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ORIGINAL ARTICLE

Fatty fish and supplements are the greatest modifiable contributors to the serum 25-hydroxyvitamin D concentration in a multiethnic population

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Summary

Objective Because vitamin D synthesis is lower in a heavily pigmented skin than in a lighter skin, the relative contribution of determinants to the vitamin D concentration might differ between ethnic groups. The aim of this study was to assess the prevalence of vitamin D deficiency and the relative contribution of vitamin D consumption and exposure to sunlight to the vitamin D concentration in a multiethnic population.

Design Cross-sectional study.

Patients A total of 613 adults aged 18–65 years from a random sample from general practices in the Netherlands (52°N, 2003–05), stratified according to gender and ethnic group.

Measurements Serum 25-hydroxyvitamin D [25(OH)D], PTH, ethnic group, sunlight exposure, consumption of foods and supplements rich in vitamin D.

Results The prevalence (95% confidence interval) of vitamin D deficiency [serum 25(OH)D < 25 nmol/l] was higher in Turkish (41·3%; 32·5–50·1), Moroccan (36·5%; 26·9–46·1), Surinam South Asian (51·4%; 41·9–60·9), Surinam Creole (45·3%; 34·0–56·6), sub-Saharan African (19·3%; 9·1–29·5) and other adults (29·1%; 17·1–41·1) compared to the indigenous Dutch (5·9%; 1·3–10·5). Modifiable, significant determinants (standardized regression coefficients) for serum 25(OH)D concentration were: consumption of fatty fish (0·160), use of vitamin D supplements (0·142), area of uncovered skin (highest category 0·136; middle category 0·028), use of tanning bed (0·103), consumption of margarine (0·093) and preference for sun (0·089). We found no significant modification of ethnic group on the effect of sunlight determinants.

Conclusion Of the modifiable determinants, fatty fish and supplements are the greatest contributors to the serum 25(OH)D concentration in a multiethnic population.

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Introduction

Vitamin D deficiency leads to secondary hyperparathyroidism and, in later stages, impaired bone mineralization, rickets in children and osteomalacia in adults.[1,2] Before these negative consequences for bone health occur, myopathy or muscle weakness may be present, leading to impaired physical functioning.[3–5] Vitamin D deficiency also seems to be a factor that contributes to the development of type 1 and type 2 diabetes mellitus, multiple sclerosis, inflammatory bowel disease and various forms of cancer.[1,6,7]

Insufficient exposure to direct sunlight, covering of the skin, a diet that is low in vitamin D and calcium, and a high fat mass have been shown to contribute to low serum 25-hydroxyvitamin D [25(OH)D] concentrations.[8–11] Additionally, vitamin D synthesis is lower in a heavily pigmented skin than in a lighter skin,[12–14] and this has led to the observation that vitamin D deficiency is more common in dark-skinned individuals living in northern countries.[10,15]

In public debate in the Netherlands, some have addressed the use of veils as the main reason for vitamin D deficiency among non-Western migrants, limiting the discussion to female individuals. However, in the Netherlands, margarine is the only food fortified with vitamin D, and margarine is hardly consumed by non-Western immigrants; hence, food might also partly explain the lower serum 25(OH)D concentrations among non-Western individuals. The aim of this study was to assess the prevalence of vitamin D deficiency among non-Western men and women, and the relative contributions of ethnic group, gender, age, vitamin D consumption and exposure to sunlight to the serum 25(OH)D concentration in a multiethnic population. Knowledge regarding the relative contribution of these determinants in non-Western immigrants is important for decision making with regard to preventive and curative actions.

Methods

We performed a cross-sectional study in four cities in the Netherlands (52°N) with large populations of non-Western immigrants: Amsterdam, The Hague, Amersfoort and Haarlem. The first two cities are highly urbanized (between 450 000 and 750 000 inhabitants) and the other two are less urbanized (between 100 000 and 150 000 inhabitants).

A random sample of 2397 adults (age 18–64 years) was drawn from the patient files of 10 general practices, stratified according to gender and ethnicity (each category of equal size): indigenous Dutch, Turkish, Moroccan, Surinam Creole, Surinam South Asian and sub-Saharan African. Ethnicity was initially based on the general practitioner's judgement, because the countries of birth of the subject and their parents were not known when the random sample was drawn. In the analysis, ethnic group was assigned according to the countries of birth of the participant and both parents. If at least one parent was not born in the Netherlands, the participant was considered to have a foreign background.[16] Because of differences between the two methods (14% were assigned to another group), we added a category of persons with ethnic origins other than those used for initial sampling (e.g. Netherlands Antilleans and Surinamese other than South Asian or Creoles).

