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Dietary intake and main food sources of vitamin D as a function of age, sex, vitamin D status, body composition, and income in an elderly German cohort

Alexandra Jungert, Andre Spinneker, Anja Nagel and Monika Neuhäuser-Berthold*

Institute of Nutritional Science, Justus-Liebig-University, Giessen, Germany

Abstract

Background: Elderly subjects are at risk of insufficient vitamin D status mainly because of diminished capacity for cutaneous vitamin D synthesis. In cases of insufficient endogenous production, vitamin D status depends on vitamin D intake.
Objective: The purpose of this study is to identify the main food sources of vitamin D in elderly subjects and to analyse whether contributing food sources differ by sex, age, vitamin D status, body mass index (BMI), or household income. In addition, we analysed the factors that influence dietary vitamin D intake in the elderly.
Design and subjects: This is a cross-sectional study in 235 independently living German elderly aged 66–96 years (BMI = 27 ± 4 kg/m^2). Vitamin D intake was assessed by a 3-day estimated dietary record.
Results: The main sources of dietary vitamin D were fish/fish products followed by eggs, fats/oils, bread/bakery products, and milk/dairy products. Differences in contributing food groups by sex, age, vitamin D status, and BMI were not found. Fish contributed more to vitamin D intake in subjects with a household income of < 1,500 €/month compared to subjects with higher income. In multiple regression analysis, fat intake and frequency of fish consumption were positive determinants of dietary vitamin D intake, whereas household income and percentage total body fat negatively affected vitamin D intake. Other parameters, including age, sex, physical activity, smoking, intake of energy, milk, eggs and alcohol, showed no significant association with vitamin D intake.
Conclusion: Low habitual dietary vitamin D intake does not affect vitamin D status in summer, and fish is the major contributor to vitamin D intake independent of sex, age, vitamin D status, BMI, and the income of subjects.

Keywords: *25-hydroxyvitamin D*; *diet*; *food sources*; *fish consumption*; *body composition*

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Worldwide, there is a high prevalence of vitamin D insufficiency, independent of whether defined as 25-hydroxyvitamin D concentrations [25(OH)D] < 50 nmol/L or < 75 nmol/L (1, 2). In particular, elderly subjects are considered as a high-risk group due to low sun exposure and a decline in subcutaneous vitamin D synthesis capacity (3). The fall in vitamin D status in advanced age seems to be accompanied by a gradual rise in chronic diseases.

Whether the improvement of vitamin D status may result in better overall health in the elderly is still under discussion, though current research stresses the need for increasing vitamin D intake (4–7). Although sun exposure is the main determinant of vitamin D status (8), at latitudes above 35°N, cutaneous vitamin D synthesis is limited or even absent during wintertime (6). At present, dietary recommendations for vitamin D are subject to re-evaluation in several European countries (6, 8). In Germany, the recommendation was recently raised to 20 µg/day in case endogenous synthesis is lacking (9), an amount that is usually not achieved by Western diets (10). The average vitamin D intakes in Europe range from 2 to 6 µg/day (6, 11–14).

Detailed data on foods contributing to the daily vitamin D intake in independently living elderly German subjects are scarce. Such data are needed to establish dietary strategies and recommendations in order to improve vitamin D intake. There is some evidence that

vitamin D intake is associated with body mass index (BMI) and socioeconomic characteristics, including sex, age, and income, in younger and middle-aged subjects (15–17), but such data for the elderly population are lacking. Therefore, the present study aimed to 1) identify food sources which contribute to the dietary vitamin D intake; 2) analyse whether food sources differ by sex, age, vitamin D status, BMI or household net income of elderly subjects; and 3) determine influencing factors of dietary vitamin D intake in the elderly.

