well as biochemical status of sufficient numbers of elderly people (based upon power calculations) in different kinds of institutions should be measured.

Vitamin intervention studies, like the one recently published by Chandra et al.[91] will help to elucidate the questions concerning the amounts of vitamins needed to reach an optimal state of nutriture. These studies should be carried out for different categories of vulnerable elderly people.

Assessment of dietary intakes

Another aspect which limits the comparability of study results is the use of different dietary assessment methods. In the studies reported in this paper four techniques have been used: the dietary history, the 24-hour recall, diet records (both weighed and non-weighed for a variable number of days) and semi-quantitative food frequency questionnaires. The highest mean dietary intakes of thiamin, riboflavin and vitamin C were reported in some studies which used the dietary history method.[12,17,29] Lower mean values for the intake of these vitamins were found in studies in which the 24-hour recall method was used.[23,24,30] This finding is not conflicting with the assumption that the dietary history methods tends to overestimate and the 24-hour recall tends to underestimate dietary intake. For vitamin B_6 intake figures are low independent of the assessment method used, and for folate and vitamin B_{12} no information on dietary intake, measured with a dietary history, is available **(Tables 1, 5, 6)**.

Recommended dietary allowances

Dietary recommendations are 'intended to reflect the scientific judgement on nutrient allowances for the maintenance of good health and to serve as the basis for evaluating the adequacy of diets of groups of people'.[1] There are some indications that the dietary recommendations for water-soluble vitamins in healthy elderly people should be different from the recommendations in younger adulthood. In a recent review by Russell and Suter[92] the vitamin requirements of elderly people are discussed. They concluded that the United States RDA for riboflavin intake for elderly people probably should be raised to the recommendations for younger adults aged 25 - 50 years (1.7 mg for males and 1.3 mg for females) to increase the margin of error. Furthermore they suggest to increase the 1989 United States RDA for vitamin B_6 back to the level of the 1980 recommendations due to the evidence that the requirements are affected by age. The recommendations for vitamin B_{12} have also been lowered wrongly they conclude since vitamin B_{12} deficiency has potential devastating effects on the nervous system. Furthermore elderly people are susceptible to vitamin B_{12} deficiency due to the high prevalence of athrophic gastritis which can affect the vitamin B_{12} metabolism.[92]

Large variations in health status due to biological ageing, may cause a relatively high prevalence of biochemical vitamin deficiencies, as a result of reasons other than inadequate intakes. Since advancing age leads to a higher prevalence of chronic disease, low dietary intakes might in fact be a result, rather than a cause of a deteriorated health status. Hence older people form a much more diverse group in comparison with apparently healthy adults, and dietary recommendations for older people therefore need to be interpreted with great caution. The description of the sampling frame of the reviewed studies as well as the response rate are very important in interpreting the study results when comparisons with dietary recommendations are made. When the sampling frame is not clearly documented, or when the response rate is low, the percentages of people who have intakes below the recommendations, can not be extrapolated to a larger category of older people.

Although most of the country specific recommendations for elderly people refer to the same age category, the daily recommended allowances differ substantially in different countries.[1,56-59,62] This has to be taken into account when comparing reported prevalence of inadequate dietary intakes of water-soluble vitamins in the different studies. For instance, the reference used for thiamin in the SENECA study[32] is comparable with two thirds of the RDA for thiamin in the United States, whereas for riboflavin the reference is higher than the United States RDA.[1] For vitamin B_6 the lowest recommended intake in Europe is only half of the RDA in the USA.[1,56] The differences in country specific recommendations have been discussed earlier in this review for each of the water-soluble vitamins separately.

Many food composition databases provide 'incomplete' information on the content of vitamin B_6 in food. This makes it particularly difficult to interpret the calculated dietary intakes of this vitamin. In this paper dietary vitamin B_6 intake is concluded to be low in a substantial part of the elderly population. Whether an increase of the vitamin B_6 intake leads to a better state of health and well being needs further investigation. More information on vitamin B_6 requirements in elderly people is needed.

Blood biochemistry

In 21 of the reviewed studies biochemical status of some of the vitamins was reported.[7,8,10,13,20-22,27,28,34,36-41,72,73,75,76,78-80,87] Correlations with dietary intake were scarce, however, the prevalence of biochemical deficiency was in line with the dietary findings. The absence of correlations is in line with expectations since although the dietary intake might be adequate, other factors influence biochemical status. These factors can be categorized in two types, methodological and physiological factors. Small sample size, poor validity of the chosen methodology for dietary intake as well as for blood biochemistry, attenuation of the coefficient due to large standard errors of the correlating parameters, and lack of correspondence between country specific food composition tables belong to the first; use of dietary supplements, absorption problems, bioavailability problems, disease and drug-nutrient interactions belong to the latter category. The use of dietary supplements might improve the biochemical status, but the other physiological factors have a negative impact. The information in the here reviewed studies is too limited to draw conclusions on the biochemical status of these vitamins.

Drinka and Goodwin have reviewed the prevalence biochemical vitamin deficiency in nursing homes.[93] Prevalence of biochemical deficiency are reported for thiamin, riboflavin, vitamin B_6, folate, vitamin B_{12} and vitamin C. Vitamin B_6 and folate showed the highest prevalence of biochemical deficiency. Differences in prevalence rates were large. It was found that in studies with only few exclusions and which were not limited to volunteers, higher prevalence rates were found.

Studies are needed which are specifically designed to disentangle the interactions of factors influencing the nutritional status of elderly people, and to define reference values of malnutrition based on normal values, determined in healthy elderly populations.

CONCLUSIONS

Overall we may conclude that with the exception of vitamin B_6 and to a lesser extent folate, the dietary intake of the reviewed water-soluble vitamins seems to be adequate in the elderly under study. The Italian elderly seem to be an exception to this conclusion since intakes of thiamin as well as riboflavin and to a lesser extent vitamin C are found to be low in this group. Despite the fact that most of the older people under study in this review were apparently healthy, it is difficult to compare dietary intakes with the recommendations due to the fact that country specific recommendations show substantial differences for the water-soluble vitamins. Furthermore, some of the larger studies used a 24-hour recall as a measure of dietary intake which cannot be used in estimating prevalence of inadequate intakes. Results of the limited number of larger studies carried out in institutionalized elderly people indicate that vitamin C intake of this category of elderly people might need extra attention. Underlying health problems appear to have a greater impact than vitamin bioavailability on biochemical status. More knowledge of the nutritional status of vulnerable elderly from a health perspective is needed. Multi-centre screening programs in healthy elderly people will be helpful in establishing uniform recommendations for dietary intake and biochemical standards.

This review does not support a recommendation for supplement use of water-soluble vitamins for elderly people in general. More data are needed on optimal as well as safe levels of intake to allow for specific advice with respect to supplement use of vulnerable groups of elderly people.

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CHAPTER 3

Dietary intakes of energy and water-soluble vitamins in different categories of ageing

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ABSTRACT

The dietary intakes of energy and the vitamins thiamin, riboflavin, B_6 and C were assessed in four groups of elderly people, using the same modified dietary history method. The groups consisted of female nursing home residents (n = 40), people at admission to a nursing home (n = 21), free-living elderly people with a sedentary life style (n = 120) and physically active free-living elderly people (n = 66). Mean energy intake varied from 6.5 ± 1.2 MJ/day (nursing home residents) to 8.8 ± 2.2 MJ/day (physically very active persons) in females and from 8.8 ± 2.5 MJ/day (admission to nursing home) to 10.1 ± 2.3 MJ/day (physically very active persons) in males. Dietary intakes of the selected vitamins were below the mean minimum requirements in almost half of the nursing home residents. However, the relative contribution of the various food groups to the dietary intake of these vitamins was similar in the four groups of elderly people. Stimulation of physical activity to increase energy requirements and use of foods with a high nutrient density may result in an improvement of dietary adequacy.

INTRODUCTION

The process of ageing is characterized by several factors, including an increasing prevalence of poor health status, reduced physical activity, and perhaps as a consequence of this, reduced intakes of food and energy.[1-3] As energy intake decreases, consumption of a well balanced diet becomes more important to provide adequate amounts of micronutrients. Dietary intakes of elderly people have been studied in several study settings, and the adequacy of both macro- and micronutrient intakes have been reviewed and criticized by several authors.[4-8] Differences in the various dietary intake measurement instruments used in those studies make it difficult to compare the study results. Furthermore, most food consumption studies in elderly people use chronological age of the participants as a criterion for inclusion in the study. However, the heterogeneity of this category of people with respect to physiological functioning should not be neglected and therefore chronological age alone is a poor selection criterion.[9,10] Rowe and Kahn made a distinction between usual ageing, associated with a variety of chronic medical conditions and disabilities, and successful ageing which is characterized by little or no loss in physiological functions with age.[11] Harris and Feldman suggest that a third category of high risk or accelerated ageing should be added.[12] This category refers to elderly people who carry the heaviest burden of chronic disease and disability.

The main purpose of this study is to compare anthropometrical parameters of the nutritional status and the adequacy of dietary intakes of energy, thiamin, riboflavin, and the vitamins B_6 and C between groups of Dutch elderly people in different health status, using the same dietary history method. The groups under study represent the different categories of ageing. The first group consists of elderly nursing home patients (either resident or at admittance) who can be classified as being in the phase of accelerated ageing. The second group, representing the usual agers, consists of a free-living, rather healthy sedentary group of elderly people. The third group under study are physically active, successful agers, who participated in the annual four day long distance march in Nijmegen in 1993.

Each of the vitamins studied plays a specific role in energy metabolism, and therefore nutrient densities were included in the analyses.[13] The dietary intakes of the groups were compared with the Dutch dietary recommendations.[14]

SUBJECTS AND METHODS

Subjects

Two groups of elderly people with a chronic somatic disability were recruited from three nursing homes, which were located in the central area of The Netherlands. The first group is referred to as the 'Resident' group and consists of 40 elderly female nursing home residents aged 65 years and older, with a chronic somatic disability. This group, recruited in April 1993 by the nursing home physicians, was in stable health condition, did not receive parenteral or tube feeding, and was resident for at least three months. Because the number of males who fulfilled these criteria was relatively small, only females were recruited. Initially, 42 women were approached and all of them were willing to participate. Two of these women died before their food consumption was assessed. The second group consisted of both elderly males and females aged 65 years and older, who were examined within five days after admittance to one of the nursing homes mentioned above, and who were free-living up to the moment of admission ('Admission' group). From October 1992 till December 1993 the patients of the 'Admission' group were asked to participate. People suffering from terminal diseases or receiving parenteral or tube feeding were not included in the study. A total of 21 persons (10 males and 11 females) were enroled in the study (response rate 75%).

In the spring of 1993 a follow up of the SENECA study, which stands for a Study in Europe on Nutrition and the Elderly, a Concerted Action, was carried out.[15] Of the 238 Dutch apparently healthy, free-living elderly who had participated in 1988, 38 had died, 69 refused further participation and 11 persons were lost to follow up. The remaining 120 persons, aged 75-80 years, are referred to as the 'SENECA' group.

In July 1993, the SENECA research protocol was used as part of a study on physical activity, exercise capacity and health in elderly participants in the annual four days long distance march in Nijmegen. Food consumption was studied in a subgroup of these elderly participants. At first, this food consumption study aimed at people above the age of 75 years. Because the number of female participants in this age category was low, the age limit for females was lowered to 70 years. Participants were all able to walk 30 or 40 kilometres on four consecutive days, and therefore can be considered to have a high exercise capacity. In total 82 elderly people were asked to participate in the food consumption part of the study. Of this group 67 persons initially agreed to participate. One woman refused further participation after the time consuming dietary assessment. The remaining 66 persons (32 females and 34 males) are referred to as the '4-day marches' group, and it is assumed that this group had a better physical condition than the more sedentary group of free-living elderly people in the SENECA study.

All four of the studies reported here were approved by the Medical Ethical Committee of the Department of Human Nutrition, Wageningen Agricultural University, and informed consent was obtained from all participants.

Anthropometric measurements

Weight (to the nearest 0.1 kg) and height (to the nearest 0.5 cm) were measured and the body mass index (BMI) was calculated as weight divided by height squared (kg/m^2). In addition, mid upper arm circumference (MUAC) was measured (to the nearest 0.1 cm), as an extra index of body composition.

Health and performance

A score of basic activities of daily living (ADL) was calculated from the abilities in bathing, dressing, toileting, feeding, and transfers. For each item the possible scores were 0 (no help needed), 1 (some help needed), 2 (intensive help needed). The ADL score ranges therefore between 0 (no help needed at all) and 10 (intensive help needed). Subjects were asked to compare their health with that of other persons of the same age. Furthermore, information was collected about the presence of chronic diseases and use of prescribed medication, levels of education, and smoking status.

Dietary intake

In a personal interview food consumption data were obtained by trained investigators using a modified version of the dietary history method.[16-18] To facilitate the dietary interview, first a global food consumption pattern of weekdays and weekend was estimated, to give the interviewer an idea of the person's pattern of eating. Using this as background information the usual pattern of intake was assessed by asking the person's usual intake, covering the last four weeks as the reference period (for the 'Admission' group the last four weeks before admittance to the nursing home). A checklist of foods was used to find out which foods were used, how often they were used, what alternatives were used on weekdays and weekend days and what other irregularities in the eating pattern were present. Each meal and all between-meal snacks were discussed, and for composite foods recipes were specified.

The checklist of foods was completed in a slightly different way for the groups under study. For the 'Admission' group, the interview took place within five days after admittance. In all interviews the partner of the participant or a proxy who helped in the meal preparation was present at the interview. Portion sizes of foods and household measures were estimated with the help of 105 photographs of different portion sizes of 23 items. The National Institute of Public Health and Environment Protection provided 24 of the pictures.[19] The same photos were used for the female nursing home residents. The menu of the last four weeks was collected for each participant, and recipes, brands of food products and portion sizes were obtained from the cooks. For the participants of the SENECA study or the 4-day marches the interview took place at the home of the participant and usual portion sizes were recorded in household measures. Portion sizes of the foods most frequently used were checked by weighing by the interviewer. All interviewers had the same intensive and standardized training at the Department of Human Nutrition, Wageningen Agricultural University, The Netherlands. Meetings were organized to discuss coding problems.

Data analysis

Food consumption data were converted into energy, nutrients and nutrient densities using a computerized version of the Dutch food consumption table.[20] All statistical analyses were performed using the SAS statistical package (SAS Institute Inc, Cary, NC).

For males and females separately in each group, means and standard deviations were calculated for sample characteristics and dietary intake variables. For all variables, normality of the frequency distribution was evaluated by visual inspection. To stabilize the variances, logarithmic transformations were carried out before the statistical analyses for daily dietary vitamin C intake and for vitamin C intake per Megajoule of energy intake. No statistical tests were performed on alcohol intake, because the distribution remained skewed after transformations. For continuous variables, differences between the groups were tested with analysis of variance (ANOVA). The 95% confidence limits (CL) were calculated and the Least Significant Difference (LSD) test for multiple comparisons was carried out to test which groups of elderly people had unequal means for the continuous variables.

Prevalence of dietary vitamin intakes below the Dutch Recommendations (RDA) or below the lower limit of the range of mean minimum requirements as determined by the Netherlands Food and Nutrition Council (1992) were calculated in each group of elderly people and pairwise comparisons between the groups and between males and females were tested with Fisher's exact test at the 1% significance level. All tests were two-tailed.

RESULTS

Demographic, anthropometric and health data

The sample characteristics are described in **Table 1**. Since the selection criteria of the groups under study were different with respect to age, the range and the distribution of age was different. Therefore it was of no use to test for age differences. From the table it is clear however that the free-living females were on average somewhat younger than the female nursing home residents. ANOVA testing showed a significant difference ($P<0.05$) for weight between the groups of elderly women. However, no significant differences for weight emerged from the

Table 1. Demographic, anthropometric and health data[a] of four groups of elderly people.

Variable		Females				Males		
		Nursing Homes		Free-Living		Nursing Homes	Free-Living	
		Resident n = 40	Admission n = 11	SENECA n = 68	4-day marches n = 32	Admission n = 10	SENECA n = 52	4-day marches n = 34
Age (years)		81.5 (7.1)	81.4 (8.2)	76.9 (1.8)	74.6 (3.6)	78.1 (10.0)	76.8 (1.7)	77.5 (2.2)
Weight (kg)[f]		65.7 (11.2)[b]	66.1 (14.4)[c]	70.9 (11.1)[b]	65.3 (9.7)	75.7 (15.2)[d]	76.3 (10.3)[e]	73.9 (9.7)
Height (m)		-	-	1.60 (0.07)[b]	1.62 (0.05)	-	1.71 (0.07)[c]	1.73 (0.07)
BMI (kg/m^2)[g]		-	-	27.8 (4.3)[b]	24.9 (3.1)	-	26.0 (3.0)[c]	24.6 (2.3)
MUAC (cm)[h]		28.6 (4.4)[cA]	28.6 (4.7)[cA]	31.2 (3.2)[bB]	28.1 (2.8)[A]	27.9 (4.5)[eA]	30.2 (2.4)[eB]	28.1 (2.0)[A]
ADL score (0-10)		6.8 (2.3)	6.4 (1.4)	0.0 (0.2)	0.0 (0.0)	6.1 (2.1)	0.0 (0.1)	0.0 (0.0)
Chronic disease (% yes)		100	100	59	53	100	50	38
Drug use (% yes)		100	91	79	50	90	69	44
Rel. health[i] (%)	Worse	12	36	4	0	20	4	0
	The same	58	18	41	25	30	40	9
	Better	30	45	54	75	50	56	91
Education (%)	Primary	35	45	44	41	20	33	12
	Secondary	52	55	47	41	70	56	50
	Higher	12	0	9	19	10	12	38
Smoking (% yes)		8	0	1	6	40	29	21

[a] Mean (SD in parentheses) or percentage.

[bcde] Incomplete data (b = 4, c = 2, d = 3, e = 1 observations missing).

[fgh] Results of ANOVA (f = $P<0.05$ for females; g = $P<0.001$ for females and $P<0.05$ for males; h = $P<0.001$ for females and males).

