Vitamin D deficiency in elderly people in Swedish nursing homes is associated with increased mortality

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Abstract

Objective: Institutionalised elderly people at northern latitudes may be at elevated risk for vitamin D deficiency. In addition to osteoporosis-related disorders, vitamin D deficiency may influence several medical conditions conferring an increased mortality risk. The aim of this study was to explore the prevalence of vitamin D deficiency and its association with mortality.

Design: The Study of Health and Drugs in the Elderly (SHADES) is a prospective cohort study among elderly people (> 65 years) in 11 nursing homes in Sweden.

Methods: We analysed the levels of 25-hydroxyvitamin D₃ (25(OH)D₃) at baseline. Vital status of the subjects was ascertained and hazard ratios (HRs) for mortality according to 25(OH)D₃ quartiles were calculated.

Results: We examined 333 study participants with a mean follow-up of 3 years. A total of 147 (44%) patients died within this period. Compared with the subjects in Q4 (25(OH)D₃ > 48 nmol/l), HR (with 95% CI) for mortality was 2.02 (1.31–3.12) in Q1 (25(OH)D₃ < 29 nmol/l) ($P < 0.05$); 2.03 (1.32–3.14) in Q2 (25(OH)D₃ 30–37 nmol/l) ($P < 0.05$) and 1.6 (1.03–2.48) in Q3 (25(OH)D₃ 38–47 nmol/l) ($P < 0.05$). The mean 25(OH)D₃ concentration was 40.2 nmol/l (s.d. 16.0) and 80% had 25(OH)D₃ below 50 nmol/l. The vitamin D levels decreased from baseline to the second and third measurements.

Conclusions: Vitamin D deficiency was highly prevalent and associated with increased mortality among the elderly in Swedish nursing homes. Strategies are needed to prevent, and maybe treat, vitamin D deficiency in the elderly in nursing homes and the benefit of vitamin D supplementation should be evaluated in randomised clinical trials.

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Introduction

Vitamin D is a fat-soluble vitamin with hormonal qualities. The two sources of vitamin D are food and sunlight, of which sunlight accounts for more than 90% of the body's vitamin D supply (1). Vitamin D is produced in the skin under the influence of u.v. B light, which at our northern latitudes in Sweden is only available during a few hours around lunchtime in the summer months (2, 3).

It is well-known that a severe vitamin D deficiency leads to rickets and osteomalacia. Vitamin D deficiency is also a risk factor for osteoporosis, falls, fractures and

muscle weakness (4), and several other studies have shown an association between low levels of vitamin D and an increased risk of fractures (5, 6, 7, 8), falls (9), cardiovascular disease (1, 10, 11, 12, 13, 14) and mortality (15, 16, 17, 18, 19, 20, 21, 22, 23). A meta-analysis of randomised trials of the effects of vitamin D supplementation has shown a modest decrease in the mortality rate predominantly in elderly women with low levels of vitamin D (24).

A recent study has shown that vitamin D levels above 90 nmol/l also were associated with an increased

mortality (25). However, it was only a small sample of the study population that had high vitamin D levels, and the increase in mortality risk and acute coronary syndrome events in this group were modest compared with the risks in the groups with low vitamin D levels. This finding has led to a discussion about what shape of curve most closely illustrates the association between levels of vitamin D and outcome (26). Thus, the optimum level of vitamin D is not yet clearly defined. Serious deficiency is considered to exist at levels of 25-hydroxyvitamin D (25(OH)D) below 25 nmol/l, due to its association with rickets and osteomalacia. The levels between 25 and 50 nmol/l are categorised as insufficiency, as 50 nmol/l is the lowest level that prevents secondary hyperparathyroidism, increased bone turnover, bone mineral loss or seasonal variations in plasma parathyroid hormone (PTH) (27).