Methods

Study design and subjects

This investigation is based on cross-sectional data from 275 independently living individuals who participated in the follow-up in 2008 of the longitudinal study on nutrition and health status of senior citizens of Giessen (GISELA study), Germany (50.6°North). Investigations took place in the Institute of Nutritional Science in Giessen from July to October. The Ethical Committee of the Faculty of Medicine at the Justus-Liebig-University, Giessen, approved the research protocol. All participants provided written informed consent. Exclusion criteria for the present study were any of the following conditions: incomplete data ($n=23$) on dietary assessment and biochemical parameters, including serum 25-hydroxyvitamin D_3 [25(OH)D_3] and parathyroid hormone; chronic renal disease ($n=5$); and lifetime history of cancer of the gastrointestinal tract (stomach, small intestine, colon; $n=11$). One female subject with an extreme parathyroid hormone value (671 ng/L) was also excluded. The final study sample consisted of 168 women and 67 men.

Biochemical analyses

Fasting blood samples were collected, and serum aliquots were stored at −70°C until further analysis. Serum 25(OH)D_3 and parathyroid hormone were measured by an electrochemiluminescence immunoassay (Roche Diagnostics GmbH, Mannheim, Germany).

Socioeconomic data, lifestyle, anthropometric data, and body composition

Participants completed a self-administered questionnaire on socioeconomic and lifestyle characteristics, such as age, sex, monthly household net income, smoking status, physical activity, and disease history. Physical activity level (PAL) was calculated as described elsewhere (18).

BMI was defined as weight (kg) divided by height squared (m^2). Percentage total body fat (% TBF) was determined by a single-frequency (50 kHz) bioelectrical impedance analyser (Akern-RJL BIA 101/S®; Data Input, Frankfurt, Germany), according to manufacturer's instructions and the predictive formula of Roubenoff et al. (19).

Dietary assessment

Nutritional intake was determined using a 3-day estimated dietary record, which was developed and validated for the GISELA study (20). Validity was evaluated by nitrogen excretion in the 24-h urine in relation to protein intake, and by comparing energy intake and resting metabolic rate assessed by indirect calorimetry according to Goldberg et al. (21). The dietary record consisted of 146 food items. For every food item, both typical household measures (e.g. slice, cup and spoon) and the appropriate weights were given. The participants were instructed to record their entire food intake on three consecutive days directly after consumption, starting on a Sunday. Food, energy, and nutrient intakes were calculated using the German Food Code and Nutrient Data Base (Federal Institute for Health Protection of Consumers and Veterinary Medicine, Berlin, Germany) (22) version II.3. For the present analysis, we created nine food groups to measure the contribution of particular food categories to vitamin D intake: *fish/fish products* (e.g. fish, canned fish, seafood); *eggs*; *fats/oils* (e.g. butter, lard, margarine, oil); *bread/bakery products* (e.g. bread, toast, cake, biscuits); *milk/dairy products* (e.g. milk, cheese, yoghurt, curd, cream); *potatoes/fruits/vegetables and related products*; *nutriments* (e.g. pasta, rice, cereals, corn flakes); *meat/meat products* (e.g. meat, innards, sausages, cold cuts, ham); and the category *others* inclusive of, for example, sauces, sweets, snacks, and beverages. The contribution of vitamin D by eggs and fats via processed foods was captured by the foods to which these components have been added during processing or, in the case of fats, of which they are an inherent component.

In addition, subjects were asked to rank their usual fish, egg, and milk consumption frequencies on a scale from never to daily intake. Data on vitamin D supplement intake were collected via a self-administered questionnaire.

Statistical analyses

Continuous data are expressed as mean and standard deviation (SD) and median and 5th to 95th percentile, when appropriate. Descriptive characteristics were compared between groups via Mann–Whitney *U* test for continuous variables. Chi-square test or Fisher's exact test was used to assess differences in proportions.

We performed stratified analyses by sex (females vs. males), median age (<76 vs. ≥ 76 years), median vitamin D status (≤ 63 vs. >63 nmol/L), median BMI (≤ 26.8 vs. >26.8 kg/m^2), and household net income ($<1{,}500$ vs. $\geq 1{,}500$ €/month) to examine whether vitamin D intake and the contributing food groups differed between the respective groups.