[i] Subjective health judgement compared to people of the same age.

[AB] On each row, means sharing the same capital letter are not significantly different (LSD test for females and males separately).

multiple comparisons test. Since many of the nursing home residents were confined to a wheelchair or had kyphosis, height could not be measured in the major part of these groups. In the free-living elderly, body mass index (BMI) was significantly higher in the 'SENECA' group compared to the '4-day marches' group in both females ($P=0.001$) and males ($P=0.026$). Mid upper arm circumference (MUAC) was higher in the 'SENECA' group compared to the other groups in both males and females.

In line with the fact that the nursing home residents all suffered from chronic somatic disabilities, the score for activities of daily living (ADL) was very high in these groups, as was the prevalence of chronic diseases and the use of prescribed medication. Small expected cell frequencies hampered statistical testing of these categorical variables.

Dietary intake

Table 2 shows the dietary energy intakes and the relative sources of energy in the different groups of elderly people. Energy intake varied from 6.5 MJ/day ('Resident' group) to 8.8 MJ/day ('4-day marches' group) in females, and from 8.8 MJ/day ('Admission' group) to 10.1 MJ/day ('4-day marches' group) in males. Analysis of variance showed a significant difference in the energy intake between groups of females but not in males. Multiple comparisons testing revealed a significant difference in mean energy intake between the 'Resident' group and the other three groups of elderly females (95% CL 5.9-7.2 MJ for the 'Resident' group, 6.5-8.9 MJ for the 'Admission' group, 7.2-8.2 MJ for the 'SENECA' group and 8.1-9.6 MJ for the '4-day marches' group). In both sex groups, the results suggest a higher energy intake in the '4-day marches' group than in the 'SENECA' group, although the data did not reach statistical significance. However, energy intake per kilogram body weight was higher in elderly female participants of the 4-day marches compared to the other three groups (95% CL 90-114 kJ for the 'Residents' group, 84-133 kJ at 'Admission', 103-120 kJ for the 'SENECA' group and 127-151 kJ for the '4-day marches' group).

No differences of statistical significance were found with respect to percentage of energy provided by macronutrients, with the exception of protein, which provided less energy in the females in the 'Admission' group compared to

Table 2. Daily dietary intakes of energy and nutrients contributing to energy[a] in four groups of elderly people.

		Females					Males			
		Nursing Homes		Free-Living			Nursing Homes	Free-Living		
		Resident	Admission	SENECA	4-day marches		Admission	SENECA	4-day marches	
Variable		n = 40	n = 11	n = 68	n = 32	P value[b]	n = 10	n = 52	n = 34	P value[b]
Energy	MJ/day	6.5 (1.2)[A]	7.7 (2.3)[B]	7.7 (2.3)[B]	8.8 (2.2)[B]	0.0001	8.8 (2.5)	9.3 (2.0)	10.1 (2.3)	ns
	kJ/kg body weight	103 (22)[cA]	119 (39)[dA]	111 (37)[cA]	139 (42)[B]	0.0003	132 (31)[e]	123 (31)[f]	138 (38)	ns
Protein	% Energy	14.3 (2.4)[AB]	12.9 (3.0)[B]	15.6 (3.0)[A]	15.9 (3.4)[A]	0.006	14.6 (2.3)	14.4 (2.7)	13.6 (2.6)	ns
Fat	% Energy	38.5 (5.8)	41.7 (6.2)	39.3 (8.7)	39.7 (6.5)	ns	43.3 (2.8)[A]	39.8 (6.0)[B]	38.2 (5.6)[B]	0.05
Carbohydrate	% Energy	47.4 (6.6)	46.1 (6.4)	45.1 (7.7)	43.8 (5.8)	ns	41.1 (5.3)	44.0 (6.7)	44.6 (7.9)	ns
Alcohol	% Energy	1.0 (1.6)	0.6 (1.1)	1.3 (4.1)	1.9 (3.1)	-	2.2 (4.4)	3.1 (3.8)	4.7 (5.6)	-

[a] Mean, SD in parentheses.

[b] Statistical significance in analysis of variance (ns = not significant; - = not tested).

[cdef] Incomplete data (c=4, d=2, e=3, f=1 observations missing).

[AB] On each row, means sharing the same capital letter are not significantly different (LSD test for females and males separately).

the two groups of free-living elderly women, and the percentage of energy provided by fat which was higher for males in the 'Admission' group compared to the '4-day marches' group.

Mean dietary intakes of thiamin, riboflavin, vitamin B_6 and vitamin C are presented in **Table 3.** The intakes of all four vitamins under study were higher in the '4-day marches' group compared to both nursing home groups, with the exception of riboflavin intake in males. For vitamin C, the dietary intake was almost three times higher in the '4-day marches' group compared to the nursing home groups (**Table 3**). In females, the dietary intakes of thiamin, vitamin B_6 and vitamin C were significantly higher in the '4-day marches' group compared to the 'SENECA' group, and the intakes of riboflavin, vitamin B_6 and vitamin C in the 'SENECA' group were significantly higher than in the 'Resident' group. In males, no differences in intakes were found between the 'SENECA' group and the '4-day marches' group. Except for riboflavin, the vitamin intakes in both groups of free-living males were higher than in the 'Admission' group (**Table 3**).

The differences between the two groups of free-living elderly disappeared when the dietary intakes were expressed per Megajoule energy intake, but generally remained significant when comparing the free-living groups with the nursing home groups (**Table 3**).

Riboflavin intakes in females, expressed per gram protein intake was lower in the 'Resident' group and the '4-day marches' group compared to the 'Admission' group. This may be explained by the lower protein intakes in the latter group (**Table 3**).

Dietary adequacy

Mean dietary intakes of the vitamins under study (**Table 3**) were below the RDAs in the female 'Resident' group as well as in the 'Admission' group, with the exception of dietary riboflavin intake in the latter group. In the female 'SENECA' group, mean dietary intakes of thiamin (mg) and of vitamin B_6 (expressed per gram protein) were below the RDAs. None of the mean dietary vitamin intakes reached the RDA in elderly males in the 'Admission' group.

Table 3. Daily dietary intakes of thiamin, riboflavin, vitamin B_6 and vitamin C[a] in four groups of elderly people.

		Females					Males			
		Nursing Homes		Free-Living			Nursing Homes	Free-Living		
		Resident	Admission	SENECA	4-day marches		Admission	SENECA	4-day marches	
Variable		n = 40	n = 11	n = 68	n = 32	*P* value[b]	n = 10	n = 52	n = 34	*P* value[b]
Thiamin	mg	0.81 (0.18)^{A}	0.81 (0.26)^{A}	0.94 (0.27)^{A}	1.18 (0.32)^{B}	0.0001	0.96 (0.20)^{A}	1.19 (0.28)^{B}	1.26 (0.44)^{B}	0.06
	mg/MJ	0.13 (0.02)^{A}	0.11 (0.02)^{B}	0.13 (0.03)^{A}	0.13 (0.03)^{A}	0.02	0.11 (0.02)	0.13 (0.03)	0.13 (0.03)	ns
Riboflavin	mg	1.20 (0.36)^{A}	1.41 (0.51)^{AB}	1.63 (0.56)^{BC}	1.73 (0.38)^{C}	0.0001	1.44 (0.43)	1.65 (0.44)	1.67 (0.49)	ns
	mg/MJ	0.19 (0.05)^{A}	0.18 (0.04)^{A}	0.22 (0.06)^{B}	0.20 (0.05)^{AB}	0.03	0.17 (0.05)	0.18 (0.05)	0.17 (0.04)	ns
	μg/g protein	22 (4)	25 (6)	24 (4)	22 (4)	ns	20 (4)	21 (5)	22 (7)	ns
Vitamin B_6	mg	0.96 (0.19)^{A}	1.09 (0.42)^{A}	1.29 (0.34)^{B}	1.63 (0.36)^{C}	0.0001	1.26 (0.32)^{A}	1.59 (0.40)^{B}	1.64 (0.42)^{B}	0.03
	mg/MJ	0.15 (0.03)^{A}	0.14 (0.03)^{A}	0.17 (0.05)^{B}	0.19 (0.03)^{B}	0.0001	0.15 (0.02)	0.17 (0.04)	0.17 (0.03)	ns
	μg/g protein	18 (3)^{A}	19 (4)^{AB}	19 (4)^{AB}	21 (4)^{B}	0.02	17 (2)^{A}	21 (4)^{B}	21 (5)^{B}	0.03
Vitamin C[c]	mg	56 (26)^{A}	68 (36)^{A}	118 (56)^{B}	148 (42)^{C}	0.0001	47 (24)^{A}	120 (58)^{B}	145 (70)^{B}	0.0001
	mg/MJ	9 (4)^{A}	9 (5)^{A}	16 (9)^{B}	17 (5)^{B}	0.0001	6 (4)^{A}	13 (6)^{B}	15 (7)^{B}	0.0001

a Mean, SD in parentheses.

b Statistical significance in analysis of variance (ns = not significant).

c Statistical analysis performed after logarithmic transformation.

ABC On each row, means sharing the same capital letter are not significantly different (LSD test for females and males separately).

Table 4. Percentage of elderly people in different categories receiving <u>less</u> than the recommendations (RDA)[a] or less than the mean minimum requirements (Minimum need)[a] from diet alone.

		Females				Males		
		Nursing Homes		Free-Living		Nurs. Homes	Free-Living	
Nutrient	Reference value	Resident n = 40	Admission n = 11	SENECA n = 68	4-day marches n = 32	Admission n = 10	SENECA n = 52	4-day marches n = 34
Thiamin	RDA 0.12 mg/MJ and >1.0 mg/day	88 A	91 AB	71 AB	44 B	90 A	48 A	53 A
	Minimum need 0.07 mg/MJ and >0.8 mg/day	55 A	45 A	31 A	6 B	20 A	6 A	3 A
Riboflavin	RDA 1.3 mg/day (females); 1.5 mg/day (males)	62 A	45 AB	26 B	12 B	60 A	38 A	32 A
	Minimum need 1.1 mg/day	45 A	36 AB	19 B	9 B	30 A	13 A	15 A
Vitamin B_6	RDA 0.02 mg/g protein[b]	90 A	91 AB	66 B	38 C	90 A	46 AB	41 B
	Min. need 0.015 mg/g prot. and >1.0 mg/day	58 A	45 AB	31 B	6 C	40 A	6 B	3 B
Vitamin C	RDA 70 mg/day	72 A	64 A	16 B	3 B	90 A	19 B	12 B
	Minimum need 50 mg/day	48 A	45 AB	12 BC	0 C	70 A	10 B	3 B

a Requirements according to the Netherlands Food and Nutrition Council (1992).

b Intakes should be at least 1.0 mg/day and 1.1 mg/day for females and males respectively (aged 65 years and older).

ABC On each row, for females and males separately, values sharing the same capital letter are not significantly different (Fisher's exact test for 2x2 tables, $P<0.01$).

The prevalence of dietary intakes below the Dutch RDAs or below the mean minimum requirements are presented in **Table 4** for the vitamins under study. The RDAs are judged to be adequate to meet the nutrient needs of practically all healthy people. To judge the dietary adequacy of a section of the population, the mean minimum dietary needs (i.e. the average level of the distribution of the individual minimum nutrient requirements to maintain normal metabolic functioning) are a more sensible guideline.[14] Pairwise comparison of the prevalences of dietary intakes below the mean minimum requirements at the 99% confidence level, resulted in statistically significant higher prevalences in the 'Resident' group compared to either of the two groups of free-living elderly females for all four vitamins under study ($P<0.01$), except for the prevalence of low thiamin intakes in the 'SENECA' females. No statistically significant differences were present between the females in the 'Admission' group compared to the 'Resident' group or the 'SENECA' group, however, the prevalences of low dietary intakes of either thiamin, vitamin B_6 or vitamin C were significantly higher than in the '4-day marches' group. Prevalences of inadequacy were also found to be significantly higher in the female 'SENECA' group compared to the '4-day marches' group for thiamin and vitamin B_6 ($P<0.01$). In males, no statistically significant differences in prevalences of inadequacy were found between the three groups, except for the prevalences of low vitamin B_6 and vitamin C intakes which were significantly higher in the 'Admission' group compared to the '4-day marches' group. In the 'SENECA' group, the prevalences of dietary inadequacy were significantly higher in females compared to males for thiamin as well as for vitamin B_6 ($P<0.005$).

Vitamin sources

Fig. 1 shows the relative contribution of various food groups to the dietary intake of the vitamins under study. About 40% of thiamin in the diet was provided by animal sources (meat, fish, eggs and milk products) in all but the '4-day marches' group. In the latter group this was about 30%. For riboflavin, 40-50% was provided by milk products and about 25% was provided by grain products, vegetables, potatoes, fruits and fruit juices. As for thiamin, vitamin B_6 was also for about 40% provided by animal products. The relative amount of vitamin C provided by vegetables (excluding potatoes) seemed to be somewhat higher in the groups

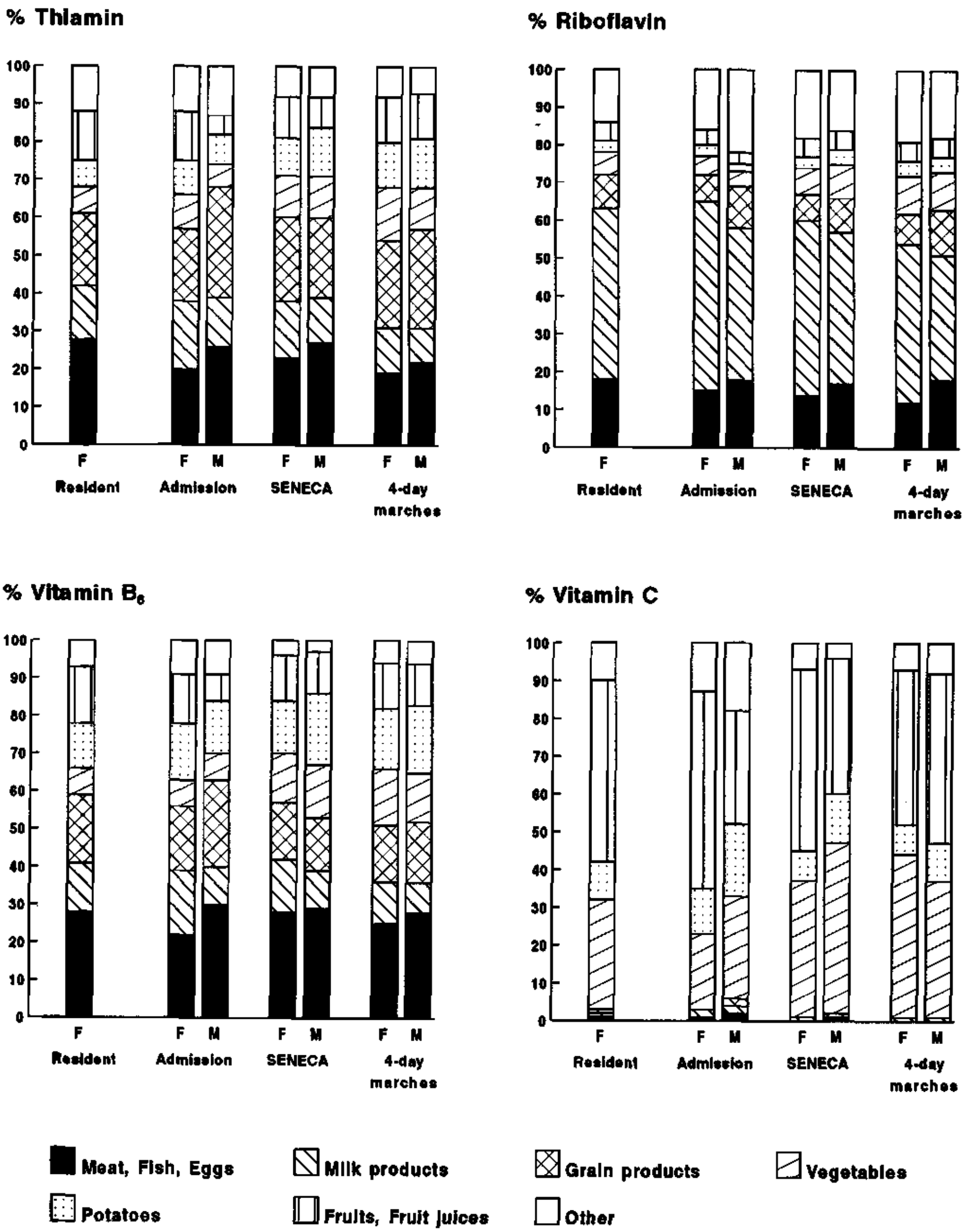

Fig. 1. Relative contribution of various food groups to the dietary intake of thiamin, riboflavin, vitamin B_6, and vitamin C (M = males; F = females).

of free-living elderly than in the nursing home groups. The relative contribution of each product group to the total amount of the vitamins consumed with the diet, however, was about the same for each category of elderly people. This evidence suggests that the food patterns are not strikingly different between the 4 groups under study.

DISCUSSION

This study shows that sedentary elderly people living in or at admission to a nursing home have lower dietary intakes of thiamin, riboflavin, and the vitamins B_6 and C, than independently living, physically active elderly people. However, the food pattern is not strikingly different between the groups.

Differences in dietary intakes between the groups under study can be explained by the differences in physical condition, rather than by age differences. Although the mean age of the two groups of female nursing home residents is somewhat higher than the mean age of the free-living elderly females, statistical analyses excluding people outside the age range of 70-80 years (n=23) in the 'Resident' group did not yield different results. In fact, mean energy intake in this subgroup was even lower (mean $\pm$ SD = 6.1 $\pm$ 1.2 MJ/day, n=17). The nursing home residents all suffer from chronic somatic disabilities, which means they are in poor physical condition. Within the two groups of free-living elderly, the higher BMI and MUAC, together with the energy intakes which tended to be lower in the 'SENECA' group compared to the '4-day marches' group, confirms that energy expenditure in the latter group is higher. As a consequence the groups can be classified as different categories of ageing. Both nursing home groups represent the accelerated or high risk agers, whereas the sedentary Dutch SENECA participants can be considered as usual agers and the elderly participants to the annual four day long distance march are successful agers.[11,12]

In all groups, the same modified dietary history technique was used, thus enabling a valid comparison of habitual food consumption between these groups. This technique has been validated against a 3-day weighed record and our research group has much experience in its use in groups of apparently healthy, free-living elderly but not in institutionalized people.[17,18,21-23] There are no indications, however, that the results are confounded by the presence of somatic disabilities in the latter groups.