Subjects who had been treated with vitamin D within a period of 6 months (oral) or 1 year (injection) before the study started, or who were unable to participate because of their mental condition, were excluded from the study.

The subjects were invited to participate in the study in a letter written by their general practitioner in Dutch, Turkish, English or French, according to their ethnic group. It was not possible to have a Moroccan translation because for Dutch Moroccans it would have to be in Berber, which is a nonwritten language. Therefore, we used the Dutch and French versions for the Moroccan participants. Several actions were taken to increase the response: a reminder by telephone (or by mail when the telephone number was not known); a remuneration of 15 Euro for participants who completed all the measurements; a press release to local newspapers; a poster in the waiting rooms of the participating general practices; and a personal recommendation by the general practitioners to persons in the sample who came for consultation.

Data collection

Data collection took place between September 2003 and June 2005. The sample was divided equally over the four seasons. Participants were asked to complete questionnaires relating to general characteristics, exposure to sunlight and dietary habits. Questions were included on pregnancy, lactation, year of residence in the Netherlands, education, employment, smoking, alcohol consumption, medication, amount of time spent outdoors (in the open air) in the summer, time of day outdoors, parts of the body uncovered during warm weather, preference for sun or shadow when outdoors, holidays to sunny destinations, tanning beds, consumption of fish (total) and fatty fish, eggs, (low-fat) margarine, milk products, cheese, chapatti, vitamin pills or food supplements. Salmon, sardines, herring, mackerel and eel are fatty fishes, and, for instance, one portion of salmon (120 g) contains 10·4 μg vitamin D. In the Netherlands, the only food that is fortified with vitamin D_3 is (low-fat) margarine, containing 7·5 μg/100 g. One portion of margarine is defined as the average quantity used for one slice of bread. Vitamin D supplements usually contain 100 or 200 IU per tablet in the Netherlands. Multivitamin tablets usually contain 100 IU per tablet or less. The total area of uncovered skin was calculated by summing the estimated percentages per body part: face 4%, hands 3·6%, lower arms 7·2%, upper arms 7·2%, lower legs 12%, upper legs 16%, upper abdomen 18%, back 18%.

To calculate the body mass index (BMI, kg/m^2), height and weight were measured in the general practice. Blood samples were taken and centrifuged, and the serum was kept frozen at –20 °C until used. Serum 25(OH)D was measured by radioimmunoassay (Diasorin, Stillwater, MN). The interassay coefficient of variation (CV) was 15% at 30 nmol/l and 10% at 60 nmol/l. Serum PTH was measured by chemiluminescence assay (Nichols Institute Diagnostics, San Juan Capistrano, CA). The interassay CV was 12% at 1·24 pmol/l and 8% at 59·2 pmol/l.

The study protocol conformed to the principles embodied in the Declaration of Helsinki, and was approved by the Medical Ethics Committee of the Haaglanden Medical Centre (Medisch Centrum Haaglanden). All participants gave written informed consent.

Statistical analysis

Median serum 25(OH)D concentrations (nmol/l) and 25th and 75th percentiles are presented to deal with the skewed distribution. Differences in median serum 25(OH)D concentrations between gender, age and ethnic groups were assessed with the median test (nonparametric), which was also used to compare differences in median PTH concentrations between participants with and without vitamin D deficiency. From the threshold levels that have been suggested for the assessment of vitamin D deficiency, we chose a level of 25 nmol/l.[2] Differences in the prevalence of vitamin D deficiency between gender, age and ethnic groups were analysed with univariate logistic regression.

A general linear model (linear regression) was used to analyse the determinants of serum 25(OH)D concentration. Serum 25(OH)D concentration was used as a dependent variable in the model, and all determinants derived from the questionnaire and season of data collection were considered as independent variables in the model. Because of the skewed distribution, serum 25(OH)D concentrations were logarithmically transformed. In the analysis, the least significant determinants were eliminated step by step until all the remaining determinants were significant ($P < 0{\cdot}05$). All eliminated determinants were included separately in the final model to check that they did not contribute to the serum 25(OH)D concentration.