Spearman correlation was applied to evaluate correlations between vitamin D intake and sex, age, BMI,

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% TBF, PAL, smoking behaviour (never smokers vs. current and ex-smokers), household net income ($<1{,}500$ vs. $\geq 1{,}500$ €/month), nutritional parameters, and 25(OH)D_3. Those variables that showed a significant association with vitamin D intake were entered in the multiple backward regression model with the logarithmically transformed (log) vitamin D intake as dependent variable. Variables with a $p \leq 0.100$ were allowed to remain in the model. Statistical analyses were conducted with SPSS® 21.0 for Windows (IBM®, Chicago, USA). Significance level was set at $p < 0.05$, and all tests were two-tailed.

Results

Characteristics of the study subjects

Characteristics of the subjects are presented in Table 1. None of the subjects had a vitamin D status <25 nmol/L. However, 25(OH)D_3 levels <50 nmol/L were noticed in 21.3% of the subjects, while 21.3% had 25(OH)D_3 levels ≥ 75 nmol/L. Both sexes failed to meet the recommended daily intake of 20 µg vitamin D (9); only one woman and two men ingested ≥ 20 µg/day. Vitamin D intakes <5 µg/day and <10 µg/day were observed in 57.4 and 90.2% of the study population, respectively. Sex differences were not found in any of these analyses ($p > 0.05$).

Of the subjects who made statements on their usual consumption frequencies of fish ($n = 226$), eggs ($n = 229$), and milk ($n = 212$), 2.2% ($n = 5$), 0.9% ($n = 2$), and 24.1% ($n = 51$) were non-consumers of fish, eggs, and milk; 75.2% ($n = 170$), 76.4% ($n = 175$), and 26.4% ($n = 56$) reported to eat seldom or several times per month fish, eggs, and milk; whereas 22.6% ($n = 51$), 22.7% ($n = 52$), and 49.5% ($n = 105$) stated that they consume fish, eggs, and milk several times per week or daily, respectively.

Contributions of food groups to dietary vitamin D intake assessed by the 3-day estimated dietary record

Table 2 presents the median values and the 5th and 95th percentiles of the daily intake levels of the nine food groups, the corresponding absolute vitamin D intake by these food groups, and the relative contributions of the food groups to the daily vitamin D intake. For some of the food groups (eggs, potatoes/fruits/vegetables, nutriments, meat/meat products, and others), median values for their contribution to vitamin D intake amounted to zero. This is due to the very low amount of vitamin D in these food groups and/or the fact that within the 3 days of dietary record, more than half of the subjects consumed no such foods (as in the case of eggs, for example). Median and mean percentage contributions of food groups to the daily vitamin D intake differed considerably, indicating non-normally distributed data. When expressed as mean values, contributions to the daily vitamin D intake amounted to approximately 40% for fish/fish products followed by eggs (15%), fats/oils (13%), bread/bakery products (12%), and milk/dairy products (12%). The other food groups altogether added to less than 10% to the mean daily vitamin D intake. No sex differences were found ($p > 0.05$).

Mean contributions of food groups to dietary vitamin D intake stratified by age, vitamin D status, BMI, and household net income

Stratifying our analysis by age (<76 vs. ≥ 76 years), vitamin D status tended to be higher in younger subjects compared to older subjects (median: 65.2 vs. 61.2 nmol/L; $p = 0.053$), whereas dietary vitamin D intake was significantly higher in older participants (median: 2.4 vs. 4.1 µg/day; $p = 0.049$). Apart from a tendency towards a higher contribution of fish to the vitamin D intake in