The energy requirement is dependent mainly on basic metabolic rate (BMR), dietary induced thermogenesis (DIT) and physical activity.[24,25] It is suggested by the FAO/WHO/UNU that the survival requirement for energy is 1.27 x BMR and that at group level the adequate energy intake should be at least 1.4 x BMR. Goldberg et al. concluded that recorded energy intakes below 1.35 x BMR, either in individuals or on group level are most unlikely to represent habitual intake.[26] Using the regression equations calculated by Schofield[27] to estimate BMR from body weight, the assessed mean energy intakes in all groups of males as well as females in the present study exceeded the estimated minimum energy needs (based on 1.4 x BMR), with the exception of the females in the 'Resident' group (7.3 MJ/day for female nursing home residents, 7.3 and 8.6 MJ/day in the 'Admission' group, 7.6 and 8.7 MJ/day in the 'SENECA' group and 7.3 and 8.5 MJ/day in the '4-day marches' group for females and males respectively). The reason for the low intake figures in the 'Resident' group may be due to the very sedentary life style or to underreporting. However, the results are in line with another Dutch study in which dietary intakes of female elderly nursing home residents was compared with females living in service flats or independently living elderly females.[28]

In a recent study using our dietary assessment technique it was found that healthy elderly women tended to underestimate their energy intake with 12%.[23] This indicates that the actual prevalences in dietary inadequacy in the '4-day marches' group and possibly in the 'SENECA' group may be lower than reported here.

Studies on seasonal variation in intake of energy and water-soluble vitamins showed that such variation is unlikely to occur in the Netherlands.[29,30] Therefore, although the dietary data in our study have not been collected in exactly the same period of the year, it is not likely that the differences in dietary intakes as found between the groups are biased by seasonal influences.

In contrast to Mensink and Arab and Voorrips et al. we detected a difference in energy intake of about 1 MJ/day between the physically active '4-day marches' group and the more sedentary 'SENECA' group.[22,31] This is most likely a result of the greater difference in degree of physical activity between the groups we studied. All groups in the other studies may fall within the range of physical activeness in the 'SENECA' participants.

The Dutch recommendations for micronutrients (RDAs) are defined as 'levels of intake which are desirable to aim at when programming the food supply of a section of a population or a homogenous category within this population'.[14] In the United States the RDA for thiamin is the same as in the Netherlands.[14,32] For riboflavin, vitamin B_6 and vitamin C, however, the Dutch recommendations are higher than the United States RDAs. Another difference between the recommendations is that, unlike in The Netherlands, the United States RDAs do not utilize mean minimum requirements of vitamins, but use a proportion of the RDA (most often 2/3) as cut off for judgement of dietary adequacy. Estimating the mean minimum requirements by using 2/3 of the United States RDA results in lower prevalences of inadequate dietary riboflavin intakes. In females the prevalences become 8% for the 'Resident' group, 0% for the 'Admission' group and the '4-day-marches' group, and 3% for the 'SENECA' group, and in males 10% for the 'Admission' group, 4% for the 'SENECA' group and 9% for the '4-day marches' group. Using 2/3 of the recommended 2.0 and 1.6 mg/day in the United States as cut off point for vitamin B_6 rather than the Dutch mean minimum requirements, does not make much difference in the prevalences found (77% for 'Resident' females, 45 and 30% for 'Admission' females and males, 26 and 20% for 'SENECA' females and males, and 0 and 15% for '4-day marches' females and males, respectively). The United States RDA for vitamin C is 60 mg/day, leading to slightly lower prevalences of inadequate intakes when using 2/3 of the recommendation. Although the prevalence of inadequate intakes of the vitamins thiamin, riboflavin, B_6 and C is lowest in the 4-day marches participants, and despite the reasonably normal mean energy intake in this group, a few persons still have intakes below the mean minimum requirements as determined by the Netherlands Food and Nutrition Council. Whether this is due to inadequacy of actual intakes, to underreporting of dietary intake by the more active people, or to a conservative safe level of mean minimum requirements is not clear.[23]

No clear differences in food consumption patterns have been found between the four groups of elderly people. For example, in males and females of all groups, 75-85% of the B vitamins provided by grain products came from brown or whole grain products. Therefore, a reduced absolute amount of food consumed (energy intake) seems to be the main reason for dietary inadequacy in this study. It has been stipulated that below an energy intake of 6.3 MJ/day (1500 kCal), it is very difficult to maintain adequate dietary micronutrient density.[33] A total of 50 participants in our study (45 females and 5 males) had an energy intake less than 6.3 MJ. Of these participants 88% had dietary intakes below the mean minimum requirements of at least one, and 60% of at least two out of the four vitamins under study. For comparison with higher intakes, of the people consuming 7 MJ/day or more (N = 81 females and 83 males), these figures were 25% and 6%, and of the people consuming at least 8 MJ/day (N = 58 females and 69 males) 20% and 2% respectively.

From this study, it can be concluded that the dietary intakes of the vitamins thiamin, riboflavin, B_6 and C are inadequate in almost half of the nursing home residents under study. It can be questioned whether adequate intake levels could be achieved by a change in food selection alone, since the energy intake is low. Although the absolute food intake of free-living elderly is higher than the intakes in nursing homes, a substantial part of the former category is still at risk of having an inadequate supply of these vitamins from diet alone. For those people, stimulating an increase in physical activity may stimulate the energy intake without leading to problems of weight gain. In periods of lack of appetite for various reasons, easy consumable micronutrient dense products might help to ensure adequate intakes of these micronutrients and to prevent nutrient deficiencies.

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CHAPTER 4

Vitamin B_6 malnutrition among elderly Europeans: The SENECA study

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ABSTRACT

Inadequate vitamin B_6 status is common among elderly people. It is still unclear to what extent factors other than reduced vitamin B_6 intake are responsible for this. We studied the vitamin B_6 intake and status (measured as plasma pyridoxal 5'-phosphate [PLP]) in 546 elderly Europeans, aged 74-76 years, with no known vitamin B_6 supplement use. In addition we examined interrelations and associations with other dietary and lifestyle factors, and with indicators of physical health. Overall, 27% of the males and 42% of the females had dietary vitamin B_6 intakes below the mean minimum requirements (0.015 mg/g protein and/or <1.0 mg/day), and 22% of both males and females had low plasma PLP levels (<20 nmol/L). Plasma PLP was associated with vitamin B_6 intake, alcohol intake, serum albumin and, to a lesser extent, body mass index. Although the serum albumin levels fell within the normal range, these findings suggest that this transport protein is related with vitamin B_6 status of elderly people, either directly or as a result of underlying health problems.

INTRODUCTION

The ageing process is associated with a reduction in total food consumption which may lead to nutrient deficiencies.[1-3] Since the population of elderly people rapidly increases, much attention is being paid to identify vulnerable categories of elderly people who are at risk of subclinical deficiencies for several nutrients.

A marginal intake of vitamin B_6 has been found in several studies on elderly people as recently has been reviewed.[4,5] Plasma pyridoxal 5'-phosphate (PLP), which is a circulating store of vitamin B_6 and reflects recent intake, is also often lower in elderly people when compared to younger adults.[6-14] It is not clear to what extent a lower dietary vitamin B_6 intake is responsible for this age related reduction in PLP levels. Several factors have been found to affect vitamin B_6 bioavailability. For instance, vitamin B_6 bioavailability from animal sources than from vegetable origin.[15-18] This may be due to the presence of pyridoxine glycosides in the latter sources.[19] The influence of protein intake on vitamin B_6 metabolism in elderly people is not clear. In younger adults a negative association between protein intake and vitamin B_6 status has been reported,[14,20] whereas this association is less pronounced in elderly subjects.[14] Experimental studies have suggested increased PLP degradation and reduced PLP formation in alcoholics.[21,22] Recently, Löwik and co-workers suggested an interaction between riboflavin and vitamin B_6 status.[23] In other studies a reduced vitamin B_6 status has been found in smokers[24] and a (short term) reduction of PLP and plasma total vitamin B_6 concentration after a glucose load.[25] Furthermore, the presence of multiple health problems[7] and age-related metabolic changes[8,11,26] may lead to higher vitamin B_6 requirements for elderly people.

In the Euronut SENECA study (a Survey in Europe on Nutrition and the Elderly, a Concerted Action),[27] dietary vitamin B_6 intake and PLP concentration were measured in elderly people living in different towns in Europe according to a standardized study protocol.[28] The overall prevalence (including those reporting usage of vitamin B_6 containing supplements) of low PLP levels (<20 nmol/L) was 23%, with considerable variations between the participating towns.[10] The purpose of the present study was to examine the combined associations between PLP concentration and dietary vitamin B_6 intake, other dietary factors, indicators of physical health and lifestyle factors in the Euronut SENECA population.

SUBJECTS AND METHODS

Subjects

In the Euronut SENECA study, the dietary and health status of elderly people from 19 towns in 12 European countries was measured. In each country, towns were selected with a stable population (no commuter town) and a socio-economic structure comparable to the country or the region as a whole. The standardized core protocol called for a random sample, stratified for age and gender.[27,28] The local research centres could choose either the birthcohorts 1913-1914 (aiming at 60 subjects per town) or 1913-1918 (aiming at 220 subjects per town). Ultimately, 2586 subjects participated (mean response rate 51%, SD 16). According to a short non-responders questionnaire, males, non-smokers, healthier subjects and better educated persons were more likely to participate.[28] Vitamin B_6 status was analyzed in the birthcohort 1913-1914 only and dietary vitamin B_6 intake was assessed in 12 towns in 9 countries. Only subjects with complete vitamin B_6 data were included in this study (n = 284 males and 264 females).

Biochemistry

Fasting blood samples (25 ml) were collected. Whole blood was collected on ethylene-diaminetetra-acetic acid (EDTA) for plasma separation for pyridoxal 5'-phosphate (PLP) analysis. Furthermore, whole blood was collected in dry tubes, with subsequent serum separation for albumin analysis.[27] Serum and plasma samples were stored at −80°C, sent on dry ice to the coordinating centre in Wageningen, the Netherlands, in batch, and stored again at −80°C. Serum albumin was analyzed by nephelometry at Nestlé Research Centre in Lausanne, Switzerland. Quality control included the measurement of blind serum duplicates of a commercial control serum (N/T Protein Control Serum, Behring) with known target value and of a serum pool from healthy donors. Plasma PLP values were determined by radioenzymatic assay using tyrosine decarboxylase apoenzyme (coefficients of variation: within-assay 1-3%, between assay 5-8%) at the TNO Nutrition and Food Research Institute, Zeist, the Netherlands.[29]

Dietary intake

Dietary intake data were collected by trained investigators in a personal interview, using a modified dietary history.[27,30,31] The method comprised a three-day estimated record and a frequency checklist of foods, based on the meal pattern of the country and with the previous month as a reference period. Usual portion sizes were checked by weighing quantities of food and household measures. Nutrient composition was calculated in each country using local food composition tables.[27]

Questionnaires

A general structured interview was used to obtain information on subjective health status, presence of chronic diseases, activities of daily living (ADL), supplement use, level of education, social isolation and smoking status. ADL was calculated as a sum of scores of level of competence for 16 items, with scores ranging from 1 (no difficulty) to 4 (unable to complete).[32] Subjects were categorized as people having no problems with ADL performance (score 16), people having problems with a few items (17-21), and people having more problems (score >21). By using the cut-off score of 21 the group of subjects with any problems was split up into subgroups of approximately equal size.

Anthropometry

Body height (to the nearest 0.5 cm) and weight (to the nearest 0.1 kg) were measured with the participants in underclothes only and body mass index (BMI) was calculated as weight divided by height squared (kg/m^2). Triceps skinfold thickness was measured to the nearest 0.2 mm with calibrated callipers and mid upper arm circumference (MUAC) was measured (to the nearest 0.1 cm). Mid upper arm muscle circumference (MUAMC) was derived from the following equation: MUAMC (cm) = MUAC − 0.3142 X triceps skinfold thickness (mm). Details about collected data are reported elsewhere.[27,28]

Data analysis

Descriptive statistics calculated are frequency distribution or mean values with standard deviation (SD), for males and females separately. After exclusion of vitamin B_6 supplement users, town- and gender-specific mean vitamin B_6 intake and PLP concentration were calculated, along with the proportion of the participants with daily vitamin B_6 intakes below 1.0 mg and/or below 0.015 mg/g protein and the proportion with a plasma PLP concentration below 20 nmol/L. The cut-off for low vitamin B_6 intake is based on the mean minimum requirements as determined by the Netherlands Food and Nutrition Council.[33] The cut-off value for low PLP levels corresponds with the 5^{th} percentile of a group of 207 healthy adult (18-65 y) Dutch blood donors.[29] Differences between males and females and between vitamin B_6 supplement users and non-users were tested at the 95% confidence level with Wilcoxon's rank-sum test. Pairwise differences in prevalence of low PLP levels between several subgroups at potential risk of PLP deficiency were tested with Fisher's exact test at the 95% confidence level. Associations with potential factors of low PLP levels were studied in linear regression models, after taking the natural logarithm of PLP concentration. All independent variables showing a significant association with PLP after additional inclusion of gender and study town, were included in a multivariate linear regression model to study their effect.

Table 1. Concentrations of plasma pyridoxal 5'-phosphate (nmol/L) in the SENECA study.

	Total		Males		Females	
	n	mean ± SD	n	mean ± SD	n	mean ± SD
All subjects	614	41 ± 46	309	38 ± 34	305	45 ± 56
		(15 - 30 - 69)[a]		(14 - 30 - 64)		(15 - 31 - 72)
No B_6 supplement use	560	38 ± 38	284	35 ± 26	276	40 ± 47
		(15 - 28 - 59)		(14 - 29 - 56)		(15 - 28 - 62)
B_6 supplement use	54	82 ± 88[b]	25	79 ± 71[b]	29	86 ± 101[b]
		(28 - 55 - 156)		(22 - 54 - 156)		(28 - 55 - 188)

[a] P10 - P50 - P90 in parentheses

[b] Significantly higher than the group without vitamin B_6 supplement use ($P<0.001$).

RESULTS

Mean plasma PLP concentration and distribution of participants selected for this study (**Table 1**), show that people who took vitamin B_6 supplements on a regular basis had significantly higher PLP levels than those who did not. Since the number of vitamin B_6 supplement users was small, and the median PLP level (55 nmol/L) was twice as high as in the non supplement users (28 nmol/L), the users were excluded from further analyses. From a dose-response study on the effect of

Table 2. Anthropometrical, dietary and biochemical characteristics of the study sample[a]

	Males		Females	
Characteristic	n	mean ± SD	n	mean ± SD
Anthropometry:				
Weight (kg)	276	74.5 ± 11.9	261	64.7 ± 11.2[b]
Body mass index (kg/m^2)	275	26.7 ± 3.9	261	27.3 ± 4.3
Midarm circumference (cm)	276	29.3 ± 3.1	262	29.3 ± 3.3
Midarm muscle circumference (cm)	276	25.3 ± 2.5	260	22.7 ± 2.7[b]
Daily dietary intake:				
Energy (MJ)	282	9.9 ± 2.9	264	7.9 ± 2.4[b]
Carbohydrate (g)	282	254 ± 93	264	213 ± 78[b]
Protein (g)	282	83 ± 25	264	69 ± 22[b]
Vegetable protein (g)	271	29 ± 15	254	24 ± 12[b]
Animal protein (g)	271	54 ± 19	254	46 ± 18[b]
Fat (g)	282	99 ± 37	264	83 ± 33[b]
Alcohol (g)	282	19 ± 22	264	3 ± 7[b]
Riboflavin (mg)	282	1.7 ± 1.0	264	1.4 ± 0.7[b]
Riboflavin (x10^{-2} mg/g protein)	282	2.1 ± 1.2	264	2.1 ± 0.7
Vitamin B_6 (mg)	282	1.5 ± 0.5	264	1.2 ± 0.5[b]
Vitamin B_6 (x10^{-2} mg/g protein)	282	1.9 ± 0.5	264	1.8 ± 0.5
Biochemistry:				
Pyridoxal 5'-phosphate (nmol/L)	282	33 ± 20	264	32 ± 18
Serum albumin (g/L)	279	41.9 ± 3.2	263	41.5 ± 3.1[c]

[a] Subjects with reported vitamin B_6 supplement use (n=54) or with Pyridoxal 5'-phosphate levels >150 nmol/L (n=14) excluded.

[b] $P<0.001$; [c] $P<0.05$ (difference in mean value between men and women).

several levels of vitamin B_6 supplementation it was concluded that PLP levels higher than 150 nmol/L are virtually always a result of supplement use (non published data, HvdB). Therefore, 14 subjects who claimed not to take vitamin B_6 supplements, but who had PLP levels >150 nmol/L were also excluded from further analyses. For comparison, the 95th percentile of the group of 207 healthy adult blood donors (including supplement users) was 86 nmol/L.[29]

In **Table 2** information is presented by gender category on anthropometric and dietary characteristics, as well as on serum albumin. On average, males had

Table 3. Dietary vitamin B_6 intake, plasma pyridoxal 5'-phosphate, and prevalence of low values in different towns of the SENECA study[a]

	Males					Females				
		vitamin B_6 (mg/d)		PLP (nmol/L)			vitamin B_6 (mg/d)		PLP (nmol/L)	
Town[b]	n	median	%<ref.[c]	median	%<ref.[d]	n	median	%<ref.[c]	median	%<ref.[d]
All	282	1.4	27	28	22	264	1.2	42	28	22
H/B	35	1.6	17	34	17	29	1.2	34	31	14
R/DK	11	1.4	9	21	45	10	0.8	60	20	40
H/F	28	1.8	0	28	29	17	1.4	6	27	35
R/F	31	1.7	6	31	16	25	1.3	20	33	8
AA/GR	21	1.2	67	21	38	29	0.8	90	18	59
M/H	18	1.4	33	30	17	20	1.5	20	23	30
C/NL	24	1.7	0	26	25	21	1.4	19	22	14
V/P	26	1.5	12	36	19	24	1.3	38	26	25
B/E	22	1.6	41	26	27	23	1.4	35	36	13
Y/CH	23	1.0	48	30	17	21	0.9	67	34	5
Bu/CH	21	1.2	62	37	5	21	1.0	57	30	5
Be/CH	22	1.2	55	35	23	24	1.2	50	30	17

PLP = Pyridoxal 5'-phosphate.