We hypothesized that in ethnic groups with darker skin types, the contribution of exposure to sunlight would be smaller than in ethnic groups with lighter skin types. We tested this hypothesis by assessing the contribution of the interaction term of the ethnic group and the determinants for exposure to sunlight, including season. Ethnic groups were categorized according to observed skin pigmentation of the group members: Western (e.g. indigenous Dutch; lightest skin types); Turkish and North African (e.g. Moroccan); Asian and Mid/South African (e.g. Surinam South Asian, Surinam Creole and sub-Saharan African; darkest skin types).

SPSS versions 12·0 and 14·0 were used for the analyses.

Results

Response

Of the 2397 adults who were invited, 677 (28%) participated, whereas no response was received from 43%. Some of these non-respondents were not known at the address registered in the general practice files (ghost patients), and therefore cannot be considered to be part of the sample, so the actual participation rate is somewhere between 28% and 50%. Known reasons for nonparticipation were: not able or not wanting to make an appointment [25% (out of 2397)], changed general practice (2%), and moved to another address (2%). Participation was higher among women (34%) than among men (22%; $P = 0{\cdot}000$). Sub-Saharan Africans showed a lower response (18%) than the indigenous Dutch (29%, $P = 0{\cdot}000$). Fifty-eight participants did not allow blood sampling, three were not within the age range, and the ethnic group of three participants could not be assessed. Thus, data from 613 respondents (234 men and 379 women) were available for the analysis; 19% were aged 18–29 years, 27% 30–39 years, 29% 40–49 years and 25% 50–65 years.

Prevalence

The median serum 25(OH)D concentrations, the 25th and 75th percentiles, and the prevalence of vitamin D deficiency (< 25 nmol/l) are presented in Table 1. The prevalence of vitamin D deficiency varied from 5·9% in the indigenous Dutch to 51·4% in the Surinam South Asians. Median 25(OH)D concentrations in the non-Western groups were significantly lower than in the indigenous Dutch. There was no significant difference in median concentrations between men and women, and serum 25(OH)D tended to increase with age.

Median PTH concentrations were significantly ($P < 0{\cdot}001$) higher among vitamin D-deficient (6·8 pmol/l) compared to nondeficient participants (5·4 pmol/l).

Determinants

Median values and the prevalences of putative determinants according to ethnic group are presented in Table 2. Potentially protective determinants, such as a higher consumption of margarine, use of vitamin D supplements, a larger area of uncovered skin, preference for sun and use of tanning beds, were more prevalent in the indigenous Dutch than in the non-Western groups. The consumption of fatty fish was highest in the sub-Saharan African group. The median value of 14·8% for the area of uncovered skin is equivalent to uncovered face, hands and lower arms.

Ethnic group, season and pregnancy or breastfeeding were related to vitamin D status (Table 3). After adjustment for all other determinants presented in Table 3, in order of relative influence, the following determinants, which can in principle be modified, were positively associated with vitamin D status: consumption of fatty fish, use of vitamin D supplements, area of uncovered skin, use of tanning bed, consumption of margarine, and preference for sun. Even if season was omitted from the model, the other, modifiable, sunlight determinants (such as time spent outdoors) were not maintained in the model. Of all determinants, ethnic group showed the largest independent association with the serum 25(OH)D concentration. All other characteristics (see methods) that are not presented in Table 3 were not independently associated with serum 25(OH)D.

None of the interaction terms between ethnic group and the determinants of exposure to sunlight were significant.

Table 1. Gender and ethnic group of the participants (aged 18–65 years), their median serum 25(OH)D concentrations and the prevalence of vitamin D deficiency [25(OH)D < 25 nmol/l], the Netherlands, 2003–2005

	n (%)	Median 25(OH)D (nmol/l)	Range 25th–75th percentile 25(OH)D (nmol/l)	Vitamin D deficiency	
				%	95% CI
Men (reference)	234 (38)	33	22–50	30·8	24·9–36·7
Women	379 (62)	30	21–50	35·6	30·8–40·4
Indigenous Dutch (reference)	102 (17)	67	50–83	5·9	1·3–10·5
Turkish	121 (20)	27**	18–39·5	41·3**	32·5–50·1
Moroccan	96 (16)	30**	20–45	36·5**	26·9–46·1
Surinam South Asian	107 (17)	24**	18–34	51·4**	41·9–60·9
Surinam Creole	75 (12)	27**	20–40	45·3**	34·0–56·6
Sub-Saharan African	57 (9)	33**	25–44·5	19·3*	9·1–29·5
Others	55 (9)	38**	23–50	29·1**	17·1–41·1
Total	613 (100)	32	21–50	33·8	30·1–37·5

CI, confidence interval, calculated assuming binomial distribution.
*P-value < 0·05 compared to indigenous Dutch using median test (non-parametric) for medians and univariate logistic regression for prevalences.
**P-value < 0·001 compared to indigenous Dutch using median test (non-parametric) for medians and univariate logistic regression for prevalences.