People living at northern latitudes are at risk for vitamin D deficiency during the winter (2, 3). Subjects at elevated risk for vitamin D deficiency are those with insufficient sun exposure, the elderly, dark-skinned people living at northern latitudes, people with clothes covering much of their body, vegans and individuals who do not eat fish or dairy products (28). Elderly people in nursing homes could be at risk for vitamin D deficiency because they have a limited exposure to sun, often eat less food and because the cutaneous synthesis of vitamin D decreases with increased age. The metabolism of vitamin D remains relatively normal in elderly people, but the renal formation of $1.25(\text{OH})_2\text{D}$ can be restricted by impaired renal function and chronic diseases (27, 29).

Several international studies have shown that vitamin D deficiency is highly prevalent in the elderly (23, 30, 31, 32, 33, 34, 35). A few relatively small Scandinavian studies found that vitamin D deficiency was common, especially in elderly people living in homes for the aged (30, 31). A prospective cohort study among elderly female patients in nursing homes in Austria showed that vitamin D deficiency was highly prevalent and that there was an association between low levels of vitamin D and an increased risk of mortality (23). There are, to our knowledge, no Northern European studies about vitamin D deficiency and mortality risk in elderly people living in nursing homes.

The aim of this study was to examine whether lower levels of vitamin D were associated with an increased risk of mortality in elderly people in Swedish nursing homes. Furthermore, our aim was to explore the prevalence of vitamin D deficiency, how the levels of vitamin D changed over time and to examine if lower levels of vitamin D were

associated with an increased risk of cardiovascular events, falls or fractures.

Subjects and methods

The Study of Health and Drugs in the Elderly (SHADES) is a cohort study conducted in 11 nursing homes in three cities in southern Sweden: Eslöv, Jönköping and Linköping. Nursing homes were defined as homes for elderly people with collective living areas and collective nursing staff. The aim of SHADES was to describe and analyse mortality, morbidity, health status and the use of medication among people living in nursing homes. The study was conducted between 2007 and 2011. New patients were included until March 2011. Analysis of deceased people was conducted in March 2012. All the residents at the start of the study and all persons who moved into the selected nursing homes were invited to participate. Exclusion criteria were as follows: planned short-term stay, for example, for rehabilitation or palliative care, language difficulties and age under 65 years. Consent has been obtained from each subject after full explanation of the purpose and nature of all procedures used. This study was approved by the Regional Ethical Review board at Linköping University, number: M150-07.

Measurements

Participants were consecutively included at six occasions as new subjects moved into the nursing homes. The following were registered: age, gender, the date of moving into the nursing home, the date of inclusion in the study and the date of leaving the nursing home or death. Every 6 months, specially trained nurses performed examinations and collected data from the county's medical records about diagnoses, chronic diseases, current medication and information concerning acute events during the last 6-month period in the nursing home. The number of visits to general practitioners (GP) and emergency wards and occurrences of hospitalisation as well as resulting diagnoses was recorded from the medical records. According to diagnosis, the visits caused by cardiovascular events, falls or fractures were classified and counted. A fall was defined as a fall causing a visit to the GP, emergency ward or hospitalisation but without fractures. The causes of death including the total number of fatal cardiovascular events were ascertained from the death certificates. To estimate the functional level of the subjects, we used the second-subscale, named physical activity in the modified Norton scale (MNS) (36), performed at inclusion

in the study. The item is assessed with a range from 1 (lack of function) to 4 (normal function): 1, bedridden; 2, chairbound (all day); 3, walks with help (wheelchair when independent transportations); and 4, ambulant. From the Downton Fall Risk Index (DFRI) (37), performed at inclusion in the study, history of known falls during the last year (yes or no) was noted, also including falls not leading to medical care.

At inclusion in the study, the subject's weight was measured to the nearest kilogram and the height to the nearest centimetre. BMI was calculated from the weight in kilograms divided by the square of the height in metres. The blood pressure was recorded three times in sitting position and the mean value was used for analyses.