[a] Subjects with reported vitamin B_6 supplement use (n=54) or with PLP levels >150 nmol/L (n=14) excluded.

[b] H/B=Hamme, Belgium; R/DK=Roskilde, Denmark; H/F=Haguenau, France; R/F=Romans, France; AA/GR=Anogia Archanes (Crete), Greece; M/H=Monor, Hungary; C/NL=Culemborg, The Netherlands; V/P=Vila Franca de Xira, Portugal; B/E=Betanzos, Spain; Y/CH=Yverdon, Switzerland; Bu/CH=Burgdorf, Switzerland; Be/CH=Bellinzona, Switzerland.

[c] People with daily dietary vitamin B_6 intakes <0.015 mg/g protein and/or <1.0 mg/day.

[d] People with PLP concentrations <20 nmol/L.

a higher body weight and mid upper arm muscle circumference than females, as well as a higher energy intake. Consequently, males had higher intakes of macronutrients and vitamin B_2 and B_6. The intakes of these vitamins, expressed as mg per g protein intake, were not different between the two sexes. Serum albumin was higher in males.

Table 3 shows the town and gender specific vitamin B_6 intakes and PLP levels, as well as prevalence of deficiency. Daily dietary vitamin B_6 intake ranged between 1.2 and 1.8 mg in males and between 0.8 and 1.5 mg for females. Overall, 27% of the males and 42% of the females had dietary vitamin B_6 intakes below the mean minimum requirements. Median PLP concentration ranged between 21 and 37 nmol/L in males and between 18 and 36 nmol/L in females, with an overall prevalence of biochemical deficiency (<20 nmol/L) in 22% of both males and females. PLP levels and prevalence <20 nmol/L are also calculated for several categories of various potential risk factors of low vitamin B_6 status (**Table 4**). Median PLP concentration tended to be lower in people who had a poor health status, having problems with performing activities of daily living (ADL), less well educated people and smokers. Prevalence of low PLP levels was most pronounced in both males and females with relatively much ADL problems ($P=0.01$).

After adjustment for gender and study site, dietary intake of vitamin B_6, protein intake (vegetable and animal protein as separate variables in the model), alcohol intake, serum albumin, body mass index, ADL, education level and smoking status were found to be associated ($P<0.10$) with log-transformed PLP in linear regression models (**Table 5**). Gender, living situation, reporting chronic diseases, subjective health feeling, and dietary riboflavin intake were not associated with PLP concentration. To assess the independent effect of each characteristic associated with PLP concentration, the factors were simultaneously included in a multivariate model. Since there were no interactions between gender and reported variables and there are no indications that the associations with PLP differ for the genders, regression analysis was performed for males and females combined, with gender included in the model. Dietary vitamin B_6 intake remained significantly associated with PLP concentration ($P=0.01$), whereas the intake of animal protein lost its significance when included in the model together with vitamin B_6 intake (data not shown). Vitamin B_6 intake, expressed in the model per gram of protein intake was not strongly associated with PLP concentration ($P=0.07$, data not shown). Alcohol intake was positively associated with PLP concentration ($P=0.01$). Serum albumin was most strongly related with PLP concentration ($P=0.0001$). Furthermore, PLP was inversely related with body mass index ($P=0.02$). Having problems with performing activities of daily living and level of education were not associated with PLP concentration in the multivariate model, nor was smoking status. However,

Table 4. Vitamin B_6 status (nmol/L) and prevalence of low levels for several subgroups.[a]

	Males (n=282)			Females (n=264)		
Characteristic	n	median	%<20	n	median	%<20
Living situation:						
Not alone	249	28	22	159	27	20
Alone	33	30	18	105	28	24
Subjective health status:[b]						
Good	181	30	19	128	30	16[d]
Fair	74	27	26	103	26	28[d]
Poor	26	27	31	32	24	25
Reporting chronic diseases:						
None reported	91	30	15[d]	59	30	17
1 Reported	105	29	29[d]	93	27	22
≥ 2 Reported	86	28	21	112	28	24
ADL problems:[c]						
None (score 16)	139	31	17[e]	72	30	15[d]
Few (score 17-21)	69	28	19	98	28	15[e]
More (score >21)	73	27	34[e]	94	24	33[de]
Education:						
Primary or less	170	27	24	194	28	25
Secondary	81	30	19	54	26	15
Higher	31	30	19	16	36	6
Smoking status:						
Never smoked	76	33	18	232	28	21
Former smoker	126	27	19	21	28	19
Current smoker	80	26	30	11	23	36

ADL = Activities of Daily Living (16 items).

[a] Subjects with reported vitamin B_6 supplement use (n=54) or with PLP levels >150 nmol/L (n=14) excluded.

[b] Data missing for one male and one female.

[c] Data missing for one male.

[d] $P<0.05$; [e] $P<0.01$: Pairwise Fisher's exact test between classes with the same symbols.

after exclusion of serum albumin concentration from the multivariate regression model, current smokers had significantly lower PLP concentrations ($P=0.02$). Exclusion of smoking status from the model did not change the association between serum albumin and PLP concentration.

Table 5. Results of the multiple regression analysis with (logarithmic transformed) pyridoxal 5'-phosphate as dependent variable.[a]

	Crude model[b]			Multivariate model[c]		
	Regression coefficient	SE	*P*-value	Regression coefficient	SE	*P*-value
Vitamin B_6 (mg/day)	0.167	0.047	0.0004	0.167	0.062	0.0073
Protein intake (g/day):						
Vegetable origin	0.001	0.002	0.7566	−0.003	0.002	0.1352
Animal origin	0.003	0.001	0.0158	0.001	0.002	0.6448
Alcohol intake (g/day)	0.004	0.001	0.0036	0.004	0.001	0.0073
Serum albumin (g/L)	0.041	0.007	0.0001	0.036	0.007	0.0001
Body mass index (kg/m^2)	−0.010	0.006	0.0494	−0.012	0.005	0.0207
ADL problems:						
None (score 16)	0			0		
Few (score 17-21)	0.039	0.056	0.492	0.028	0.054	0.6077
More (score >21)	−0.136	0.060	0.023	−0.091	0.059	0.1205
Education level:						
Primary or less	0			0		
Secondary	0.111	0.059	0.061	0.104	0.056	0.0660
Higher	0.155	0.084	0.065	0.123	0.080	0.1228
Smoking status:						
Never smoked	0			0		
Former smoker	−0.078	0.064	0.221	−0.064	0.061	0.2973
Current smoker	−0.143	0.075	0.057	−0.134	0.073	0.0652

ADL = Activities of Daily Living (based on 16 items).

[a] Subjects with reported vitamin B_6 supplement use (n=54), with PLP levels >150 nmol/L (n=14), or with incomplete data (n=35) excluded, n=511 (261 males, 250 females) in analyses.

[b] Gender and study site also included in the model.

[c] Gender, study site, and all listed variables simultaneously included in the model.

DISCUSSION

In this standardized multicentre study we examined both dietary vitamin B_6 intake and plasma PLP, as well as several health status and lifestyle parameters, in apparently healthy Europeans aged 74-76 years. Prevalence of inadequate dietary vitamin B_6 intakes and plasma PLP levels was high. Plasma PLP concentration was strongly positively associated with dietary vitamin B_6 intake and with serum albumin. Furthermore, alcohol intake was positively and body mass index inversely associated with plasma PLP concentration.

The association between dietary vitamin B_6 intake and plasma PLP concentration was relatively strong, despite the use of different country specific nutrient databases which may have slightly weakened this effect. Since the nutrient databases may have been incomplete and not up to date with respect to information on the vitamin B_6 content of several foods, the actual association between vitamin B_6 intake and PLP concentration is expected to be somewhat higher than the one found in this study.

The disappearance of the positive association between intake of animal protein and plasma PLP concentration after inclusion of vitamin B_6 intake, indicates that animal protein intake reflects the intake of bioavailable vitamin B_6. The lack of association between vegetable protein intake and PLP concentration is in agreement with the findings that vitamin B_6 from vegetable sources may be less bioavailable than vitamin B_6 from animal origin.[15-18]

The association of vitamin B_6 status with (moderate) alcohol consumption has been found in other studies also, in elderly[34-36] as well as in younger subjects.[37] In alcoholics, however, a negative association has been demonstrated between alcohol consumption and vitamin B_6 status, both measured as PLP or as the PLP induced erythrocyte aspartate aminotransferase activation coefficient (EAST-AC).[38] In a number of studies the direct actions of alcohol on the biokinetics and metabolism of vitamin B_6 have been examined.[21,22,39] These experimental studies on the interactions between alcohol and vitamin B_6 suggest that PLP degradation is increased and the formation of PLP is reduced by chronic high alcohol intake, but it is not clear whether this occurs only when hepatic pathology is present or which doses of ethanol lead to these changes. Our SENECA data suggest that PLP formation is not impaired and that alcohol contributes positively to the vitamin B_6

status in this population. It may be that alcohol intake reflects vitamin B_6 intake through some alcoholic beverages, since vitamin B_6 contents data partly are missing for these drinks in the Swiss centres and the Dutch centre (all using the Dutch food composition table of 1986)[40] and possibly also for other centres.

Unfortunately, the association between fibre intake and PLP concentration could not be studied, due to inconsistencies in different types of dietary fibre between the country specific food composition tables. Previous studies did not show an adverse effect of dietary fibre on the availability or metabolism of vitamin B_6.[41,42] Other studies, however, did find a lower availability of vitamin B_6 from vegetable products.[15,17] Possibly, dietary fibre is a proxy of glycosides, which are known to decrease vitamin B_6 bioavailability when conjugated with this vitamin.[43]

Albumin is the transport protein of PLP in the bloodstream.[44] Several studies have demonstrated a decline in serum albumin concentration with advancing age.[45-47] Recently it was reported that only 2% of the SENECA population had serum albumin levels below 35 g/L.[48] The odds ratio of hypoalbuminaemia was 3 to 4 times higher for current and former smokers respectively compared with nonsmokers. This finding was in line with other studies.[47,49,50] The present results indicate that the inverse association between smoking and PLP concentration (after exclusion of serum albumin from the model) may be explained by the albumin lowering effect of smoking, even when albumin levels are almost all within the normal range. Despite the low prevalence of albumin deficiency in this study, and the well known high PLP binding capacity of albumin, relatively low levels of this transport protein are associated with low PLP levels. Whether this is a direct effect of albumin itself (e.g. by protecting PLP against rapid alkaline phosphatase mediated hydrolysis to pyridoxal), or a result of underlying health problems warrants further study. More parameters of vitamin B_6 metabolism should be measured for this purpose.

An inverse association has been found earlier between vitamin B_6 status and body weight but not with body mass index in the Boston Nutritional Status Survey,[36] and with ponderal index (as an estimator of body fatness) by Herbeth et al..[34] We have no clear explanation for this finding, however, the vitamin B_6 needs might be lower in obese people due to a lower lean body mass, reduced physical activeness, or underlying health problems.

Although the SENECA participants in general were apparently healthy elderly people, 36% reported having 1, and another 36% 2 or more chronic diseases.

However, neither this classification, nor classification based on subjective health feeling were associated with PLP concentration.

In conclusion, these data show that vitamin B_6 is a risk nutrient among apparently healthy elderly Europeans not using vitamin B_6 supplements. A low vitamin B_6 status is strongly associated with dietary vitamin B_6 intake and, independent of this intake, also strongly associated with alcohol intake and albumin status. Despite the high PLP binding capacity of albumin and serum albumin levels within the normal range, serum albumin may have a greater influence on vitamin B_6 status of elderly people than expected.

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CHAPTER 5

Serum vitamin D concentrations among elderly people in Europe

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ABSTRACT

Vitamin D status decreases with age, mainly as a result of restricted sunlight exposure, reduced capacity of the skin to produce vitamin D and reduced dietary vitamin D intake. We measured winter-time serum 25-hydroxyvitamin D [25(OH)D] concentrations in 824 elderly people from 11 European countries. Prevalence of 25(OH)D concentrations below 30 nmol/L was 36% for males and 47% for females. Users of vitamin D supplements and/or sunlamps had higher 25(OH)D levels (median 54 nmol/L) than those who did not (median 31 nmol/L). Surprisingly, lowest mean 25(OH)D concentrations were observed in southern European countries. Low 25(OH)D concentrations could for a large part be explained by attitudes towards sunlight exposure and factors of physical health status, after exclusion of users of vitamin D supplements or UV sunlamps. Having several problems in performing activities of daily living and wearing clothes with long sleeves during periods of sunshine were the strongest predictors of having low winter-time serum 25(OH)D concentrations. These findings show that free-living elderly Europeans, regardless of geographical location are at substantial risk of having an inadequate vitamin D status in winter, and that dietary enrichment or supplementation with vitamin D should be seriously considered during this season.

INTRODUCTION

Both lifestyle characteristics and physiological factors make elderly people prone to vitamin D deficiency, whereby restricted sunlight exposure, capacity of the skin to produce vitamin D, and low vitamin D intake are considered to be the main responsible factors.[1-4] Plasma or serum 25-hydroxyvitamin D [25(OH)D] is the most commonly used index of vitamin D status.[5,6] Low 25(OH)D concentrations may elevate serum parathyroid hormone (PTH) concentration, which leads to calcium resorption from bone, and therefore enhance the osteoporosis process.[7-10] Since 25(OH)D concentrations are affected by the hours of sunlight exposure and its intensity,[1,3,11] it may be expected that these concentrations would be a function of geographical location (both altitude and latitude). A review of 25(OH)D in elderly people in different reports indicated (with a few exceptions) an inverse association between mean concentration and latitude.[12] However, drawing parallels between different studies is seriously hampered by lack of standardization as to the population under study, the methodology used, and season.

We evaluated the serum 25(OH)D concentrations of elderly people living in different towns in Europe, who participated in the Euronut SENECA study (a concerted action of the European Community).[13] All participating towns were subject to a strictly standardized study protocol.[14] We report the geographical distribution of mean serum 25(OH)D concentrations and the relationship with indicators of physical condition, sunlight exposure and consumption of foods.

SUBJECTS AND METHODS

Subjects

The Euronut SENECA study is an investigation of the diet and health of elderly people from 19 towns in 12 European countries. In each country towns were selected with a population size of 10,000-20,000 and as far as possible a socio-economic structure comparable to the country or the region as a whole. Data were collected between December 1988 and March 1989 in 16 towns in 11 countries. Subject selection and data collection were carried out according to a strictly standardized protocol.[13,14] In each town, random samples of the residents were stratified for age and sex, whereby the size of the age-groups depended on calendar year of birth: n=30 for 1913 and 1914, n=35 for 1915 and 1916, n=45 for 1917 and 1918. Inclusion of the birth-cohorts 1913 and 1914 was obligatory, and in nine towns people born in 1915-1918 were also studied. Ultimately, 2586 subjects participated. The mean response rate was 51% (Standard Deviation [SD] 16) and from a non-responders questionnaire (completed by 60% of the non-responders) it was concluded that males, non-smokers, healthier and better educated persons were more likely to participate.[14] Since 25(OH)D concentrations may fluctuate seasonally, only blood samples collected in January-March 1989 were used in this study (n=414 males and 410 females).

Biochemistry

Fasting blood samples (25 ml) were collected; 10 ml were transferred to dry tubes, with subsequent serum separation. A portion (0.5 ml) of each serum sample was frozen and stored at −80°C for 25(OH)D determination.[13] All blood samples were sent on dry ice to the coordinating centre in Wageningen, the Netherlands, and again stored at −80°C. Serum 25(OH)D values were analyzed by competitive protein-binding assay (coefficients of variation: within-assay 4-7%, between-assay 7-10%)[5] at the TNO Nutrition and Food Research Institute, Zeist, the Netherlands.

Dietary intake

Dietary intake data were collected by trained personnel, using a modified dietary history.[13,15] The method comprised a three-day estimated record and a frequency checklist of foods, based on the meal pattern of the country and with the previous month as a reference period. Portion sizes were checked by weighing quantities of food and household measures. Intakes of nutrients and food groups were calculated in each country using local food composition tables.[13]

Questionnaires

In a general structured interview in the participant's home, information was obtained on potential determinants of vitamin D status: use of dietary supplements, use of sunray lamps, presence of chronic disease, activities of daily living (ADL), social isolation, and exposure to sunlight. ADL was calculated as a sum of scores of level of competence for 16 items, with scores ranging from 1 (no difficulty) to 4 (unable to complete).[16] Subjects were categorized as people having no problems with ADL performance (score 16), people having problems with a few items (score 17-21), and people having more problems (score >21). By using the cut-off score of 21 the group of subjects with any problems was split up into subgroups of approximately equal sample size. Hours spent outdoors with walking, cycling, gardening and other activities were summed to estimate an outdoor leisure time activity score. Questions on sunlight exposure concerned the frequency of going outside during sunny periods; and the clothes worn when outdoors during the summer. Body height and weight were measured with the participants in underclothes only. Details about collected data are reported elsewhere.[13,14]

Data analysis

Town- and sex-specific means are reported for the total population under study, along with the proportion of participants with a 25(OH)D concentration below 30 nmol/L. In a group of 207 healthy adult (18-65 yr) Dutch blood donors, the cut-off value corresponded to the 10th percentile.[5] It has also functional significance as in a recent study concentrations of 25(OH)D below 30 nmol/L were associated with secondary hyperparathyroidism, increased bone turnover and decreased bone mass density at the hip, whereas no association with these parameters was found above 30 nmol/L.[10] Differences in 25(OH)D concentration between users of vitamin D supplements and/or sunlamps and those who did not, were tested at the 95% confidence level with Wilcoxon's rank-sum test. Associations with several potential risk factors of low 25(OH)D status were studied in linear regression models, after taking the natural logarithm of 25(OH)D concentrations. Thus, the model predicts geometric rather than arithmetic means and, regression coefficients approximate relative differences from the reference category rather than absolute differences.