Table 2. Median values and prevalences (%) of putative determinants of vitamin D deficiency according to ethnic group (18–65 years), the Netherlands, 2003–2005

	Indigenous Dutch	Turkish	Moroccan	Surinam South Asian	Surinam Creole	Sub-Saharan African	Others
N	102	121	96	107	75	57	55
% Men	40	41	41	37	31	46	29
Age (years)	45	35***	38*	41	43	40·5***	40·5*
% Pregnant or breastfeeding†	7	14	13	8	10	14	8
BMI (kg/m^2)	25·3	28·7*	26·6	25·8	26·5	26·8	26·6
Fatty fish intake (portions/month)	2·0	1·0	2·0*	2·0**	1·0	4·0***	1·0
Margarine intake (portions/day)	3·0	1·0***	2·0**	2·5	2·0*	2·0	2·0
Intake of milk products (portions/week)	11·3	7·0***	9·0	7·0***	4·0***	7·0***	6·0**
% Use of vitamin D-containing supplements	25	6***	10*	21	16	26	20
Time spent outdoors (hours/week)	21·0	19·0	16·0	18·0	25·5	16·0	22·8
Area of uncovered skin (%)	34·0	17·2***	14·8***	22·0***	26·8**	20·6***	26·8*
% Preference for sun	41	28*	27*	25*	26*	32	36
% Use of tanning bed	32	7***	7***	0	8***	5***	7***
% Measurements in autumn or winter	56	58	62	49	49	46	31***

**P*-value < 0·05; ***P*-value < 0·01; ****P*-value < 0·005; all tests compared to indigenous Dutch, using univariate logistic regression for prevalences and median test (nonparametric) for medians
†Females 18–45 years of age.

Discussion

The prevalence of vitamin D deficiency [serum 25(OH)D < 25 nmol/l] was considerably and significantly higher in the non-Western groups than in the indigenous Dutch group. Of the modifiable determinants, the consumption of fatty fish and the use of vitamin D supplements showed the largest association with serum 25(OH)D concentration. Protective determinants were more prevalent in the indigenous Dutch, except for the consumption of fatty fish, which was more prevalent in the sub-Saharan African group.

A threshold level of 25 nmol/l for vitamin D deficiency is often used,[2] but levels up to 50 or 75 nmol/l are designated as vitamin D insufficiency.[17] Higher thresholds (e.g. 50–80 nmol/l)[17–19] would lead to even higher prevalence rates. For instance, 23·5% of the indigenous Dutch and 84·0% of the others had a serum 25(OH)D concentration < 50 nmol/l.

Our findings, that is a high prevalence of vitamin D deficiency in non-Western groups, confirm the results of other studies among adult immigrant groups living in northern countries.[9,10,15,20] Standardized regression coefficients showed that ethnic group was the most important determinant of serum 25(OH)D concentration. Thus, the possibility should be considered that changing behaviour (increase of intake of vitamin D-rich food products, increase of sunlight exposure) may not completely rule out ethnic differences in serum 25(OH)D concentrations.

Men and women were analysed together to provide more variation in the prevalence of determinants. In some studies, women have been found to have lower serum 25(OH)D concentrations than men.[10,21–23] In the total population of our study, as in another previous study, no significant difference was found.[24] Wearing a veil is a possible reason for the lower serum 25(OH)D in non-Western women.[23,25,26] In our study, we assumed that the highest proportion of veil wearers is found among the Turkish and Moroccan participants. In those groups, serum 25(OH)D was significantly ($P < 0{\cdot}001$) higher among men (median 33·5 nmol/l) than women (median 25·0 nmol/l). however, the area of uncovered skin, which is a more general measure applicable to both genders, did not differ between these men and women.

The negative association of pregnancy or breastfeeding with serum 25(OH)D concentration, along with earlier published data on vitamin D deficiency among pregnant women,[27–30] is an additional reason to pay special attention to the serum 25(OH)D concentration of pregnant women.