Laboratory methods

Fasting blood samples were collected and frozen for later analyses. The levels of 25(OH)D₃ were analysed in serum on three occasions with a 1 year interval: at inclusion and after 1 and 2 years. All blood samples were analysed at the Department of Clinical Chemistry, County Hospital of Ryhov, Jönköping, Sweden, with HPLC technology. Following extraction, separation of 25(OH)D₃ was carried out by HPLC-System (reagent kit and HPLC column from Chromsystems Instruments & Chemicals GmbH, Munich, Germany) with u.v. detection at a wavelength of 265 nm (u.v. detector from Dionex ThermoFisher Scientific, Inc., Sunnyvale, CA, USA). The lowest detection limit was 6.0 nmol/l and the measuring interval was 6–1250 nmol/l.

Haemoglobin, creatinine and cystatin C were analysed at inclusion in the study. Glomerular filtration rate (GFR) was estimated by cystatin C (eGFR) in ml/min per 1.73 m² and was calculated as: $eGFR = 84.69 \times (1/\text{cystatin C}^{1.680})$ (38).

Statistical analyses

Statistica 10 (StatSoft, Inc., Tulsa, OK, USA) was used for the statistical analyses. Comparisons between groups were performed with *t*-test and ANOVA. Differences between proportions were calculated with χ^2 -test. Correlation between two variables was calculated with Spearman's rank correlation. Cox regression analyses were used to calculate hazard ratios (HRs) for mortality in the different 25(OH)D₃ quartiles, with the fourth quartile as a reference. Logistic regression analyses were used to calculate odds ratio for cardiovascular events, falls and fractures in the different 25(OH)D₃ quartiles, with the fourth quartile as a reference.

Results

From the total number of participants in SHADES (*n*=429), 96 were excluded from the analyses: 55 (14%) for being on vitamin D medication in combination with calcium and 41 for lacking data (Fig. 1). Thus, 333 subjects remained for further analyses in this study and were categorised into four quartiles according to their 25(OH)D₃ levels at inclusion. Baseline characteristics of the study population are shown in Table 1. Of the participants, 226 (68%) were women and 107 (32%) men. Mean age for the women was 86 years and for the men 83 years. There was a difference in age between Q1 and Q4 for men, but no differences in age were seen between the quartiles for women. The proportion of Q4 that had lived <1 year in the nursing home at inclusion was larger than in Q1 (*P*=0.05), but otherwise no differences were seen between the quartiles in time spent in the nursing homes. There was no difference in BMI, haemoglobin levels, blood pressure or levels of physical activity between the quartiles. There was a difference in creatinine levels between Q1 and Q3 (*P*<0.05), and for women also between Q1 and Q4 (*P*<0.05). However, no

Figure 1

Flow chart of the patients in the Study of Health and Drugs in the Elderly (SHADES). *n*, number of patients; 25(OH)D₃, 25-hydroxyvitamin D₃.

Table 1 Baseline characteristics according to 25(OH)D₃ quartiles. Data are presented as mean and s.d. or as percentages and (n). Differences between groups were calculated with ANOVA and differences between proportions were calculated with χ^2 -test.