Similar to relative risks in logistic regression, relative differences can be calculated as the anti-log of the regression coefficient minus one.[17] Continuous variables (with the exception of age and body mass index) were categorized according to tertiles of the distribution. Categories with the highest median 25(OH)D concentration were chosen as the reference categories. All independent variables showing a significant association with 25(OH)D in either males, females, or both sexes combined, were included in a multivariate linear regression model to study their effect. In this model, study site was also included as n – 1 dummy variables.

Table 1. Concentration of 25-hydroxyvitamin D and prevalence of low concentrations in different towns of the SENECA study.

		Males			Females		
Town	latitude (° north)	n	mean (nmol/L)	<30 (%)	n	mean (nmol/L)	<30 (%)
E/N	61	32	45	28	28	48	18
R/DK	56	33	44	24	25	40	32
C/NL	52	30	42	20	29	42	38
H/B	51	31	43	26	29	40	24
H/F	49	30	35	47	26	37	62
CA/F	48	16	35	38	11	32	36
M/H	47	19	33	37	23	32	52
Bu/CH	47	24	42	25	24	44	25
Y/CH	47	26	59	12	32	46	12
Be/CH	46	22	36	45	25	34	44
R/F	45	35	40	34	25	37	44
B/E	43	27	30	52	29	21	86
FMP/I	42	12	32	42	13	24	92
V/P	39	29	39	31	30	39	33
M/GR	38	21	31	52	25	22	80
AA/GR	35	27	25	70	36	21	83

E/N = Elverum, Norway; R/DK = Roskilde, Denmark; C/NL = Culemborg, the Netherlands; H/B = Hamme, Belgium; H/F = Haguenau, France; CA/F = Chateau Renault-Amboise, France; M/H = Monor, Hungary; Bu/CH = Burgdorf, Switzerland; Y/CH = Yverdon, Switzerland; Be/CH = Bellinzona, Switzerland; R/F = Romans, France; B/E = Betanzos, Spain; FMP/I = Fara Sabina-Magliano Sabina-Poggio Mirteto, Italy; V/P = Vila Franca de Xira, Portugal; M/GR = Markopoulo, Greece; AA/GR = Anogia-Archanes, Greece.

RESULTS

Town specific mean serum 25(OH)D concentrations ranged from 25 nmol/L (Anogia, Archanes; Greece) to 59 nmol/L (Yverdon, Switzerland) for males, and from 21 nmol/L (Anogia, Archanes; Greece and Betanzos; Spain) to 48 nmol/L (Yverdon, Switzerland) for females (**Table 1**). Overall the prevalence of values below 30 nmol/L was 36% for males and 47% for females. **Fig. 1** shows the geographical distribution of mean 25(OH)D concentrations. Lowest mean concentrations of 25(OH)D were found in the southern European towns in Greece, Spain and Italy. Town specific median 25(OH)D concentrations showed similar results (data not shown).

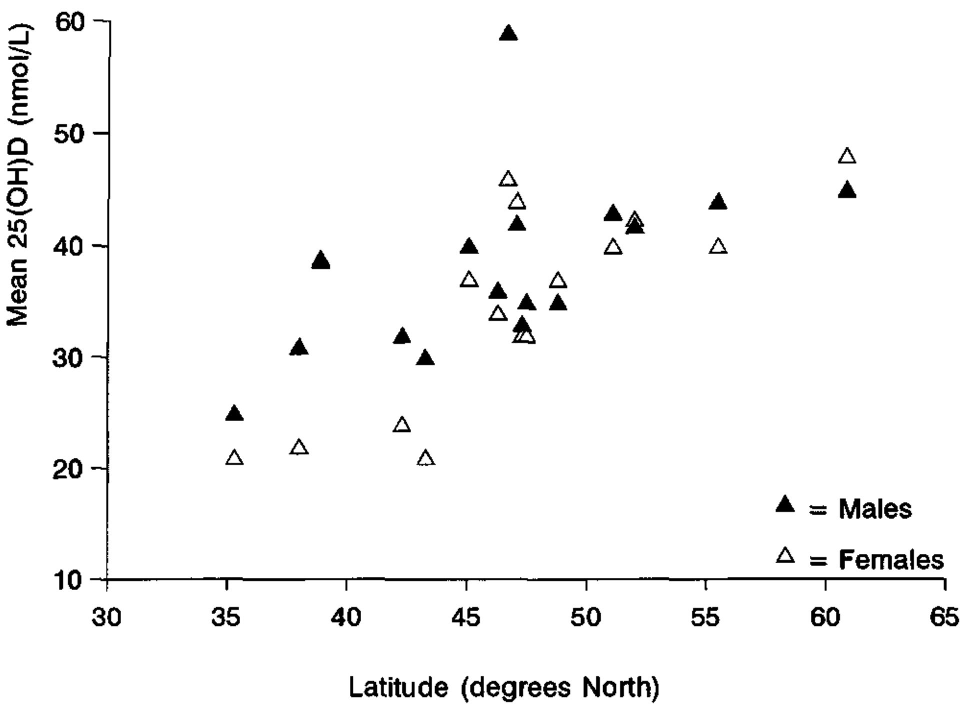

Fig. 1. Geographical distribution (latitude) of mean 25-hydroxyvitamin D concentrations by study site.

People who indicated to use sunlamps and/or vitamin D supplements were found to have much higher 25(OH)D concentrations than those who did not (**Table 2**). Males had slightly but significantly higher 25(OH)D concentrations than females ($P<0.001$), in the total population (medians 34 and 30 nmol/L respectively) as well as in the non-users (medians 34 and 29 nmol/L respectively). Two thirds of the users of vitamin D supplements and/or sunray lamps lived in Elverum, Norway (n = 32) or in Roskilde, Denmark (n = 31). After exclusion of these subjects median 25(OH)D concentrations were 31 and 35 nmol/L in Elverum, and 32 and 26 nmol/L in Roskilde for males and females, respectively.

Table 2. Serum 25-hydroxyvitamin D (nmol/L).

	n	P10	median	P90
All subjects	824	16	33	62
No sunlamps or D supplement users	731	15	31	56
Sunlamps and/or D supplement users	93	29	54 [a]	89

[a] Significantly higher than in the group without sunlamp and/or D supplement use ($P<0.001$)

Since differences in 25(OH)D between users and non-users were large, the former (n = 93) were excluded from further analyses investigating the impact of several other plausible determinants of 25(OH)D concentration, as were people with incomplete data with respect to these determinants (n = 46). In the remaining 685, linear regression analysis was performed on log-transformed data. Gender, activities of daily living score, going outside during periods of sunshine, clothing attitudes during sunny periods, and tertiles of body weight, calcium intake, energy intake, meat- and fish consumption were found to be associated ($P<0.10$) with 25(OH)D concentration in linear regression models. To assess the independent effect of each characteristic, all these variables together with study site and age were simultaneously included in a multivariate model (**Table 3**). Body mass index, social isolation, and dietary intake of oils and fat were not associated with 25(OH)D concentration. According to the relative differences in **Table 3**, wearing short sleeved shirts in the sunshine would result in a 14% reduction of the estimated 25(OH)D concentrations compared to wearing beach clothes, and wearing long sleeved shirts even in a reduction of 20%. Having several problems in performing activities of daily living resulted in an estimated reduction of 25(OH)D concentration with 18% compared to having no problems. Age, body weight, and intakes of calcium, energy and meat had no major remaining effect in the multivariate model. Similar results were found for males and females separately (data not shown).

Table 3. Concentrations of 25-hydroxyvitamin D for selected characteristics and results of the multiple regression analysis.[a]

Characteristic	n	median (nmol/L)	relative difference[b]	(95% CI)
Gender:				
Males	346	34	0	
Females	339	29	−0.09	(−0.16;−0.02)
ADL problems:				
None (score 16)	270	35	0	
Few (score 17-21)	214	32	−0.03	(−0.11;0.05)
More (score >21)	201	26	−0.18	(−0.25;−0.10)
Sunny periods:				
Daily outside	562	33	0	
Sometimes outside	74	28	0.01	(−0.09;0.13)
Avoid to go outside	49	23	−0.13	(−0.24;0.00)
Clothing in sunshine:				
Beach clothes	77	41	0	
Short sleeves	466	32	−0.14	(−0.23;−0.03)
Long sleeves	142	25	−0.20	(−0.30;−0.08)
Fish consumption (g/d):				
>32	225	31	0	
15-32	223	34	−0.04	(−0.12;0.05)
<15	237	30	−0.10	(−0.19;−0.02)

ADL = Activities of Daily Living (based on 16 items).

[a] Users of vitamin D supplements, sunlamp users, and subjects with incomplete data are excluded.

[b] Relative difference in 25-hydroxyvitamin D status compared to the reference category (after simultaneous inclusion in the model of study site, gender, age, going outside during periods of sunlight, clothing attitudes during sunny periods, ADL score, body weight, and intake of calcium, energy, meat, and fish.

From back translation of the general questionnaire it was revealed that questions regarding outdoor leisure time activities were coded differently in the French towns and could not be recoded. After exclusion of the French towns, 25(OH)D concentration and hours spent on activities outdoors (tertiles) were significantly associated in the multivariate model in the remaining 276 males and 284 females. Compared to daily performing outdoor leisure time activities for 2 hours or more, spending less than 1 hour on these activities resulted in a 12% lower 25(OH)D concentration (95% CI −0.20; −0.03). Except for the effect of gender, which disappeared, the other relative differences showed only minor changes.

DISCUSSION

This multicentre study showed that 25(OH)D concentrations below 30 nmol/L are widespread among elderly people in Europe. Contrary to the expectations, in general lower median values were observed in southern Europe than in northern Europe. Low 25(OH)D concentrations could generally be explained by reduced sunlight exposure (avoidance of sunlight, clothing habits, performance of outdoor leisure time activities) and by problems with performing activities of daily living (an indicator of physical health status).

To our knowledge, this is the first study in which serum 25(OH)D concentrations were determined in a standardized way (analyzed in one laboratory, collected in the same period of the same year from elderly people in the same age category, living in relatively small towns widespread over Europe). All blood samples in this study were collected in winter, during which period 25(OH)D concentrations are lowest.[1,18-20]

The use of 30 nmol/L as cut-off value for low 25(OH)D concentrations in our study is in agreement with the recent finding that 25(OH)D levels below 30 nmol/L are associated with secondary hyperparathyroidism, increased bone turnover and decreased bone mass density at the hip, whereas no such association was found above this level [10]. Other studies in elderly people have shown associations with parathyroid hormone concentration and bone density at higher 25(OH)D concentrations (38-95 nmol/L).[7-9]. However, in those studies different biochemical analysis methods were used and therefore the latter results could not be used in estimating a cut-off value for low 25(OH)D concentration.

Vitamin D formation in the skin is affected by both intensity and duration of exposure to ultraviolet light. Intensity is higher in summer and in the south. Apart from spending less time in the sun in summer, low 25(OH)D concentrations in winter may as well be a consequence of other factors, like a lower efficiency of utilisation of vitamin D or a low vitamin D intake.

When calcium intake is inadequate, production of 1,25-dihydroxyvitamin D increases, leading to a more rapid decline of 25(OH)D compared to an adequate calcium supply.[21] In the SENECA study, calcium intake (median 894 mg/d) was not significantly lower in the southern European study sites.[22] The disappearance of the association between calcium intake and 25(OH)D indicates that this association is at the most very weak, possibly because the calcium intake is in the adequate range.

Positive associations between intake of vitamin D and serum 25(OH)D have frequently been observed among elderly people, especially in winter.[4,9,23-27] Dawson-Hughes et al.[28] showed that a daily intake of 12.5 μg greatly attenuated the change in 25(OH)D from summer to winter. Unfortunately, most European food composition databanks do not contain vitamin D and are not standardized regarding analytical methods. It was therefore not possible in this study to calculate the vitamin D intake. However, since animal products are the only natural vitamin D containing food source, we included these products as tertiles in the multivariate model. No effects on vitamin D status were found of consumption of animal products, with the exception of low fish consumption, which was associated with a reduced vitamin D status.

In some countries edible oils and fats are vitamin D enriched, and therefore may become important dietary vitamin D sources, especially in winter when sunlight exposure is scarce. Vitamin D addition to margarine is compulsory in Norway, Denmark, the Netherlands, Belgium and Portugal, prohibited in France, and optional but not performed in Hungary, Switzerland, Spain, Italy, Portugal and Greece (personal communication with the principle investigators of each country). In the countries with the lowest mean winter-time 25(OH)D concentrations, no vitamin D fortification of foodstuffs takes place. In a nationwide Dutch nutritional survey in apparently healthy elderly people[29,30] (n = 538), autumn and winter

25(OH)D concentrations were comparable to our Dutch data, whereas mean dietary vitamin D intakes were estimated to be 6.38 μg/day and 4.83 μg/day (SD 1.78) for males and females, respectively. Edible oils and fats were the main vitamin D source (41% and 45% in males and females, respectively), indicating the importance of vitamin D fortification. Recently, a much higher median winter-time 25(OH)D concentration (75 nmol/L) was found in elderly white females living on Curaçao (an island in the Caribbean sea, 12° north latitude) compared to their counterparts living in a retirement home in the Netherlands (median 25 nmol/L) where sunlight exposure is negligible in winter.[31] It is clear from these studies, that the usual dietary vitamin D intake is not sufficient to keep vitamin D status at an adequate level in periods when the skin is not able to produce enough vitamin D. This has consequences for the vitamin D supplementation policy in the elderly.

In conclusion, our results show that vitamin D is a high risk nutrient among free-living elderly in Europe. Surprisingly low mean 25(OH)D concentrations were found in elderly people living in southern European towns. The reasons for this should be further quantified in order to devise preventive measures. Dietary enrichment or supplementation with vitamin D should be seriously considered to assure an adequate winter-time vitamin D status.

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CHAPTER 6

Nutritional status of elderly female nursing home residents; the effect of supplementation with a physiological dose of water-soluble vitamins

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ABSTRACT

The nutritional status of forty-two female elderly nursing home residents was assessed. Furthermore, the effect of dietary supplementation with a physiological dose of water-soluble vitamins for 12 weeks was studied in a single-blind, randomized, placebo controlled intervention trial. The participants were aged 60 years and older, in relatively stable health condition, and at least 3 months resident at baseline. The daily consumed supplement consisted of fortified fruit juice containing 50 g carbohydrate and 50% of the daily dietary recommendations of water-soluble vitamins. Regular fruit juice was used as placebo. Dietary intake was assessed at baseline. A fasting bloodsample, anthropometric measurements and medical information were collected at baseline and after 4 and 12 weeks of supplementation. The participants had a poor nutritional status. Dietary supplementation significantly improved the concentrations of thiamin pyrophosphate and pyridoxal 5'-phosphate, increased body weight and decreased serum homocysteine concentration in the supplement group. Plasma vitamin C levels were significantly increased in both supplement and control group. Even in this heterogeneous population of female nursing home elderly it is possible to improve the nutritional status through dietary intervention with a physiological dose of water-soluble vitamins.

INTRODUCTION

Ageing is accompanied by a deterioration of health status. The onset and intensity of this process is not age-determined but differs from person to person, leading to a substantial heterogeneity within age groups.[1-3] Depending on the rapidness of the ageing process, a distinction can be made between successful, normal and accelerated ageing.[4,5] Nursing home residents are a very heterogeneous group but may generally be classified as accelerated agers. They carry a heavy burden of chronic diseases and disabilities and are often found to be at risk of having reduced dietary intakes and a marginal nutritional status.[6-13]

Inadequate dietary intakes of energy and micronutrients, co-morbidity and drug use may lead to multiple micronutrient deficiencies. Concentrations of water-soluble vitamins show the fastest decline since body reserves are limited and absorption may be hampered.[14] Supplementation may improve the nutritional status of nursing home residents. However, relatively few studies have investigated this.[15-22]

Therefore we studied the nutritional status of female elderly nursing home residents and the effect of a dietary supplement with a physiological dose of water-soluble vitamins.

SUBJECTS AND METHODS

Subjects

Female elderly nursing home residents with a chronic somatic disability were recruited from three nursing homes located in the central area of the Netherlands. The women, who were selected by the nursing home physicians in April 1993, were resident for at least 3 months and had to be in stable health condition with no dementia, severe gastrointestinal problems or type I diabetes. Further inclusion criteria were being at least 60 years of age and belonging to the Caucasian race, and no use of multimicronutrient supplements, parenteral or tube feeding.

After the study protocol was comprehensively explained, all 42 women approached were initially willing to participate and gave their written informed consent. The study protocol was approved by the Medical Ethical Committee of nursing home 'De Braamberg' in Arnhem, and by the external Ethical Committee of the Department of Human Nutrition of the Wageningen Agricultural University.

In each of the nursing homes, seven women were randomly assigned to the supplement group and seven to the control group. Two subjects in the control group, and one subject in the supplement group died within 5 weeks after the baseline measurements and were therefore not included in the analyses. Furthermore, five women in the supplement group and nine in the control group did not complete the 12-week intervention period for personal reasons.

Design

The intervention period was 12 weeks. The daily supplement consisted of two fruit juices (200 ml apple-pear juice and 200 ml orange-apricot), enriched with energy (as carbohydrates) and ~25% of the Dutch dietary recommendations[23] of water-soluble vitamins, minerals and trace elements per 200 ml juice, and were exclusively developed for this study by the clinical food division of the Nutricia Company, the Netherlands. The energy content of the juices was 840 kJ per 200 ml (as carbohydrate). The total amount of the vitamins under study in the daily portion of 400 ml was: vitamin C 31.5 mg, thiamin 0.44 mg, vitamin B_6 0.81 mg, folic acid 63 μg and vitamin B_{12} 1.10 μg. The subjects in the control group received two regular fruit juices on a daily basis (total amount of energy 465 kJ, vitamin C 40.5 mg, other vitamins negligible). Participants were encouraged by the nursing staff to drink the complete amount of 400 ml and compliance was checked by registering the amounts consumed to the nearest 50 ml.