Table 1. Descriptive characteristics of the study population

	Women ($n = 168$)		Men ($n = 67$)		
	Median	P_5, P_{95}	Median	P_5, P_{95}	p^a
Age (years)	75.5	68.0–87.0	76.0	68.8–85.6	0.359
Body mass index (kg/m^2)	26.9	21.1–35.2	26.5	22.9–32.9	0.844
Total body fat (%)	42.8	32.4–50.8	28.9	21.2–42.4	<0.0001
25-Hydroxyvitamin D_3 (nmol/L)	62.6	38.8–91.9	65.6	38.9–91.4	0.234
Vitamin D intake (µg/day)	3.0	0.4–10.6	3.2	0.8–15.8	0.243
Energy intake (kcal/day)	1,829	1,072–2,907	2,124	1,417–3,320	<0.0001
Fat intake (g/day)	65.5	33.8–115.6	71.0	47.2–140.4	0.010
Alcohol intake (g/day)	0.4	0.0–19.4	5.1	0.0–28.9	<0.0001
Physical activity level	1.6	1.4–2.0	1.6	1.4–1.9	0.095
Vitamin D supplement user (*n*, %)		30 (17.9)		4 (6.0)	0.023
Current or ex-smokers (*n*, %)		39 (23.5)		47 (70.1)	<0.0001
Household income $\geq 1{,}500$ €/month (*n*, %)		71 (51.4)		44 (78.6)	<0.001

[a]Mann–Whitney *U* test, Chi-square test, and Fisher's exact test for analysing sex differences; missing data were present on total body fat ($n = 5$), physical activity level ($n = 26$), smoking behaviour ($n = 2$), and monthly household net income ($n = 41$).

Table 2. Daily intake levels of food groups and corresponding vitamin D intake ($N = 235$)

	Intake of the food group (g/day)		Vitamin D intake (μg/day)		Contributions to vitamin D intake (%)	
Food group	Median	P_5, P_{95}	Median	P_5, P_{95}	Median	P_5, P_{95}
Fish/fish products	20.0	(0.0–111.3)	1.0	(0.0–9.6)	38.5	(0.0–91.4)
Eggs	0.0	(0.0–45.3)	0.0	(0.0–1.4)	0.0	(0.0–62.2)
Fats/oils	13.3	(4.0–30.8)	0.2	(0.0–0.5)	6.9	(0.6–44.8)
Bread/bakery products	171.7	(63.2–346.7)	0.2	(0.0–1.0)	4.6	(0.0–53.0)
Milk/dairy products	205.0	(30.0–478.7)	0.2	(0.0–0.6)	6.3	(0.0–39.6)
Potatoes/fruits/vegetables	471.0	(213.6–993.8)	0.0	(0.0–0.4)	0.0	(0.0–12.5)
Nutriments	60.0	(0.0–201.3)	0.0	(0.0–0.8)	0.0	(0.0–18.5)
Meat/meat products	116.7	(15.3–258.7)	0.0	(0.0–0.2)	0.0	(0.0–11.8)
Others	1,697.0	(729.7–2,851.8)	0.0	(0.0–0.1)	0.0	(0.0–5.9)

older participants (35 vs. 44%; $p = 0.102$), contributing food groups did not differ between age groups.

No substantial differences in vitamin D intake levels or in relative contributions of food groups were found after stratifying the cohort according to the median vitamin D status ($p > 0.05$). However, a slightly higher contribution of meat/meat products to the dietary vitamin D intake in subjects with a vitamin D status ≤ 63 nmol/L compared to subjects who had a higher vitamin D status was noticed (2.05 vs. 2.02%; $p = 0.024$).

After stratifying the cohort into two groups based on the median BMI, vitamin D status of subjects with a BMI ≤ 26.8 kg/m^2 was higher than in subjects with a BMI $>$ 26.8 kg/m^2 (median: 67.3 vs. 59.3 nmol/L; $p < 0.001$). No significant differences in vitamin D intake or in contributions of food groups were found ($p > 0.05$). Similar results were observed when the cohort was divided according to the sex-specific median % TBF ($p > 0.05$).