	Serum 25(OH)D ₃ quartile				P value
	1	2	3	4	
n	86	82	85	80	
25(OH)D ₃					
Range (nmol/l)	11–29	30–37	38–47	48–120	
Mean (nmol/l)	24.1 ± 4.1	33.4 ± 2.2	42.1 ± 2.8	62.3 ± 14.7	
Male	38% (n=33)	23% (n=19)	42% (n=36)	24% (n=19)	NS
Age (years)	86.3 ± 6.2	84.7 ± 6.8	84.5 ± 7.0	84.3 ± 7.2	NS
Male	85.8 ± 6.4	83.2 ± 5.6	81.9 ± 7.4	79.4 ± 6.7	P<0.01, Q1–Q4
Female	86.6 ± 6.1	85.2 ± 7.1	86.3 ± 6.2	85.8 ± 6.8	NS
Time in nursing home (years)					
< 1	48% (n=41)	54% (n=44)	55% (n=47)	68% (n=54)	P=0.05, Q1–Q4
1–3	30% (n=26)	22% (n=18)	26% (n=22)	16% (n=13)	NS
> 3	22% (n=19)	24% (n=20)	19% (n=16)	16% (n=13)	NS
BMI (kg/m ²)	24.6 ± 4.5	24.7 ± 5.6	25.9 ± 5.1	24.9 ± 3.9	NS
Male	24.6 ± 4.0	25.4 ± 3.8	24.8 ± 4.8	24.9 ± 3.8	NS
Female	24.6 ± 4.8	24.5 ± 6.0	26.7 ± 5.2	24.9 ± 3.9	NS
Haemoglobin (g/l)	126.3 ± 14.5	125.0 ± 14.8	126.4 ± 12.5	125.4 ± 14.2	NS
Male	127.8 ± 15.0	126.4 ± 11.8	128.6 ± 13.5	126.8 ± 16.7	NS
Female	125.4 ± 14.3	124.5 ± 15.6	124.9 ± 11.5	125.0 ± 13.6	NS
Creatinine (μmol/l)	79.0 ± 30.0	86.3 ± 34.4	98.9 ± 64.5	93.9 ± 37.0	P<0.05, Q1–Q3
Male	92.2 ± 39.4	101.0 ± 43.4	117.8 ± 91.3	106.5 ± 55.0	NS
Female	70.8 ± 18.2	81.9 ± 30.3	84.8 ± 25.8	89.9 ± 28.8	P<0.05, Q1–Q3 and 4
GFR (estimated by cystatin C) (ml/min per 1.73 m ²)	62.4 ± 25.4	62.8 ± 27.2	56.0 ± 24.6	56.4 ± 25.8	NS
Male	63.1 ± 25.9	60.8 ± 26.4	55.4 ± 27.2	56.3 ± 20.8	NS
Female	62.0 ± 25.3	63.4 ± 27.7	56.4 ± 22.8	56.4 ± 27.3	NS
Systolic blood pressure (mmHg)	130.5 ± 26.3	130.3 ± 23.6	135.4 ± 21.6	135.9 ± 23.1	NS
Male	128.2 ± 26.9	121.4 ± 19.4	126.2 ± 18.2	132.4 ± 27.7	NS
Female	132.0 ± 26.0	132.7 ± 24.2	143.0 ± 21.4	137.0 ± 21.6	NS
Diastolic blood pressure (mmHg)	70.5 ± 11.2	71.7 ± 11.4	72.6 ± 10.5	73.4 ± 11.6	NS
Male	71.5 ± 9.7	68.5 ± 9.7	71.5 ± 9.2	70.7 ± 10.8	NS
Female	69.8 ± 12.2	72.6 ± 11.7	73.5 ± 11.4	74.2 ± 11.8	NS
Frequency of patients with hypertension diagnosis (%)	24% (n=21)	28% (n=23)	27% (n=23)	40% (n=32)	NS
Male	36% (n=12)	32% (n=6)	22% (n=8)	47% (n=9)	NS
Female	17% (n=9)	27% (n=17)	31% (n=15)	38% (n=23)	NS
Frequency of patients with cardiovascular diagnosis other than hypertension (%)	55% (n=47)	60% (n=49)	60% (n=51)	54% (n=43)	NS
Male	52% (n=17)	68% (n=13)	64% (n=23)	53% (n=10)	NS
Female	57% (n=30)	57% (n=36)	57% (n=28)	54% (n=33)	NS
Level of physical activity in the modified Norton scale					
Bedridden	–	–	–	–	NS
Chairbound	35% (n=30)	25% (n=20)	24% (n=20)	23% (n=18)	NS
Walks with help	24% (n=21)	17% (n=14)	14% (n=12)	15% (n=12)	NS
Ambulant	41% (n=35)	58% (n=47)	61% (n=51)	63% (n=50)	NS