On three occasions (at baseline, and after 4 and 12 weeks intervention) data were collected.

Dietary intake

At baseline, food consumption data were obtained in a personal interview by two trained dieticians, using a validated modified version of the dietary history method.[24,25] After an inventory of the global food consumption pattern of weekdays and weekend, the habitual dietary intake covering the last 4 weeks as a reference period was assessed, using a checklist of foods. Food consumption data were converted into energy and nutrients using a computerized version of the Dutch food composition table.[26] Details of the used method are described elsewhere.[27]

Questionnaires

Medication and smoking habits were registered. Ability to perform basic activities of daily living (ADL) was calculated as a sum of scores from the abilities in washing upper part of the body, washing lower part of the body, dressing, toileting and feeding. For each item the possible scores were 0 (no help needed), 1 (some help needed), 2 (intensive help needed). A mobility score was calculated from the abilities in standing, walking and transfers (same scores possible as for ADL items), endurance (consecutive hours out of bed: 0 = more than six, 1 = two to six 2 = less than two) and confinement to a wheelchair (0 = no, 1 = yes but mobile, 2 = yes and immobile).

Physiological measurements

Body weight (to the nearest 0.1 kg) with the subject dressed in light clothing (Seca scale in which the subject could sit) and mid upper arm circumference (MUAC, to the nearest 0.1 cm) were measured as indices of body composition. Grip strength of the strongest hand was measured and recorded to the nearest 0.5 kg using a hand dynamometer (Lafayette, Indiana, USA, Type 78011). The highest value of four consecutive grips was registered. Blood pressure was measured using an automatic blood pressure device (oscillometric method, Takeda Medical UA-751, Adquipment Medical BV, Rotterdam, the Netherlands).

Biochemistry

Fasting blood samples (one 5 ml EDTA tube, one 10 ml heparin tube, one 10 ml gel tube) were collected at baseline, and after 4 and 12 weeks of intervention. Of the heparin-blood 2x2 ml was separated and frozen at −20 °C for the high-performance liquid chromatography (HPLC) analysis of thiamin pyrophosphate[28,29] and pyridoxal 5′-phosphate[30], and after centrifugation of the remaining part, 1 ml plasma was immediately added to 4 ml metaphosphoric acid (0.68 M) and frozen for the HPLC analysis of ascorbic acid.[31,32] The Gel tube was also centrifugated and frozen. The serum was used for the analysis of albumin with a bromocresol green method on a Beckman CX4CE clinical chemical analyzer (Beckman, Brea, California, USA); pre-albumin, C-reactive protein, α_1-glycoprotein and transferrin with a turbidimetric method (Turbox system, Orion Diagnostica, Espoo, Finland); total homocysteine with a HPLC method[33]; folic acid and vitamin B_{12} by a dual count solid phase no-boil radioimmunoassay (Diagnostic Corporation, Los Angeles, California, USA). Within 2 weeks the samples were transported to a −40 °C freezer and for each measurement moment (baseline and after 4 and 12 weeks) analysed in batches. Haemoglobin and lymphocytes were analysed in fresh EDTA blood on a Technicon H1 haematology analyser (Technicon Instruments Co, Tarrytown, New York, USA).

Data analysis

Descriptive measures are expressed as mean values with standard deviations (SD) or as frequency distribution. For the biochemical parameters, the prevalence of women with concentrations deviating from the reference (lower or upper levels of the 95% confidence interval based on 20-100 healthy individuals) are also calculated. Since most of the data were not normally distributed, non-parametric tests were used. Spearman correlation coefficients were calculated between functional parameters of nutrition and health status. The effect after 12 weeks of supplementation was studied in the supplement group by the Wilcoxon sign-rank test. Comparisons between the supplement and control group were made using the Wilcoxon rank-sum test. Relative risks of mortality within one year according to baseline levels of health status parameters were calculated by Cox proportional hazard (survival) analysis. In all data analyses, $P<0.05$ was considered significant. Data analysis was performed using the statistical program SAS (SAS Institute Inc, Cary, NC, USA).

Table 1. Baseline characteristics of female nursing home residents.

Variable	Total population (n=39)		Control group (n=18)[a]		Supplement group (n=15)[a]	
Age (y)	81	(7)	82	(8)	81	(6)
Activities of Daily Living[b]	6.3	(2.7)	6.5	(2.6)	6.7	(2.4)
Mobility[b]	6.0	(2.3)	6.4	(2.3)	5.8	(2.3)
Body weight (kg)[c]	66.4	(11.3)	63.2	(11.0)	69.9	(7.6)
Mid Upper Arm Circumference (cm)	28.6	(4.4)	27.7	(3.1)	29.0	(3.2)
Grip strength (kg)	11	(5)	9	(5)	13	(4)
Diastolic blood pressure (mm Hg)	74	(16)	73	(19)	75	(15)
Systolic blood pressure (mm Hg)	131	(26)	121	(20)	140	(29)
Smoking (% yes)	8		6		7	
Indication diagnosis (%):						
Nervous system disorders	10		11		7	
Cardiovascular disorders	54		56		53	
Respiratory disorders	5		0		13	
Physical mobility disorders	31		33		27	
Drug use (% yes):						
Cardiovascular disorders	77		67		87	
Nervous system disorders	69		67		67	
Analgesics	56		67		47	
Respiratory disorders	18		22		20	
Dermatologics	23		22		20	
Antibiotics	5		6		7	
Digestive tract disorders	67		67		80	
Hormones	20		22		20	
Other medications	39		44		27	

Data shown as mean (SD) or as percentage 'yes'.

a Only women who completed the intervention period are included.

b On a 10-point scale (1 = *no assistance needed*, 10 = *always assistance needed*).

c Incomplete data as explained in the text (n=32, 16, and 11 respectively).

RESULTS

Baseline characteristics of the 39 female elderly nursing home residents are given in **Table 1**. All participants had problems with performing activities of daily living. The main cause for being admitted to the nursing home was stroke (46%). All participants used medication (6 ± 3 different types per individual), mainly prescribed for cardiovascular or nervous system disorders.

In **Table 2** dietary intake data are presented. Although energy intakes were low (6.6 ± 1.2 MJ/day), protein intake was in general adequate (total protein 55 ± 11 g/day, animal origin 38 ± 10 g/day, vegetable origin 16 ± 3 g/day). Mean daily dietary intakes of thiamin, riboflavin, vitamin B_6 and vitamin C were all below the Dutch dietary recommendations (1.0 mg/day, 1.3 mg/day, 0.02 mg/g protein and 70 mg/day respectively).[23]

Table 2. Baseline information on daily dietary intakes of female elderly nursing home residents.

Nutrient	Total population (n=39)		Control group (n=18)[a]		Supplement group (n=15)[a]	
	Mean	(SD)	Mean	(SD)	Mean	(SD)
Energy (MJ)	6.6	(1.2)	6.8	(1.0)	6.6	(1.2)
(Mcal)	1.6	(0.3)	1.6	(0.2)	1.6	(0.3)
Carbohydrate (g)	184	(48)	195	(48)	178	(41)
Protein (g)	55	(11)	56	(9)	56	(12)
Fat (g)	66	(14)	68	(13)	68	(14)
Thiamin (mg)	0.82	(0.18)	0.86	(0.17)	0.79	(0.16)
Riboflavin (mg)	1.21	(0.36)	1.26	(0.37)	1.27	(0.35)
Vitamin B_6 (mg)	0.97	(0.18)	1.00	(0.15)	0.94	(0.20)
Vitamin C (mg)	56	(26)	62	(24)	49	(24)

[a] Only women who completed the intervention period are included.

In **Table 3** biochemical indicators of nutritional and health status are presented together with the prevalence of subjects with inadequate levels. The prevalence of low albumin levels was very high (67%), as was the prevalence of low transferrin (46%) and high C-reactive protein levels (38%), and of low numbers of lymphocytes (36%). Furthermore, the prevalence of low levels of ascorbic acid (33%) and pyridoxal 5'-phosphate (23%), and of increased levels of homocysteine (26%) was substantial.

Table 3. Biochemical indicators of nutritional and health status of female elderly nursing home residents.

Parameter group	Total population			Control group		Supplement	
	(n = 39)		Deviation from reference[b]	(n = 18)[a]		(n = 15)[a]	
	mean	(SD)		mean	(SD)	mean	(SD)
Haemoglobin (mmol/L)	8.0	(0.9)	13 % < 7.3	8.0	(0.7)	8.0	(1.0)
Albumin (g/L)	31	(7)	67 % < 35	30.5	(7.4)	32.2	(5.9)
Pre-albumin (g/L)	0.21	(0.08)	8 % < 0.10	0.22	(0.08)	0.20	(0.08)
CRP (mg/L)	16.9	(32.4)	38 % > 10.0	13.6	(20.9)	18.3	(43.8)
α_1-glycoprotein (g/L)	0.88	(0.45)	15 % > 1.10	0.86	(0.39)	0.90	(0.50)
Transferrin (g/L)	2.38	(0.71)	46 % < 2.30	2.46	(0.70)	2.53	(0.65)
Lymphocytes ($\times 10^9$/L)	1.30	(0.66)	36 % < 1.00	1.27	(0.40)	1.12	(0.55)
Homocysteine (μmol/L)[c]	18	(6)	26 % > 20	17	(5)	18	(8)
Ascorbic acid (μmol/L)	24	(21)	33 % < 11	20	(14)	33	(28)
Thiamin PP (nmol/L)	141	(36)	3 % < 90	149	(42)	131	(26)
PLP (nmol/L)	43	(21)	23 % < 26	46	(25)	39	(16)
Folic acid (nmol/L)[d]	13	(11)	8 % < 5	14	(11)	10	(5)
Vitamin B_{12} (pmol/L)[e]	377	(315)	14 % < 160	365	(224)	320	(202)

CRP = C-Reactive Protein, PP = Pyrophosphate, PLP = Pyridoxal-5'-phosphate

[a] Only women who completed the intervention period included.

[b] Lower or upper levels of the 95% confidence interval based on 20-100 healthy individuals for various tests.

[c] Folic acid and vitamin B_{12} supplement users excluded.

[d] Two subjects (supplement group) excluded from analyses (one folic acid supplement user and not enough serum for another subject).

[e] Two vitamin B_{12} supplement users excluded (control group) and not enough serum for another subject (supplement group).

Spearman correlations between some indicators of health status are given in **Table 4**. Both albumin and pre-albumin correlated very well with MUAC and body weight. Albumin was also significantly positively correlated with pre-albumin and lymphocyte count, and negatively with C-reactive protein and α_1-glycoprotein.

Although not shown, the mobility score correlated significantly with ADL (r = 0.49) as expected. Furthermore, vitamin C significantly correlated with mobility score (r = −0.44), MUAC (r = 0.34) and C-reactive protein (r = −0.48); thiamin pyrophosphate with transferrin (r = −0.41); pyridoxal 5'-phosphate with mobility score (r = −0.32); vitamin B_{12} with mobility score (r = −0.33), grip strength (r = −0.38), iron (r = −0.40), C-reactive protein (r = 0.40) and α_1-glycoprotein (r = 0.38). No clear association could be detected between having high levels of serum homocysteine and low levels of either pyridoxal 5'-phosphate, folic acid, or vitamin B_{12}.

Table 4. Spearman correlation coefficient between health status parameters at baseline (n = 39).

	MUAC	Grip strength	Body weight	Albumin	Pre-albumin	C-Reactive Protein	α_1-Glyco-Protein
Grip strength	0.38[a]						
Body weight	0.86[c]	0.44[a]					
Albumin	0.53[c]	0.16	0.37[a]				
Pre-albumin	0.52[c]	0.08	0.46[b]	0.59[c]			
C-Reactive Protein	−0.45[b]	−0.36[a]	−0.22	−0.37[a]	−0.21		
α_1-Glycoprotein	−0.18	−0.23	−0.01	−0.32[a]	−0.16	0.49[b]	
Lymphocyte count	0.23	0.15	0.12	0.45[b]	0.18	−0.18	−0.44[b]

MUAC = Mid Upper Arm Circumference.
[a] $P < 0.05$; [b] $P < 0.01$; [c] $P < 0.001$.

After randomization, the two groups were similar at baseline with respect to all measured variables (**Tables 1-3**). The intervention period was completed by 18 women in the control group and 15 women in the supplement group. In **Table 5**, the effect of supplementation is presented for the water-soluble vitamin concentrations, as well as for the other variables, demonstrating a significant effect of supplementation. By mistake, body weight was not measured in one nursing home unit at baseline (n = 6) and in another unit after 4 weeks of intervention (n = 9). In spite of the missing values at baseline, a significant increase in body weight was found after 12 weeks in the supplemented group compared to the controls. When comparing the differences in concentration change between the supplement group and the control group, concentrations of thiamin pyrophosphate and pyridoxal 5'-phosphate significantly increased and homocysteine concentration significantly decreased. Plasma vitamin C concentration significantly increased in both the supplement- ($P<0.05$) and control group ($P<0.05$). No relevant nor statistically significant differences in changes between the groups were found for the other parameters measured in this study.

Table 5. Absolute changes in body weight, vitamin status and homocysteine concentration after 4 and 12 weeks of treatment.

	Control group (n = 18)				Supplement group (n = 15)			
	Δ 4 weeks		Δ 12 weeks		Δ 4 weeks		Δ 12 weeks	
	mean	(SD)	mean	(SD)	mean	(SD)	mean	(SD)
Body weight (kg)[a]	+0.2	(1.0)	+0.9	(2.0)	+1.2	(2.5)	+2.4	(1.3)*
Vitamin C (µmol/L)	+23	(19)	+14	(25)	+28	(30)	+17	(25)
Thiamin PP (nmol/L)	−38	(50)	−22	(43)	−15	(30)	+16	(21)**
PLP (nmol/L)	+17	(36)	−1	(21)	+42	(26)*	+45	(24)***
Folic acid (nmol/L)[b]	+0	(5)	+3	(9)	+3	(5)	+6	(5)
Vitamin B_{12} (pmol/L)[c]	−68	(101)	−22	(114)	−31	(130)	−11	(131)
Homocysteine (µmol/L)[d]	−4	(5)	+2	(12)	−9	(7)	−7	(8)*

PP = Pyrophosphate; PLP = Pyridoxal 5'-phosphate.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$ changes between treatment groups (Wilcoxon rank-sum test).

[a] Incomplete data as explained in the text (n = 11, 16, 7, and 11 for the four columns respectively).

[b] Two subjects (supplement group) excluded from analyses (one folic acid supplement user and not enough serum for another subject).

[c] Two vitamin B_{12} supplement users excluded (control group) and not enough serum for another subject (supplement group).

[d] Folic acid and vitamin B_{12} supplement users excluded.

Of the 39 subjects with complete baseline data, 11 died within 1 year. Serum albumin showed a significant inverse relationship with mortality (risk ratio = 0.87, $P = 0.0003$). Inclusion of age in the model had no effect, nor did supplement use. Of the 11 incident cases, six belonged to the lowest tertile of baseline albumin concentration (< 29 g/L), two to the middle (29-35 g/L) and two to the highest (> 35 g/L). Other indicators of poor health status did not show a significant association with mortality.

DISCUSSION

This study showed that in a heterogeneous group of female elderly nursing home residents with a poor health and nutritional status, dietary enrichment with a physiological dose (~ ½RDA) of water-soluble vitamins for 12 weeks significantly improved the concentrations of thiamin pyrophosphate, pyridoxal 5'-phosphate and vitamin C. As a result of the natural occurrence of vitamin C in fruit juice, mean vitamin C concentration significantly increased in both supplement and control group. Furthermore, a small but significant increase in body weight and a decrease in serum homocysteine concentration was found. The supplement had no statistically significant effect on other health status parameters.

Although only residents with a more or less stable health condition were selected, low levels of serum albumin and transferrin, low lymphocyte count and high levels of C-reactive protein and homocysteine indicate a high prevalence of chronic as well as acute illness in this population.[34-38] Serum albumin was found to be a risk factor of mortality within 1 year, which is in agreement with earlier findings.[34,35]

In spite of the low total energy intakes, protein intake was adequate in all subjects which may explain the lack of correlation between protein intake and serum albumin concentration. Low serum albumin levels seem to be an indicator of chronic disease prevalence rather than of protein malnutrition.[39,40]

Homocysteine is an intermediate amino acid formed during the conversion of methionine to cystathionine. Pyridoxal 5'-phosphate is an essential cofactor in the formation of cystathionine from homocysteine.[37] The majority of homocysteine, however, is recycled into methionine by a transmethylation reaction which requires folate and vitamin B_{12}.[37] High doses of these vitamins have been shown to reduce serum homocysteine levels in people with homocystinuria and in folate or vitamin B_{12}-deficient subjects.[41-43] In our study we found no association between baseline serum homocysteine and concentration of the three vitamins, which might be a result of the heterogeneity in medication and disease.[37,44] Low dosage dietary supplementation, significantly reduced serum homocysteine concentrations compared to the controls, which calls for further studies in this field.

Low dietary intakes of elderly people are most probably a combined result of health deterioration, reduced physical activeness and reduced energy needs.[45] We recently compared dietary intakes of energy and water-soluble vitamins between representatives of the three proposed categories of ageing (i.e. successful, normal and accelerated) using the same dietary method.[27] Our group of female nursing home residents were considered to be the accelerated agers. Lowest intakes were found in this group and this was the result of a general reduction of intakes from all food groups. Although not statistically significant, the initial mean body weight in the supplement group was slightly higher than in the control group. Therefore the significant increase in body weight in our intervention group most probably is not a 'regression-to-the-mean' type of effect, but indicates that the dietary supplement was consumed in addition to, rather than replacing a part of, the normal diet. We did not collect extensive body composition data to indicate whether the changes in body weight were a result of an increase in fat mass or in muscle mass. However, the weight gain will probably be due to an increase in mainly fat mass, based on the fact that no physical activity intervention was performed.

