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ORIGINAL PAPER

Vitamin D insufficiency in the elderly orthopaedic patient: an epidemic phenomenon

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Abstract
Purpose The purpose of this observational study was to evaluate serum levels of 25-OH-D of elderly patients presenting with orthopaedic illness. Furthermore, we enquired about potential confounders and risk factors of hypovitaminosis D in comorbidities and daily medication of the elderly.
Methods Vitamin D levels in 1,083 patients aged >70 years and admitted to an orthopaedic surgery department were measured. Univariate and multivariate analyses were used to assess risk factors for insufficient vitamin D levels.
Results Overall, 86 % of patients had insufficient serum levels of 25-OH-D and >60 % were vitamin D deficient. Serum vitamin D levels were lower during winter and months with fewer sunshine hours. Patients presenting with obesity, hypertension and osteoporosis were more likely to have low vitamin D levels.
Conclusions We found a high prevalence of hypovitaminosis D in elderly, nonhospitalized orthopaedic patients. Given the well-known effects of vitamin D on bone metabolism and muscle health, as well as its nonskeletal effects, vitamin D insufficiency may have a negative impact.

Keywords Hypovitaminosis D · Vitamin D deficiency · Elderly · Orthopaedic patients

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Introduction

The essential role of vitamin D on bone health and calcium regulation is well known [1]. Inadequate low serum or plasma levels of 25-hydroxyvitamin D (25-OH-D) leads not only to skeletal effects such as rickets, osteoporosis and osteomalacia, but, as several recent studies suggest, exhibits also a number of nonskeletal effects [2]. In particular, hypovitaminosis D has been reported to increase the risk of cardiovascular diseases, type 2 diabetes and mental illness [3–5]. Furthermore, several studies suggest that it also regulates innate and adaptive immune function by activating macrophages, dendritic cells and lymphocytes [6]. Low serum 25-OH-D levels have been shown to increase the risk of respiratory tract infection and periprosthetic joint infection, and a recent clinical trial demonstrated that vitamin D supplementation reduced the risk of influenza A infection [7–9].

Vitamin D deficiency and insufficiency have been reported in several studies around the world [10]. It is estimated to affect more than one billion people of all races, ethnic backgrounds and age groups [1]. Especially among the elderly, high rates of vitamin D deficiency have been described [11–14]. Among inpatients of geriatric acute care units, lower vitamin D serum levels have been associated with a greater severity of chronic diseases, increased risks of acute decompensation and a higher risk of in-hospital mortality [15–17]. In line with this, hypovitaminosis D doubled the risk of hospitalisation for >14 days in a geriatric acute care unit [18].

Although several studies reported a widespread rate of vitamin D deficiency, epidemic data on orthopaedic patients, and furthermore, geriatric/orthopaedic patients, is scarce. Data revealing the prevalence of vitamin D insufficiency and deficiency in elderly patients may be of value to orthopaedic surgeons and geriatricians when treating their patients to prevent potential negative consequences in the operative and postoperative settings, to maintain good physical function and to preserve independence in daily life.

The purpose of this observational study was to evaluate serum levels of 25-OH-D of elderly patients presenting with orthopaedic illness in an orthopaedic university hospital in central Europe. Furthermore, we enquired about potential confounders and risk factors of hypovitaminosis D in comorbidities and daily medication of the elderly, as comorbidities and multimedication use are well known in such patients. We also assessed possible seasonal variations in serum 25-OH-D levels and its feasible association with the mean sunshine hours per month.

Table 1 Patient characteristics

Characteristics	Tested patients
No. of patients	1,083 (100 %)
Men	516 (47.5 %)
Women	567 (52.4 %)
Age in years	76 (±7,9)
Alcoholism	32 (3 %)
Nicotine abuse	119 (11 %)
Obesity (body mass index > 30 kg/m^2)	281 (26 %)
Carcinoma	205 (19 %)
Psychiatric diseases (depression, schizophrenia, borderline psychosis)	184 (17 %)
Osteoporosis	238 (22 %)
Hypertension	606 (56 %)
Cardiovascular disease (chronic/congestive heart failure, myocardial infarction)	530 (49 %)
Thyreotic abnormality (hypo-/hyperthyroidism)	465 (43 %)
Pulmonary disease (COPD, asthma)	205 (19 %)
Renal failure	238 (22 %)
Infectious diseases (HIV, hepatitis A/B/C, tuberculosis)	22 (2 %)
Vitamin D supplementation orally	162 (15 %)
Diabetes	509 (47 %)

Methods

Between 1 January 2011 and 31 December 2012, serum 25-OH-D levels of all patients >70 years admitted to the orthopaedic department of our institution (1,083) were measured on admission. Generally, blood was taken on the day of admission. Mean patient age was 76 (±7.9) years (Table 1).