Subsequent to the separation of the study population with regard to the monthly household net income ($<$1,500 vs. $\geq$1,500 €), vitamin D status was higher in the upper income group (median: 59.4 vs. 65.6 nmol/L; $p = 0.020$), while vitamin D intake was significantly lower (median: 5.5 vs. 2.7 μg/day; $p = 0.007$). Compared to subjects reporting an income $\geq$1,500 €/month, subjects with an income $<$1,500 €/month showed higher mean fractional contributions to dietary vitamin D intake by 'fish' (49 vs. 36%; $p = 0.028$) and by 'potatoes/fruits/vegetables' (2.4 vs. 2.3%, $p = 0.044$), whereas the contributions of 'fats/oils' (9 vs. 16%, $p = 0.010$) and, albeit not significant, of 'milk/dairy products' (9 vs. 13%, $p = 0.066$) were lower.

Determinants of the dietary vitamin D intake in the elderly

Spearman correlations between relevant parameters and vitamin D intake are presented in Table 3. Dietary vitamin D intake was associated with age, % TBF, intake of energy, fat and alcohol, frequency of fish intake, and household net income, but did not correlate with sex, BMI, smoking, PAL, use of vitamin D supplements, and consumption frequencies of eggs and milk. Except for a positive correlation with alcohol intake ($r_S = 0.152$; $p = 0.020$), 25(OH)D_3 levels did not correlate with dietary parameters ($p > 0.05$).

Multiple regression analysis ($n = 185$) was performed with log vitamin D intake as the dependent variable and age, % TBF, intake of energy, fat and alcohol, frequency of fish intake, and household net income as independent variables. Thereby, fat intake ($\beta = 0.283$; $p < 0.0001$) and frequency of fish consumption ($\beta = 0.235$; $p = 0.001$) were identified as positive determinants of dietary vitamin D intake, whereas alcohol intake ($\beta = -0.122$; $p = 0.082$), net income ($\beta = -0.174$; $p = 0.013$), and % TBF ($\beta = -0.174$; $p = 0.014$) negatively affected vitamin D intake. This regression model explained 19.6% of the variance in dietary vitamin D intake in elderly subjects. The exclusion of two people with very high dietary vitamin D intake levels (26 and 37 μg/day) provided approximately equivalent results.

Discussion

This cross-sectional study demonstrates that independently living elderly subjects can generally obtain 25(OH)D_3 concentrations ≥ 50 nmol/L despite a very low vitamin D intake level. The facts that this study was conducted in summer and GISELA subjects spent on average 2 h daily outdoors are probably the main reasons for this observation (23). A sun exposure of 5–15 min/day of hands, face, and arms from 10 AM to 3 PM in summer is considered as sufficient to provide 1,000 IU of vitamin D (24).

Contrary to the present investigation, several studies found a significant association between vitamin D intake and serum 25(OH)D levels (1, 4, 25, 26), but predominantly these studies did not focus on vitamin D status of elderly subjects during summer. In addition, studies were frequently carried out in countries, such as the United States and Canada, where food fortification is

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Table 3. Spearman correlations between vitamin D intake and relevant parameters[a]

	Vitamin D intake (μg/day)	
	r_S	p
25-Hydroxyvitamin D_3 (nmol/L)	−0.020	0.761
Sex (female/male)	0.077	0.242
Age (years)	0.176	0.007
Body mass index (kg/m^2)	−0.038	0.557
Total body fat (%)	−0.138	0.037
Energy intake (kcal/day)	0.317	<0.0001
Fat intake (g/day)	0.350	<0.0001
Frequency of fish intake[b]	0.184	0.006
Frequency of egg intake[b]	0.091	0.168
Frequency of milk intake[b]	0.056	0.418
Alcohol intake (g/day)	−0.132	0.043
Physical activity level	−0.046	0.504
Use of vitamin D supplements (no/yes)	−0.120	0.066
Smoking (no/yes)	−0.035	0.599
Household income ≥1,500 €/month (no/yes)	−0.195	0.007

r_S = Spearman correlation coefficient.