Brocklehurst et al. reported that a low vitamin C and thiamin status was present in respectively 78% and 76% of the 80 nursing home residents studied, and that the vitamin status significantly improved after twelve months of supplementation with approximately 5 times the RDA.[15] Although in recent decades poor status of water-soluble vitamins has been reported frequently in institutionalized elderly, relatively few studies have tried to improve this situation. Baker et al. suggested that the absorption of small amounts of vitamins, despite oral vitamin supplementation, may not be sufficient to saturate storage tissue and that intramuscular administration may be a more effective method.[18] Other studies found, however, that it is possible to improve the status of vitamin B_1,[16,19] vitamin

B_2,[16] vitamin B_6,[16,22] or vitamin C,[17,19-21] in institutionalized elderly patients. The dosage supplied in those studies varied form ~1 RDA to even 20 times the RDA and only a few vitamins were supplemented, whereas dietary inadequacy in this category of elderly people most often involves multiple micronutrient deficiency due to a general decrease in food intake. Recently, Fiatarone et al. showed that it is possible to counteract muscle weakness and physical frailty in elderly nursing home residents by exercise training for ten weeks.[46] Additional multinutrient supplementation as an energy rich (1.5 MJ) liquid providing approximately one-third of the RDA of vitamins and minerals resulted in a significant increase of total energy intake in the exercise group, indicating that it is possible to increase food intake in institutionalized elderly.

Several factors may explain why there are only limited data available on attempting to improve the nutritional status of elderly nursing home residents. Although they form a group using a similar health care system, they are still very heterogeneous with respect to disease status and use of medicines. Obtaining the data in a standardized way is hampered by severe chronical physical handicaps. In our study, patients generally needed a lot of help from the nursing staff, which made it impossible to measure body weight without clothes. Furthermore, most participants were in a wheelchair and had kyphosis, which prohibited us from carrying out height measurements. However, since we were interested in changes, height adjusted weight measurements were not relevant.

Despite the heterogeneity of our population the results of this study look promising by showing that the ability to improve the nutritional status through dietary intervention is possible in chronically ill elderly people.

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CHAPTER 7

General discussion

CONTENTS

The studies in this thesis, were performed to expand the available knowledge of the nutritional situation of elderly people, and to come with recommendations of how the nutritional status of vulnerable groups from a nutritional point of view may be improved.

In December 1991, descriptive results of the SENECA study (a Survey in Europe on Nutrition and the Elderly, a Concerted Action) were published.[1] The main purpose of the SENECA study was 'to explore dietary patterns in the elderly living in different European communities in relation to both social and economic conditions and to health and performance'. People who were 70-75 years of age were studied in 1988/'89, and were followed up in the years thereafter to examine the nutritional situation before and during the period of rapid health deterioration. Baseline results showed that, although the participants were relatively healthy, the prevalence of biochemical deficiency was high for the vitamins B_6 and D. A review of the literature on the adequacy of the diet to provide elderly people with adequate amounts of water-soluble vitamins (*Chapter 2*) showed that, with the exception of vitamin B_6, the diet was generally adequate to provide these vitamins in free-living elderly people. Dietary information of vulnerable groups with respect to nutrition and health status is relatively scarce.

Based on the knowledge, obtained from both the SENECA baseline study and the literature review, follow up data on the dietary intakes of energy and water-soluble vitamins of the Dutch SENECA participants were compared with intakes of two groups of elderly people in the same age category but in different phases of health deterioration (*Chapter 3*). The first group consisted of people who suffered from chronic somatic disabilities and were living in nursing homes, whereas the second group were people who were in an excellent physical condition, and participated in the annual four days long distance march (walking 30 or 40 km/d on four consecutive days) in Nijmegen, the Netherlands.

To characterize apparently healthy SENECA participants with biochemical deficiency of the vitamins B_6 or D, possible determinants of these vitamins were tested in multivariate models (*Chapters 4 and 5*). Finally, in the vulnerable group of nursing home residents, it was studied whether the nutritional status could be improved by supplementation with a physiological dose of water-soluble vitamins (*Chapter 6*).

The first part of this chapter summarizes the main findings of the studies, followed by a discussion of some methodological aspects. Next, dietary recommendations and the feasibility of these recommendations are discussed. This chapter ends with the main conclusions of the thesis.

MAIN FINDINGS

The prevalence of inadequate dietary intakes of water-soluble vitamins varies widely among different groups of elderly people (*Chapter 2*). This variation is strongly affected by the large differences in the rate of biological ageing (*Chapter 3*). Elderly people who have an excellent health, and are physically very active, have food intakes sufficiently high to cover the daily needs of water-soluble vitamins. Apparently healthy elderly with a much more sedentary lifestyle, generally follow similar dietary patterns, but have a lower energy intake. This makes the latter category more prone to dietary inadequacy of these vitamins. In fact, a substantial part of this group has inadequate dietary intakes of thiamin (6% of the males and 31% of the females), riboflavin (13% of the males and 19% of the females), vitamin B_6 (6% of the males and 31% of the females) and vitamin C (10% of the males and 12% of the females). Nursing home residents, who suffer from chronic somatic disabilities, and are often wheelchair bound, have very low energy needs and consequently are at very high risk of nutrient deficiencies. The prevalence of low dietary intake levels was about 50% for all four vitamins under study. However the relative contribution of various food groups to these vitamins was similar among the groups, which suggested a general decrease in intake of all foods in the more vulnerable elderly people, rather than a change in dietary pattern.

In the apparently healthy participants of the SENECA baseline study, the prevalence of an inadequate status of the vitamins B_6 and D was very high (*Chapter 4, 5*). For vitamin B_6, 27% of the males and 42% of the females had insufficient dietary intakes (below the mean minimum requirements of 0.015 mg/g protein and/or <1.0 mg/day). Plasma pyridoxal 5'-phosphate (levels below 20 nmol/L in 22% of both males and females) was positively associated with vitamin B_6 intake, (moderate) alcohol consumption and serum albumin levels, and inversely associated with body mass index. Although the serum albumin levels were in the adequate range, relatively low levels may be a result of health deterioration which is not yet manifest. For vitamin D, 36% of the males and 47% of the females had low serum 25-hydroxyvitamin D [25(OH)D] levels (<30 nmol/L) in winter. In Europe, the main source of vitamin D is not the diet, but sunlight exposure of the skin. Avoidance of sunlight exposure, either deliberately or as a result of problems with physical mobility, combined with an age associated reduced capacity of the skin to produce vitamin D are the main causes of vitamin D deficiency. Surprisingly, lowest mean 25(OH)D levels were found in the southern European study sites, whereas the intensity of the light is higher in the south. Low 25-hydroxyvitamin D levels were strongest associated with attitudes towards avoidance of sunlight exposure and with having problems in performing activities of daily living. The reasons for the lower 25(OH)D concentrations in the southern study sites need further quantification.

In the group of female nursing home residents, dietary intervention for 3 months with fruit juices enriched with energy and a physiological dose of water-soluble vitamins, resulted in increased concentrations of the vitamins B_1, B_6 and C in the intervention group (*Chapter 6*). In the control group, who received regular (non-enriched) fruit juice, the vitamin C status also improved significantly. An increase in body weight in the people who used the supplement, indicated that the supplement was used in addition to, rather than replacing parts of the regular diet consumed in these institutions. Apart from a small but significant decrease in serum homocysteine concentration, the supplement had no significant beneficial effect on other health status parameters. Further studies on the relation between improving nutritional status and its effects on health and well being are needed.

METHODOLOGICAL CONSIDERATIONS

Subjects

In the SENECA baseline study, the subjects belonged to the narrow age range of 70-75 years. However, even within this range, the elderly population is very heterogeneous. Descriptive results of the SENECA study showed that the participation was somewhat selective, with a tendency towards a better participation of the relatively healthy elderly.[1] In the SENECA follow-up study, this tendency persevered. Consequently, the results are not truly representative for the total population of 70-75 and 75-80 years old respectively. For that reason, the dietary intake data of energy and water-soluble vitamins in the Dutch follow-up part of the SENECA study, were compared with dietary data of elderly people in a comparable age range, with either a better or a worse health status in order to distinguish between different categories of ageing.

The elderly participants in the annual four days long distance march, clearly represent a very healthy segment of the population aged 75-80 years (70-80 for females) with no indications of dietary problems. On the other hand, the nursing home residents, although on average slightly older than the other groups under study, belong to the category of accelerated agers with severe health problems and at great risk of dietary inadequacy. Since notably the latter category is still very heterogeneous with respect to level of health deterioration and self-sustainability, results may not be simply extrapolated to other groups with health problems (e.g. elderly who suffer from dementia, who are hospitalized with acute illnesses, or who are homebound). A similar problem occurs for the elderly participants in the annual four days long distance march in Nijmegen. This group has not just aged successfully, but probably belongs to the healthiest segment of the elderly population.

It is important to notify that in most epidemiological surveys among independently living elderly, less healthy, socially isolated, and less educated people are more likely to refuse participation, whereas those are the people in which nutritional problems are most likely to occur. Inevitably, results of those population based surveys will lead to an underestimation of the degree of nutritional inadequacies.

Dietary assessment

As explained in *Chapter 2*, comparison of dietary intake data from different studies is often hampered due to differences in used dietary assessment methodology (24-hour recall, food frequency questionnaire, dietary history, food record) and food composition databases. The main advantage of the studies in this thesis is the use of the same modified, validated dietary history method in the different groups of elderly people. This enhanced the comparability of the dietary intake levels of water-soluble vitamins.

The dietary history method had shown to be an appropriate method to get information about the regular food consumption pattern in an accurate way.[2-4] However, it is a very time consuming method. An average interview of an elderly subject takes about 1.5 hours. It takes another 3.5 hours approximately before the data are all stored in the computer. Five hours for each subject is often not feasible in epidemiological studies. On the other hand, short food frequency questionnaires, measuring intakes of macro- as well as micronutrients in an accurate way do not exist, and 24-hour recalls do not give accurate information on an individual level.[5-7] Therefore, there is a strong need for a valid dietary assessment tool which is much less time consuming. The expanding variety of food products available in westernized societies hampers the development of such a tool, as a simplification of the dietary assessment method will inevitably affect validity and reliability of the results in a negative way.

Biomarkers of nutritional status

In nutritional epidemiology, dietary nutrient intake is primarily studied as one of the determinants of nutritional status and its association with disease. Biochemical parameters to judge nutritional status are generally referred to as indicators of nutritional status.[8] Although they may reflect short- or longer term dietary nutrient intakes, the measures are also influenced by factors other than intake (e.g. health problems and drug use). From a nutritional epidemiology point of view, biomarkers have been characterized into six groups: Biomarkers of intake, status, disease susceptibility, metabolic effect, disease occurrence and of compliance.[9] The blood vitamin concentrations in this thesis in *Chapters 4-6* are biomarkers of nutritional status.

Vitamin deficiency goes through several stages of biochemical deficiency, before clinical signs become manifest. When dietary intakes of vitamins decrease, circulating blood levels of these vitamins will also show a decrease, due to a lower body content of this vitamin. Blood levels of water-soluble vitamins will generally respond sooner than levels of fat-soluble vitamins, because body stores are higher for the latter. The next stage is a reduction of metabolite synthesis, followed by a reduction in the activity of vitamin dependent enzymes and hormones and finally, biochemical and functional disturbances and morphological changes (Fig. 1).[10]

The concentrations of the vitamins in this thesis reflect the body pool, which does not mean that they are necessarily correlated with intake values. For water-soluble vitamins, homeostatic mechanisms control the blood levels. At low levels of intake, blood levels will rise with increased intake, whereas excessive intakes will lead to an increase in urinary excretion. Especially in elderly people, several confounders like disease, drug-nutrient interactions and gastro-intestinal problems may also interfere with this association. Furthermore, the biochemical indicator may not be the only or limiting constituent of the body pool. For vitamin D there is another aspect to take into account when evaluating the nutritional status. Since vitamin D status strongly depends on its formation in the skin, under influence of sunlight exposure, its association with vitamin D intake is generally low in summer, but may be much higher in winter.[11]

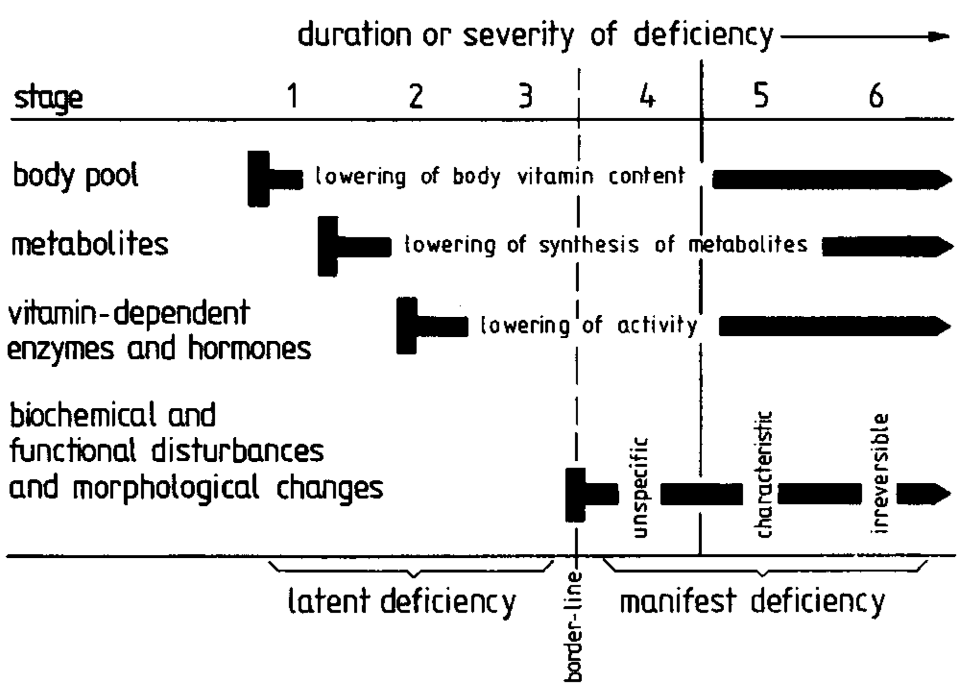

Fig. 1. Stages of vitamin deficiency.[10]

Biomarkers of nutritional status give the opportunity to detect suboptimal levels of the parameter under study, in a much earlier stage of deficiency (often referred to as biochemical deficiency) than when clinical deficiency becomes manifest. A major problem in the evaluation of the nutritional status is the choice of a cut-off level for biochemical deficiency. Different laboratories, often use different biochemical analysis methods, or deviations from the same method, to analyze the same metabolite. This may lead to inter-laboratory differences in level of vitamin concentration. Therefore, laboratories often define their own cut-off level of deficiency. For most vitamins, no clear cut-off levels exist. In those cases, the level is often based on the 5^{th} percentile of the distribution of concentrations in a reference population of healthy adults. In the case of vitamin D in *Chapter 5*, however, 30 nmol/L was chosen as a cut-off, based on previous findings that concentrations below this level are associated with secondary hyperparathyroidism and increased bone turnover.[12]

Although specific cut-off values of biochemical deficiency are often not available, the prevalence of vitamin concentrations below an arbitrary cut-off level may also give a good impression of the nutritional status of the population under study in intervention trials, as shown in *Chapter 6*. In female nursing home residents a high prevalence of biochemical deficiency was found for the vitamins B_6 and C, and dietary supplementation with a physiological dose of water-soluble vitamins significantly increased the concentrations of these vitamins. This means that the residents most probably did have a low status for these water-soluble vitamins. Otherwise the additional supply of these vitamins would have been excessive and therefore excreted in the urine, without elevating the blood levels. In the case of vitamin B_1, the situation was more complicated. During the 12 weeks of supplementation, the mean whole blood thiamin pyrophosphate concentration increased in the supplement group, but at the same time decreased in the control group. Therefore it is not possible to judge whether the cut-off chosen for biochemical deficiency of vitamin B_1 was correct.

In general, it can be concluded that biochemical standards are needed for vitamins, to enhance the comparability between studies using different analysis laboratories and/or techniques. For the comparison of nutritional status of categories of elderly people, living in different study sites, analysis in central laboratories as performed in the SENECA study, are preferable.

DIETARY RECOMMENDATIONS

Recently the dietary needs of elderly people have been evaluated.[13,14] Based on the available scientific knowledge, it was concluded that there are no strong indications that the dietary needs for water-soluble vitamins are different for healthy elderly people as compared to healthy younger adults. It was stated, however, that more research is needed to more accurately determine these needs in elderly people.

For vitamin D the situation is different. The age related decrease in capacity of the skin to produce vitamin D, together with a reduction in sunlight exposure as a consequence of reduced mobility or avoidance of sunlight, call for a higher vitamin D intake by elderly people compared to younger adults. In the Netherlands, young elderly people (65-75 years) who expose themselves seldom to sunlight, as well as all elderly people aged 75 years and older, are advised to increase their vitamin D intake from 2.5 μg/day to 7.5-10 μg/day.[14] In the United Kingdom, it is recommended that a vitamin D intake of 10 μg/d should meet the needs of virtually all people aged 65 years or above.[13] *Chapter 5* confirms the high prevalence of vitamin D deficiency in free-living elderly Europeans. In the female nursing home residents in *Chapters 3 and 6*, the prevalence of vitamin D deficiency (levels below 30 nmol/L) was extremely high (93%, mean $\pm$ SD = 20 $\pm$ 22 nmol/L) in blood samples collected in April 1993 (unpublished data).

FEASIBILITY OF DIETARY RECOMMENDATIONS

Managing to cover the daily dietary needs of water-soluble vitamins generally seems to be no problem in elderly people who are healthy and physically active, and therefore have high food intakes. However, the major part of elderly people suffers from one or more chronic diseases, or has other problems (dental problems, reduced perception of taste and smell, mental problems, socio-economic problems), which may alter physical activeness and or total food intake. Furthermore, most elderly use one or more drugs which may influence nutritional status. A large part of the elderly population is at risk of having inadequate intakes of water-soluble vitamins and vitamin D. Yet there are indications that absolute food intake may increase when the level of physical activity rises.[15,16] The consumption of a variety of nutrient dense foods (both naturally occurring foods and products developed by food industry) will also help to cover the needs for the water-soluble vitamins. In the development and/or preparation of these foods, it is important to take into consideration the age associated decline in smell and taste perception.[17,18] With respect to vitamin D, dietary enrichment will be necessary to cover its needs.