Measurement of serum 25-OH-D was standardised; the hospital laboratory used the ARCHITECT® 25-OH Vitamin D assay (Abbott GmbH & Co KG, Wiesbaden-Delkenheim, Germany). Patient demographic variables and background data were evaluated by retrospective chart review and checked for potential association with 25-OH-D levels. Included variables were age, sex, primary musculoskeletal diagnosis, body mass index (BMI), comorbidities, orally administered medication and any vitamin D supplements taken before admission (Table 1).

As yet there is no universally accepted classification of vitamin D levels. Vitamin D status was categorised primarily according to cutoff points used by Holick [1]. We defined sufficient vitamin D status as a serum 25-OH-D level >30 ng/ml. Vitamin D inadequacy was defined as >30 ng/ml and was further divided into insufficiency (20–30 ng/ml) and deficiency (<20 ng/ml). The distribution percentages of patients with insufficiency and deficiency were determined. To investigate the correlation between climate factors and vitamin D levels, sunshine hours for every month in 2011 and 2012 were collected by Deutscher Wetterdienst (the German weather center) in the region around Mainz, Germany. Weather data were taken for a radius of 50 km around the city centre of Mainz, corresponding to the living area of most tested patients. For each month, we correlated mean sunshine hours with mean vitamin D levels measured in the same month to evaluate any significant correlation.

Univariate analyses were used to assess the independent relative risk (RR) for vitamin D insufficiency or deficiency associated with potential risk factors [age, sex, nicotine abuse, obesity (BMI >30 kg/m^2), carcinoma, psychiatric diseases, osteoporosis, hypertension, diabetes, cardiovascular diseases, alcoholism, hyperthyroidism/hypothyroidism, pulmonary diseases, renal failure, infectious diseases]. All analyses were performed with use of two-tailed tests. The level of significance was set at $p \leq 0.05$.;95 % confidence interval (CI) and p value were calculated for each risk factor.

To determine what factors are predictors and what factors are confounders of hypovitaminosis D, multivariate linear regression analysis using the vitamin D level as a continuous variable was performed. All collected potential risk factors were included. To evaluate a possible association between the different medications patients received, these were also included in the multivariate regression analyses. The medication had to have been taken for at least the last three months before measurement of serum vitamin D level. All collected medications (proton-pump inhibitors, acetylsalicylic acid, metamizol, diclofenac, iso-butyl-propanoic-phenolic acid, N-acetyl-p-aminophenol, indomethacin) were included. The level of significance was set at $p \leq 0.05$. With use of a forward stepwise method, variables were considered to be of significance if they had a final $p \leq 0.05$ after adjusting for all other variables .

Results

A total of 1,083 patients participated in this study: 52.4 % were women, and ranged from 70 to 97 (mean 76) years. Overall, 86 % of patients were vitamin D insufficient and 64 % deficient; only 8 % were in the target range of 30–60 ng/ml. Serum vitamin D levels of all patients were normally distributed, with a mean of 17.1 ng/ml; minimum and maximum values ranged from 8 to 78.5 ng/ml, respectively.

Univariate analyses showed that obesity [$p=0.028$, odds ratio (OR) 3.09], hypertension ($p=0.011$, OR 3.08), osteoporosis ($p=0.001$, OR 5.79), diabetes ($p=0.001$, OR 5.4), and renal failure ($p=0.018$, OR 5.93) were associated with low vitamin D levels. Patients supplementing vitamin D orally had a significantly higher level ($p=0.009$) than patients without supplementation; sex ($p=0.433$) was not associated with differences. Furthermore, the following variables showed no association with low levels: nicotine abuse ($p=0.673$), carcinoma ($p=0.522$), psychiatric diseases ($p=0.462$), cardiovascular diseases ($p=0.812$), alcoholism ($p=0.128$), hyperthyroidism/hypothyroidism ($p=0.553$) and pulmonary ($p=0.493$) and infectious ($p=0.732$) diseases (Table 2).

In multiple regression analysis, osteoporosis was significantly associated with low vitamin D levels ($p=0.007$), as was hypertension ($p=0.032$) and diabetes ($p=0.033$) after adjustment for possible confounders. All other factors significantly associated with low vitamin D levels in univariate analysis showed no significant relationship and were dropped from the model obesity ($p=0.059$), and renal failure ($p=0.246$). Multivariate regression analyses showed no significant correlation between medication history and hypovitaminosis D (Table 3).

Variations in 25-OH-D levels between the winter and summer months were seen in our participants. During the summer months, the mean vitamin D level was 17.9 ng/ml; during the 6 winter months, the mean level was 15.1 ng/ml. The lowest concentrations occurred in November (13.1 ng/ml) and peak concentrations in August (19.97 ng/ml). Mean sunshine hours per month showed a strong correlation ($p=0.004$, Pearson's correlation 0.072) with mean levels, with higher mean levels during sunnier months (Table 4).