[a]Missing data were present on total body fat (n = 5); consumption frequencies of fish (n = 9), eggs (n = 6), and milk (n = 23); physical activity level (n = 26); smoking behaviour (n = 2); and monthly household net income (n = 41).

[b]Frequencies were dichotomised in never to several times per month (coded as 0) versus several times per week to daily (coded as 1).

more common than in Germany. A vitamin D intake of 3–4 μg/day as noticed in the present study is apparently too low to influence 25(OH)D_3 levels of the elderly in summer, when UVB exposure is the main contributor (8, 23). This is in agreement with the results of Bates et al. (25) who found a significant association between vitamin D intake and vitamin D status in 507 free-living subjects aged 65–84 years in all seasons except for summer. Similarly, in the study by Macdonald et al. (27) with 3,113 postmenopausal women, the association between dietary vitamin D and 25(OH)D was significant only in winter and spring. Obviously, vitamin D intake becomes negligible in case of sufficient sun exposure, but it may gain in importance in wintertime, particularly for elderly obese subjects as a higher % TBF has been linked to lower 25(OH)D_3 levels (23). Our results indicate that subjects with higher % TBF consume less vitamin D than lean subjects even after taking energy intake and frequency of fish consumption into account. This may further enhance the impairment of the vitamin D status in case of an insufficient sun exposure.

In our study, fish and fish products were by far the major sources of dietary vitamin D independent of sex, age, vitamin D status, BMI, and net income. In addition, fats/oils, eggs, bread/bakery products, and milk/dairy products contributed to vitamin D intake. Nutriments and meat/meat products proved as less important. Although innards contain high amounts of vitamin D (6), such foods are not commonly consumed by the general population. In the present study, only seven subjects reported an intake of innards within the dietary record. A representative study of German subjects aged 14–80 years provided comparable results by also stressing the importance of regular fish intake as a main source of vitamin D followed by fat spreads, eggs, and dairy products (13), but 25(OH)D concentrations were not investigated.

Although regular intake of fish was associated with a higher vitamin D intake in our study, fish intake did not affect vitamin D status. It should be stressed that fish intake of the GISELA participants was only slightly below the current German food-based dietary guideline which recommends a weekly intake of at least 150 g of fish (28), but still vitamin D intake was low. This may be due to a higher consumption of lean fish, which contains lower quantities of vitamin D than fatty fish (29). Compared to other European countries, fish intake in Germany is rather low (30). However, even in populations with higher fish consumption, frequency of fish intake is not associated with 25(OH)D levels in the elderly (31). In general, the amount of vitamin D in fish varies widely, and often differs from the vitamin D content that is listed in current food composition tables (32). For example, it has been shown that wild-caught salmon contains nearly five times more vitamin D than farmed salmon (33). This hampers valid conclusions on vitamin D intake from fish consumption.

Regular consumption of fatty fish such as herring and salmon is required to get high amounts of dietary vitamin D. As pointed out by Sirot et al. (29), recommendations on fish consumption should refer to species and not only differentiate between lean and fatty fish to take into account differences in contents of nutrients and contaminants. Current German food-based dietary guidelines recommend a higher consumption of lean rather than fatty fish and give no explicit statement on fish species (28). Whether a re-evaluation of the current guidelines could result in an increased vitamin D intake has to be evaluated. Contaminants in seafood and aspects of sustainability of fisheries may argue against an increase in fish consumption.

Main vitamin D providing food groups differ among countries. In the United States and Canada, milk, meat, and fish are the leading food sources of vitamin D (7, 15), while in the United Kingdom, these are fish, meat, cereals, and fat spreads (34). In Japan, fish intake is by far the main contributor followed by eggs and mushrooms (35). Differences in assessment methods, dietary habits, and food fortification policies may account for these divergent results (7, 36). In Germany, only a few

foods are allowed to be fortified with vitamin D including margarine, edible oil, and some diet and dairy products (37).