The reports by the working groups on the nutrition of elderly people of both the Committee on Medical Aspects of Food Policy (COMA) in the United Kingdom and the Netherlands Food and Nutrition Council, recommend an active life style as contributing to good health and high food intake.[13,14] Furthermore, the consumption of nutrient dense foods is strongly recommended. The ability and interest of elderly people living a very sedentary life, to change their activity pattern, as well as the effects on dietary intake needs further study.

Chapter 3 shows that the category of elderly people at risk of dietary nutrient inadequacies, basically has a similar dietary pattern as the more healthy elderly people, but eat less of everything. Therefore, apart from stimulating physical activeness, the availability of nutrient dense products should increase. *Chapter 6* shows that it is possible to improve the nutritional status of vulnerable elderly people, enriching the diet with a physiological dose of water-soluble vitamins. With the exception of addition of the vitamins A and D to margarine, dietary enrichment with vitamins is prohibited in the Netherlands. Elderly people with low energy requirements may benefit from nutrient dense products to cover their daily dietary micronutrient needs. Until legislation changes, food industry will not be able to increase the availability of these products for elderly people. The Netherlands Food and Nutrition Council should review the scientific merit of food fortification as a basis for possible legislation in future.

Institutionalized elderly people are dependent on the supply of their meals by the kitchen and nursing staff. For different reasons (e.g. undercapacity of personnel, working hours, logistics) the main meals are often provided between 9 AM and 5 PM, which means that the main nutrient suppliers are consumed in a time span of only 8 hours. Spreading the meals over a larger time span may lead to a higher consumption of these meals, and may consequently improve the quantity and quality of the diet.

As the population of elderly people is increasing, health policy will put more emphasis on increasing home care rather than on expanding institutional care, in order to limit the increase in costs of health care for the elderly. Health professionals play a crucial role in the application of recommendations with respect to dietary intake and physical activity, since they have direct contacts with people at risk of dietary inadequacies and are the first to identify nutritional problems. In a recent study the nutrition guidance activities of Dutch general practitioners were evaluated.[19] Although 70% expressed considerable interest in the role of nutrition in health, in daily practice nutrition plays only a minor role in their work. The Netherlands Food and Nutrition Council is the authoritative body in discussing and reporting the scientific evidence of food and nutrition for maintaining good health. Unfortunately, the reports of the Council seem to have limited influence on food, nutrition and health policy of the Dutch Government (ministries of Health, Welfare and Sports; Agriculture, Nature Management and Fisheries; Education, Culture and Science), nor do they stimulate nutritional advice by health practitioners as preventive measure. Especially the elderly population in the Netherlands could benefit very much from the growing scientific evidence on nutrition and health if this would be supported by adequate food, nutrition, and health policies in future.

GENERAL CONCLUSIONS

The studies in this thesis contribute to the knowledge that in categories of accelerated ageing, and to a lesser extent in categories of normal ageing, dietary intakes of water-soluble vitamins are inadequate. In the case of vitamin D, elderly people who are less mobile or who avoid sunlight exposure as well as very old people have serious problems to ensure vitamin D adequacy, since the needs for vitamin D cannot be covered by diet alone. For those people, dietary fortification with vitamin D will be of much help.

The main reason of dietary inadequacy are low dietary energy need and/or intake. Stimulation of physical activity may help to ensure dietary adequacy of elderly people. Health professionals could encourage people to perform physical activities, not only during adulthood, but throughout the entire lifespan. When increasing physical activeness is not feasible (e.g. due to physical constraints), the consumption of nutrient dense food products may be advised. Nutritional sciences, health policy, and food industries should put joined effort in optimizing the nutritional situation of elderly people. Nutritional advice to the target group, as well as increasing the availability of attractive nutrient dense products for elderly people can help for this purpose.

With the increase of home care for the elderly, home catering (like 'meals on wheels') will grow. Assuring the dietary quality of the meals is as important as assuring a good taste and smell for an acceptable price. Quality control programmes need to be developed for this purpose.

Besides all the previous, the most important fact to bear in mind is that it is up to the elderly people themselves to decide what they want and whether or not they are willing to increase or adjust their activity pattern and/or food intake if necessary. However, attractive guidance and a variation of suggestions to maintain or improve nutrition and health status may help to enjoy their last decades of life.

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Summary

The population of elderly people is growing in Western societies. Ageing is associated with increased risk of morbidity, which by consequence leads to an increased demand for health care of this segment of the human population. Since the ageing process takes place at a different pace in each person, elderly people form a very heterogeneous group. Roughly three categories of ageing people can be distinguished: 'normal' agers with an average decline in physical and health functioning, 'successful' agers who remain in good health throughout their life, and 'accelerated' agers with a very fast decline in health status at increasing age (*Chapter 1*). One aspect of the ageing process is a decrease in energy intake, which may lead to concurrent nutrient inadequacies and consequently enhance health deterioration.

This thesis aimed at expanding the available knowledge of the nutritional situation of elderly people, to focus on the nutritional adequacy of selected water-soluble vitamins and vitamin D, and to come with recommendations of how the nutritional status of vulnerable groups with respect to dietary inadequacy may be improved.

First, the literature on dietary intakes of water-soluble vitamins was reviewed (*Chapter 2*). The diversity of the groups under study, as well as the wide variation in dietary assessment methods used, hampered comparability of the different results. Vitamin B_6 intake was found to be the nutrient most frequently below the recommendations. Furthermore, folate intakes were low in a substantial part of the studies. Vitamin C intake tended to be low in institutionalized elderly. The findings showed that there is no need to recommend the use of water-soluble vitamin supplements for elderly people in general. However, there is a strong need for studies to identify vulnerable groups of elderly people in order to define dietary recommendations for these groups.

For that purpose, the dietary intakes of energy, thiamin, riboflavin, and the vitamins B_6 and C, were assessed in 75-80 years old apparently healthy Dutch participants to the SENECA study (a Survey in Europe on Nutrition and the Elderly, a Concerted Action). Using the same dietary history technique, results were compared in *Chapter 3* with intakes in two groups of elderly people, either living

in a nursing home (accelerated agers) or being physically very active as participants in the annual 4-days-long-distance march in Nijmegen (successful agers). Due to lower absolute food intake, dietary inadequacy was much higher in nursing home residents (for each vitamin about 50% had intakes below the mean minimum requirements) compared to the apparently healthy normal agers (10–30% had intakes below the mean minimum requirements). Virtually none of the physically very active elderly had dietary inadequacies for these vitamins. The relative contribution of various food groups to the dietary intake of these vitamins was similar among the groups, suggesting a general decrease in intake of all foods in the more vulnerable groups, rather than a change in dietary pattern.

Since the prevalence of biochemical deficiency of the vitamins B_6 and D was high in the SENECA study (22% and 36% respectively for males, 22% and 47% for females), associations with possible determinants of these vitamins were investigated (*Chapters 4 and 5*). Vitamin B_6 status was positively associated with vitamin B_6 intake, alcohol intake, serum albumin and, to a lesser extent, body mass index (*Chapter 4*). Underlying health problems may have caused low vitamin B_6 status.

Surprisingly, mean winter-time 25-hydroxyvitamin D levels were lower in the southern European study sites than in the north (*Chapter 5*). Users of vitamin D supplements and/or ultraviolet sunlamps had much higher levels (median 54 nmol/L) than non-users (median 31 nmol/L). Low levels were associated with avoidance of sunlight exposure and inability to perform activities of daily living. It was concluded that for elderly people, dietary enrichment or supplementation with vitamin D should be seriously considered in winter.

Since the nutritional status of the nursing home residents was expected to be inadequate, the effect of dietary supplementation with a physiological dose of water-soluble vitamins was assessed in a single-blind, placebo controlled intervention trial (*Chapter 6*). The supplement was given for 12 weeks as energy- and vitamin-enriched fruit juice. The results showed that nutritional status indeed was poor, and that supplementation significantly improved the status of the vitamins B_1, B_6 and C. Furthermore, body weight significantly increased in the supplement group compared to the control group, indicating that it was consumed in addition to, rather than replacing parts of the diet.

In conclusion, the main reason for an inadequate dietary intake of water-soluble vitamins is a reduction of energy intake, which is not compensated by intake of more nutrient dense foods. Even in apparently healthy elderly people, the prevalence of an inadequate vitamin B_6 status was generally high. It may be that underlying health problems, reflected by a reduced serum albumin concentration, are a reason for this inadequacy. This topic needs further research. With respect to vitamin D status, elderly people who are less mobile or who avoid sunlight exposure have serious problems to ensure an adequate vitamin D status in winter, as the needs for vitamin D cannot be covered by diet alone. Dietary fortification with vitamin D is therefore needed for these people.

Nursing home residents have generally low dietary intakes of energy and water-soluble vitamins. Nutrient dense products seem to have a beneficial effect on the status of these vitamins. Nutritional sciences, health policy, and food industries should put a joined effort in optimizing the nutritional situation of these vulnerable elderly people. On the one hand by stimulating physical activity to avoid a decrease in energy needs, on the other hand by facilitating the availability of attractive nutrient dense foods. However, it is up to the elderly people themselves to decide whether or not they are willing to change their dietary and/or activity pattern.

Samenvatting

Het aantal ouderen groeit in de Westerse wereld. Ouderdom is geassocieerd met chronische ziekte en invaliditeit. Als gevolg hiervan bestaat er een toenemende behoefte aan gezondheidszorg onder dit segment van de bevolking. Aangezien de snelheid van verouderen verschilt van persoon tot persoon, vormen ouderen een zeer heterogene groep. Globaal kunnen er drie categorieën van veroudering worden onderscheiden: "normale" veroudering gekenmerkt door een gemiddelde afname in lichamelijk functioneren en gezondheid, "succesvolle" veroudering met een goede gezondheid gedurende het hele leven, en "versnelde" veroudering met een zeer snelle afname in gezondheid naarmate men ouder wordt (*Hoofdstuk 1*). Eén aspect van het proces van veroudering betreft een vermindering van de energieinneming. Dit kan gepaard gaan met een tekort aan voedingsstoffen waardoor de gezondheid mogelijkerwijs versneld achteruitgaat.

Het doel van dit proefschrift was het uitbreiden van de beschikbare kennis van de voedingstoestand van ouderen, om vervolgens te komen tot aanbevelingen ter verbetering van de voedingstoestand van uit voedingsoogpunt kwetsbare groepen ouderen. De nadruk werd hierbij gelegd op geselecteerde wateroplosbare vitamines en vitamine D.

Allereerst is een overzicht gegeven van de literatuur die verschenen is op het gebied van inneming van wateroplosbare vitamines via de voeding (*Hoofdstuk 2*). Belangrijke problemen in de vergelijkbaarheid van de verschillende resultaten werden veroorzaakt door de diversiteit van de onderzochte groepen, alsmede door de grote variatie in gebruikte methoden om de voedselconsumptie te meten. De inneming van vitamine B_6 bleek het meest frequent onder de aanbevelingen te liggen. Tevens was in een aantal studies de inneming van foliumzuur laag. De vitamine C inneming neigde onvoldoende te zijn onder geïnstitutionaliseerde ouderen. De resultaten gaven aan dat er geen aanleiding is het gebruik van supplementen met wateroplosbare vitamines aan te bevelen voor ouderen in zijn algemeenheid. Er is echter een grote behoefte aan studies gericht op specifieke voedingsaanbevelingen voor groepen kwetsbare ouderen.

Met behulp van een "Dietary History" voedingsanamnese werd de inneming van energie, thiamine, riboflavine, vitamine B_6 en vitamine C met de voeding gemeten in ogenschijnlijk gezonde 75-80 jarige Nederlandse deelnemers aan de SENECA studie (een Europees onderzoek naar de voeding van ouderen). De resultaten van deze groep "normaal verouderden" werden in *Hoofdstuk 3* vergeleken met verpleeghuisbewoners enerzijds ("versneld verouderden") en oudere deelnemers aan de Nijmeegse wandelvierdaagse ("succesvol verouderden") anderzijds. Omdat de verpleeghuisbewoners minder aten, hadden zij grotere tekorten aan voedingsstoffen (voor elk van de vitamines had ongeveer de helft een inneming onder de gemiddelde minimum behoefte) dan de ogenschijnlijk gezonde, "normaal verouderden" (10-30% had een inneming onder de gemiddelde minimum behoefte). Onder de vierdaagse deelnemers kwamen nagenoeg geen tekorten voor. De relatieve bijdrage van verschillende voedingsmiddelengroepen aan de inneming van deze vitamines was vergelijkbaar voor de verschillende onderzochte groepen. Dit betekent dat de groepen, ondanks verschillen in veroudering, in grote lijnen hetzelfde voedselconsumptiepatroon hebben.

Aangezien in de SENECA studie biochemische deficiënties voor de vitamines B_6 en D regelmatig voorkwamen (respectievelijk in 22% en 36% van de mannen, en in 22% en 47% van de vrouwen), zijn associaties met mogelijke determinanten van deze vitamines onderzocht (*Hoofdstukken 4 en 5*). De vitamine B_6 status was positief geassocieerd met de vitamine B_6 inneming, de alcohol consumptie, de serum albumine concentratie en, in mindere mate, met de quetelet index (*Hoofdstuk 4*). Onderliggende gezondheidsproblemen hebben mogelijk een lage vitamine B_6 status tot gevolg gehad. Tegen de verwachting in was de vitamine D status in de winter lager in de Zuid-Europese onderzoekscentra dan in de meer noordelijk gelegen centra (*Hoofdstuk 5*). Mensen die vitamine D supplementen en/of een hoogtezon gebruikten, hadden veel hogere waarden (mediaan 54 nmol/L) dan degenen die dat niet deden (mediaan 31 nmol/L). Lage waarden waren geassocieerd met het vermijden van blootstelling aan zonlicht en met problemen in het uitvoeren van algemene activiteiten van het dagelijks leven. Geconcludeerd werd dat, voor ouderen, voedselverrijking met vitamine D of het gebruik van vitamine D supplementen serieus overwogen dient te worden in de winter.

Aangezien verwacht werd dat de voedingstoestand van de verpleeghuisbewoners inadequaat zou zijn, werd het effect van verrijking van de voeding met een fysiologische dosis wateroplosbare vitamines onderzocht in een enkel-blind, placebo gecontroleerde interventie studie (*Hoofdstuk 6*). Gedurende 12 weken werd hiertoe een met energie (in de vorm van koolhydraten) en wateroplosbare vitamines verrijkte vruchtendrank verstrekt. De resultaten lieten zien dat de voedingstoestand van deze ouderen inderdaad verontrustend was, maar dat dankzij het supplement de bloedconcentraties van de vitamines B_1, B_6, en C significant verbeterden. Tevens nam het lichaamsgewicht in de supplement groep significant toe vergeleken met de controle groep. Hieruit blijkt dat het supplement waarschijnlijk als aanvulling op het gangbare voedingspatroon werd genuttigd, en niet in de plaats van gebruikelijke voedingsmiddelen.

Concluderend kan worden gesteld dat een inadequate inneming van wateroplosbare vitamines met de voeding met name gelegen is in een verlaagde inneming van energie. Deze verlaagde inneming van energie wordt niet gecompenseerd door het gebruik van voedingsmiddelen met een hoge voedingsstoffendichtheid. Zelfs onder ogenschijnlijk gezonde ouderen kwam een inadequate vitamine B_6 status veelvuldig voor. Mogelijkerwijs liggen gezondheidsproblemen, weerspiegeld door een verlaagde albumine spiegel, hieraan ten grondslag. Dit onderwerp dient nader onderzocht te worden. Voor ouderen die minder mobiel zijn, of die blootstelling aan zonlicht vermijden, is het met name in de winter moeilijk om een adequate vitamine D status te handhaven, aangezien de voeding alleen niet in de vitamine D behoefte kan voorzien. Verrijking van de voeding met vitamine D is daarom nodig voor deze ouderen.

Verpleeghuisbewoners hebben in het algemeen een lage inneming van energie en wateroplosbare vitamines. Voedingsmiddelen met een hoge voedingsstoffendichtheid lijken een positief effect te hebben op de voedingstoestand. De voedingswetenschap, politiek en de voedingsmiddelen industrie zouden gezamenlijk actie moeten ondernemen om de voedingstoestand van deze groep kwetsbare ouderen te verbeteren. Enerzijds door het stimuleren van lichamelijke activiteit om zo een verminderde behoefte aan energie tegen te gaan, anderzijds door het vergroten van de beschikbaarheid van aantrekkelijke voedingsmiddelen met een hoge voedingsstoffendichtheid. Het is echter aan de oudere zelf om te beslissen of hij/zij bereid is een verandering aan te brengen in zijn/haar gangbare voedings en/of activiteiten patroon.

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From May 1989 to January 1991, he was appointed as research associate at the Department of Human Nutrition, Wageningen Agricultural University. In this period he was datamanager of the SENECA study (Survey in Europe on Nutrition and the Elderly, a Concerted Action). In 1990 he attended the Third Residential Summer Course, a 3-weeks course of the European Educational Programme in Epidemiology, in Florence, Italy.

In February 1991 he started the research described in this thesis as a PhD-fellow in the Netherlands Postgraduate Programme in Human Nutrition at the Department of Human Nutrition, Wageningen Agricultural University. He represented the PhD-fellows in the board of this Department. In 1993 he was registered as Master of Science in Epidemiology by the Council of the Netherlands Epidemiological Society. He participated in the second European Nutrition Leadership Programme, March 1995, Luxembourg City, Luxembourg.

From April 1995 to June 1995, he was appointed as an associate investigator at the Department of Human Nutrition in Wageningen, involved in the data-management of the SENECA follow-up study.

In October 1995, he will start working at Unilever Nederland B.V. as a 'research and development' associate.