Table 2 Univariate analyses of potential risk factors for vitamin D insufficiency and deficiency in 1,083 study participants

	Mean vitamin D level (ng/ml)	Significance (*P*)	95 % confidence intervall
Male (*n*=516)	16.8 (±12.7)	(Reference)	
Female (*n*=567)	17.8 (±14.3)	0.433	−0.79 to 3.33
Alcoholism (*n*=32)	17.9 (±6.4	0.128	−8.23 to 0.54
Nicotine abuse (*n*=119)	20.3 (±8.7)	0.673	−2.8 to 2.45
Obesity (body mass index > 30 kg/m2) (*n*=281)	15.6 (±9.3)	0.028	−3.4 to −1.56
Carcinoma (*n*=205)	18.6 (±17.3)	0.522	−2.63 to 1.59
Psychiatric diseases (*n*=184)	17.4 (±10.2)	0.462	−3.2 to 1,1
Osteoporosis (*n*=238)	14.9 (±13.4)	0.001	3.9 to 8.01
Hypertension (*n*=606)	15.1 (±12.5)	0.011	−3.24 to −0.95
Cardiovascular disease (*n*=530)	18.2 (± 17.3)	0.812	−1.9 to 3.1
Thyreotic abnormality (*n*=465)	17.9 (±9.3)	0.553	−3.97 to 5.99
Pulmonary disease (*n*=205)	18.5 (± 7.9)	0.493	−4.17 to 2.39
Renal failure (*n*=238)	14.9 (±11)	0.018	−4.77 to −0.46
Infectious diseases (*n*=22)	17.8 (±6.2)	0.732	−6.23 to 3.91
Vitamin D supplementation (*n*=162)	21.7 (±10.3)	0.012	2.28 to 7.83
Diabetes (*n*=509)	15.3 (±8.9)	0.001	−6.13 to −1.67
Proton-pump inhibitors (*n*=629)	16.9 (±9.7)	0.537	8.27 to 13.28
Acetylsalicylic acid (*n*=484)	17.0 (±10.9)	0.796	10.9 to 22
Metamizol (*n*=378)	16.8 (±10.1)	0.099	9.89 to 22.4
Diclofenac (*n*=314)	17.4 (±13.9)	0.689	11.6 to 23.9
Iso-butyl-propanoic-phenolic acid (*n*=69)	18.2 (±10,7)	0.321	11.1 to 22.1
N-acetyl-p-aminophenol (*n*=301)	17.5 (±10.8)	0.792	10.6 to 24.2
Indomethacin (*n*=401)	16.8 (±11.3)	0.616	5.7 to 23.2

Table 3 Multivariate linear regression analyses of potential risk factors for hypovitaminosis D

Risk factor	Standard error	Regression coefficient	Beta coefficient	*P* value
Osteoporosis	2.001	4.62	0.145	0.007
Hypertension	1.806	−2.26	−0.09	0.032
Diabetes	1.431	−2.83	−0.75	0.033

Discussion

To the best of our knowledge, this is the first study to report on an association between hypovitaminosis D and elderly orthopaedic patients in general. We found a high prevalence of vitamin D deficiency and insufficiency in our patients. These results are in line with former studies showing high rates of hypovitaminosis D in the elderly [13, 19]. We were able to show that not only orthopaedic patients with hip or vertebral fractures have low vitamin D levels but also the elderly orthopaedic patient in general. A novelty in this study is that mainly nonhospitalised elderly patients were tested. Extremely low vitamin D levels have been associated with osteomalacia and impaired muscle function, both core elements in the field of orthopaedic surgery. Good muscle function and healthy bones are essential for fast rehabilitation and positive outcome after orthopaedic surgery, and, especially in elderly patients, for good physical function [11, 20]. Physical function is important for the preservation of independence in daily life and the prevention of falls, which are associated with fractures and high mortality rates [21, 22]. Vitamin D depletion has been linked with impaired cognition, with specific damage to executive functions and speed of information processing, which can have a direct impact on selection of postural control strategies and reaction to falls [23]. Low vitamin D levels negatively affect muscle strength, which may impact fall patterns, severity and reaction to them [24]. Furthermore, several studies showed that lower 25-OH-D serum levels are a risk factor for orthostatic hypotension, which was reported to deteriorate functional autonomy of older patients and to have a close relationship with mortality and morbidity in the elderly [25, 26]: In a study of 546 patients >65 years, it was shown that vitamin D deficiency is a factor in the development of orthostatic hypotension. The authors concluded that during