Positive associations of fatty fish consumption, the use of vitamin D supplements or total dietary vitamin D intake with serum 25(OH)D have been found in other studies among non-Western immigrants living in northern countries.[10,15,24]

We observed significant associations between some sunlight determinants (season, area of uncovered skin, preference for sun) but not others, such as time spent outdoors. This latter association has been reported previously by some studies[31–34] but not others.[26,35,36] There could be several explanations, for instance the effect of clothing and skin pigmentation might overrule the effect of time spent outdoors. Season, the greatest determinant after ethnic group in our study, and a measure of sunlight exposure, did not overrule the effect of time spent outdoors as the same modifiable sunlight variables were maintained in the model after omitting season from the model.

A darker skin needs more exposure to sunlight to produce vitamin D.[12] However, in our study we did not find differences in the associations of sunlight variables, including season, with serum 25(OH)D between ethnic groups in our multiethnic study population at this latitude (52°N).

We could not confirm the association between BMI and serum 25(OH)D concentrations observed in other studies when performing

Table 3. Standardized regression coefficients and adjusted mean serum 25(OH)D concentrations of significant determinants of the logarithmic transformed serum 25(OH)D concentration in a multiethnic population (18–65 years), the Netherlands, 2003–2005

Determinants	Standardized regression coefficient	*P*-value	Adjusted* mean serum 25(OH)D concentration (nmol/l)	95% CI mean serum 25(OH)D concentration (nmol/l)
Ethnic group		< 0·001		
Western (lightest skin types; *n* = 110)	0		58	49–68
Turkish and North African (*n* = 223)	–0·423		33	28–39
Asian and Mid/South African (darkest skin types; *n* = 280)	–0·555		29	25–34
Season		< 0·001		
Summer	0		44	37–51
Autumn	–0·152		36	30–42
Winter	–0·192		33	28–39
Spring	–0·059		40	35–47
Pregnant or breastfeeding				
No	0		46	41–51
Yes	–0·127	< 0·001	31	25–39
Fatty fish	0·160	< 0·001		
0–3–6–9 portions/month			35–39–43–47	(30–40)–(34–45)–(37–50)–(40–56)
Use of vitamin D supplements				
No	0		34	29–39
Yes	0·142	< 0·001	43	36–51
Area of uncovered skin		0·003		
0–14·8%	0		35	30–41
14·9–28·7%	0·028		37	31–43
28·8%–highest	0·136		42	36–49
Use of tanning bed				
No	0		33	29–37
Yes	0·103	0·005	44	35–55
Margarine	0·093	0·008		
0–2–4 portions/day			36–38–40	(31–41)–(33–43)–(34–46)
Preference for sun				
No	0		36	31–42
Yes	0·089	0·012	40	35–47
Adjusted R^2	0·361			

CI, confidence interval.
*Adjusted for all other determinants presented in the table.

multivariate analysis.[10,11,15,37] BMI ≥ 25 (overweight and obesity) was only negatively associated with serum 25(OH)D without adjustment for other determinants (e.g. ethnic group).

Because the response rate was low, the estimates of the medians and prevalences are not very precise, and are potentially biased. We were unable to contact a large percentage (43%) of the sample, partially because of the existence of 'ghost patients', that is registered adults who no longer visited the general practice, e.g. due to moving. In fact, these persons should not have been included in the sample. Other causes for nonresponse could have led to underestimation (individuals living indoor lives being less willing to participate) or to overestimation (unhealthier individuals worrying about their health being more willing to participate). In two studies among non-Western pregnant women in the Netherlands, in which these reasons for nonresponse did not apply, the prevalence of vitamin D deficiency was higher than in the present study.[29,30] The strength of our study was the use of a random sample that was drawn from 10 general practices and contained a large variety of ethnic groups.

The present study provides some insight into the vitamin D status and determinants of serum 25(OH)D in a multiethnic population in the Netherlands. Our results suggest that more emphasis should be laid on the potential contribution of fatty fish and supplements to serum 25(OH)D concentration. Especially for non-Western populations, the effect of modifying sunlight exposure should not be overrated. However, because of the very low serum 25(OH)D concentrations, a combination of behavioural changes, including increasing oral vitamin D intake and sunshine exposure, is necessary. Efficacious ways to achieve the desired change in behavioural habits should be further developed. The public health authorities and governments of northern countries could also consider fortification of food products that are consumed by non-Western individuals.[38]

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