Enhanced food fortification with vitamin D and supplement use are recommended to achieve an optimal vitamin D status (4, 7). Whether these recommendations are appropriate for all people independent of their individual risk for vitamin D deficiency is up for discussion. Vitamin D supplements are considered as a simple, effective, and low-cost intervention (38). However, elderly subjects often take many different drugs, so that an additional supplement may not be an appropriate public health strategy regarding compliance and potential interactions. Likewise, an expansion of food fortification polices should undergo a well-considered risk–benefit assessment. There are indications that food enrichment cannot ensure adequate vitamin D intake levels for the elderly without putting children at risk (3). Consequently, staple foods might not be the best fortification medium. Furthermore, lactose malabsorption/intolerance is frequently observed in the elderly (39) and thus milk as a food providing vitamin D seems unsuitable for the elderly population. Therefore, current vitamin D food fortification practices may not capture risk groups. Our results indicate that a high vitamin D intake level is apparently not required in free-living elderly subjects in summer when sun exposure is sufficient. Hence, a food fortification which is limited to winter months might be appropriate, but may be difficult to implement.

A special feature of our approach is that we investigated in a subgroup analysis whether vitamin D intake and vitamin D food sources differ by sex, age, vitamin D status, BMI, or income. Overall, considerable differences regarding the contribution of food groups to the dietary vitamin D intake were not found except for household income. In this context, fish/fish products contributed less to the vitamin D intake of subjects with a monthly household net income of $\geq$1,500 € compared to subjects who reported a lower income, whereas in the upper income group, a higher percentage of dietary vitamin D was provided by the food category 'fats/oils'. In contrast to some previous studies (15, 16), in which income was a positive predictor of vitamin D intake, household income was inversely associated with vitamin D intake in our subjects. However, despite a lower intake level, serum 25(OH)D_3 concentrations were higher in the upper income class, although the self-reported time spent outdoors and the proportion of supplement users did not differ between these two income groups ($p > 0.05$). These observations may be due to the fact that the overall vitamin D intake levels were too low to influence the vitamin D status significantly during the summer. In addition, low income subjects had a significantly higher % TBF than subjects with higher income (42 vs. 38%, $p = 0.001$), which may have masked any potential effect of a somewhat higher vitamin D intake on the vitamin D status of the subjects with lower income, as it was shown that the % TBF is a negative predictor of 25(OH)D_3 concentrations (23).

Limitations of the present study are the cross-sectional design and the sample size. Although the GISELA study is not based on a nationally representative sample, independently living elderly people represent the majority of older individuals in industrialised countries (4). In general, dietary assessment tools have several limitations including the presence of under-/over-reporting and intra-/inter-subject variability of food intake (40). Another problem is the insufficient information on the real vitamin D content of foods. Nutrient databases are frequently not up-to-date, not standardised, and fortified and convenience foods are under-represented (41). In addition, vitamin D intake levels by supplements were not assessed; however, the number of supplement users was small. Concerning the association between net income and vitamin D intake, some subjects gave no statement on their net income, which may have biased the association.

Conclusion

Elderly people living in private households do not reach the current recommended vitamin D intake level. Frequency of fish consumption and intake of fat are positive determinants of vitamin D intake, while % TBF and household net income are inversely associated with vitamin D intake. Fish is the major contributor to dietary vitamin D intake. There are no substantial differences in vitamin D food sources depending on sex, age, vitamin D status, and BMI. Income-dependent differences in habitual dietary vitamin D intake are not reflected by serum 25(OH)D_3 concentrations in the independently living elderly during summertime. Dietary advice and food enrichment strategies should consider food preferences of target groups. If sun exposure and dietary vitamin D intake cannot provide sufficient vitamin D concentrations, supplements may be advisable.

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*Monika Neuhäuser-Berthold
Human Nutrition, Institute of Nutritional Science
Justus-Liebig-University, Goethestrasse 55
DE-35390 Giessen, Germany
Email: monika.neuhaeuser-berthold@ernaehrung.uni-giessen.de

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