Table 4 Mean 25-OH-D levels per month and sunshine hours per day

Month	Sunshine hours per day	Mean serum 25-OH-D (ng/ml)	95 % confidence interval (ng/ml)
January 2011	1.37	13.47	11.9–16.0
February 2011	2.25	13.97	12.1–15.7
March 2011	6.82	14.36	12.3–16.4
April 2011	8.58	17.51	16.1–19.6
May 2011	9.94	18.75	17.4–20.9
June 2011	6.34	19.81	17.6–21.5
July 2011	5.70	19.22	18.5–21.9
August 2011	6.70	19.33	17.9–22.0
September 2011	6.71	18.22	16.4–20.0
October 2011	4.76	18.79	16.1–20.5
November 2011	2.72	16.10	13.5–18.7
December 2011	1.02	16.09	13.8–17.3
January 2012	1.88	14.73	11.9–16.6
February 2012	2.83	13.45	12.4–16.7
March 2012	5.73	14.97	12.9–17.2
April 2012	7.98	17.89	15.1–20.6
May 2012	8.99	18.98	16.8–21.9
June 2012	7.43	19.96	16.9–21.7
July 2012	6.43	19.32	17.7–22.3
August 2012	7.89	19.97	16.9–22.9
September 2012	6.99	18.25	15.9–21.2
October 2012	4.01	17.69	15.7–19.5
November 2012	3.12	13.10	12.5–16.7
December 2012	1.23	14.09	13.4–17.7

the evaluation of orthostatic hypotension, serum 25-OH-D levels should be checked and detected deficiency should be treated [25].

In our study, we found a mean vitamin D level of 17.1 ng/ml amongst 1,083 patients >70 years. There are few data on such geriatric and elderly orthopaedic patients, but they all report a widespread rate of hypovitaminosis D in the elderly [27, 28]. This is an alarming fact, knowing that the official recommendation by the European Society for Clinical and Economic Aspects of Osteoporosis and Osteoarthritis (ESCEO) is a minimum serum 25-OH-D level of 30 ng/ml in fragile elderly individuals, who are at an elevated risk of falls and fractures [29]. Bischoff-Ferrari et al. showed a 22 % reduction in falls of patients taking vitamin D supplements [30]. Gerdhem et al. evaluated 986 postmenopausal women and showed a twofold increased fracture risk for patients with 25-OH-D levels <20 ng/ml compared with patients with higher serum vitamin D levels [31]. Furthermore, a contributing role of vitamin D deficiency in the occurrence of simultaneous fractures has recently been described in a study of 472 elderly hip fracture patients [32].

We show the extent of seasonal variation in 25-OH-D levels throughout a two year period, as well as the association between mean sunshine hours and mean 25-OH-D serum levels in central Europe or comparable latitudes (e,g, Vancouver, 49°, 17′ N). Brustad et al. described seasonal variations a latitude of 69° North (northern Europe), which is in line with our results; however, owing to a generally high dietary intake of vitamin D in their patients, mean levels were sufficient (>30 ng/ml) in all tested seasons [33]. Our work demonstrated a correlation between sunshine hours per month and patient serum vitamin D levels, with higher mean levels during sunnier months. However, even in the months with the most sunshine hours, the mean level did not reach sufficient values. In May 2011, the sunniest month in the region around Mainz, a mean level of 18.75 ng/ml was measured. Vitamin D synthesis in the skin under the influence of UV light decreases with aging due to insufficient sunlight exposure and decreaes functional capacity of the skin [34, 35]. Our data suggest increasing vitamin D production from sunlight is not a realistic option for most elderly patients living in latitudes comparable with that of Mainz [50° N; e.g. Vancouver (49°, 17° N), Paris (48°, 51′ N) or Kiev (50°, 17′ N)].

Our data confirmed a significant association between vitamin D deficiency and obesity, diabetes mellitus, renal failure, hypertension and osteoporosis [14, 36]. Comparable with former studies, multivariate analyses showed no significant correlation between medication history and hypovitaminosis D [11].

As with any single-centre analysis, our study has some limitations. The majority of tested patients was light skinned. Given the predisposition of darker-skin-toned humans towards lower 25-OH-D levels, vitamin D deficiency and insufficiency amongst darker-skin-toned patients may be underrepresented in this study. The reported associations do not prove causal relationship. Actual daily sunlight exposure of our patients was only approximated, not truly known. Furthermore, doses of and compliance with vitamin D supplementation were not assessed.

We found a high frequency of vitamin D deficiency among our elderly orthopaedic patients in central Germany. More than 85 % of patients were vitamin D insufficient, with values measured below the target of 30–60 ng/ml. Adequate levels are required for effective bone metabolism and fracture and fall prevention, especially in the elderly, and also for many paracrine effects. Vitamin D supplementation is often perceived by patients and their physicians as an excessive medication and is easily dismissed to avoid polypharmacy. Therefore, screening and treating hypovitaminosis D is difficult, but it appears to be important in this patient population.

Conflict of interest None.

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