Significant differences are presented with P values. 25(OH)D₃, 25-hydroxyvitamin D₃; n, number of patients; NS, non-significant; Q, quartile; GFR, glomerular filtration rate.

differences were seen between the quartiles in GFR estimated by cystatin C. For women who stayed > 1 year in the nursing home a significant increase in body weight was seen 1 year after the first measurement at inclusion in the study, but otherwise no variation in body weight was noticed over time.

During the study period, 147 (44%) of the 333 subjects died of any cause. The most common causes of death according to the death certificates were cardiovascular disease (48%), infections (14%), dementia (10%), general organ failure (10%), neoplastic disease (3%), kidney failure (3%) and other causes (12%). The vitamin D levels in the

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Table 2 Outcome according to 25(OH)D₃ quartiles, categorised from the baseline 25(OH)D₃ levels. Data are presented as percentages and (n). Differences between proportions were calculated with χ^2 -test.

Outcome	Serum 25(OH)D ₃ quartile				P value
	1 (n=86)	2 (n=82)	3 (n=85)	4 (n=80)	
Death during the study	59% (n=51)	44% (n=36)	45% (n=38)	28% (n=22)	$P<0.05$, Q1–Q4
Incidence of fatal cardiovascular events during the study (from death certificates)	26% (n=22)	21% (n=17)	24% (n=20)	14% (n=11)	NS
Incidence of nonfatal cardiovascular events during 3 years (from medical records)	9% (n=8)	10% (n=8)	18% (n=15)	21% (n=17)	NS
Incidence of falls during 3 years (from medical records)	8% (n=7)	11% (n=9)	15% (n=13)	9% (n=7)	NS
Incidence of fractures during 3 years (from medical records)	13% (n=11)	15% (n=12)	14% (n=12)	11% (n=9)	NS
Incidence of falls from interview DFRI, yes or no, at inclusion	69% (n=59)	59% (n=48)	65% (n=55)	53% (n=42)	NS

Significant differences are presented with *P* values. 25(OH)D₃, 25-hydroxyvitamin D₃; n, number of patients; Q, quartile; NS, non-significant; DFRI, Downton Fall Risk Index.

deceased subjects were lower at inclusion compared with the living subjects: 37.6 nmol/l compared with 42.2 nmol/l ($P<0.01$), as were the vitamin D levels from the last occasion of measuring: 35.3 nmol/l in the deceased subjects compared with 39.5 nmol/l in the living subjects ($P<0.05$) with no significant differences between men and women. After a mean follow-up of 3 years, 59% of the patients in Q1 had died compared with 28% in Q4 (Table 2). The cumulative survival for the persons in the different vitamin D quartiles is shown in Fig. 2. HR (with 95% CI) for mortality was 2.02 (1.31–3.12) in Q1 compared with Q4 ($P<0.05$), 2.03 (1.32–3.14) in Q2 compared with Q4 ($P<0.05$), and 1.6 (1.03–2.48) in Q3 compared with Q4 ($P<0.05$). In the analysis, we adjusted for differences in age, gender, BMI, systolic and diastolic blood pressure, GFR estimated from cystatin C, the season when the blood sample for vitamin D was collected, the time living in the nursing home, previous cardiovascular diseases, neoplastic diseases, dementia and the level of physical activity. Of these variables, only an increase in age and a limited level of physical activity were associated with a higher mortality risk in the Cox regression analyses. HR (with 95% CI) for mortality was 1.06 (1.04–1.09) for age ($P<0.01$). HR (with 95% CI) for mortality was 1.56 (1.12–2.17) in the group with physical activity level assessed as 2, who were chairbound (all day), and 1.88 (1.32–2.68) in the group with physical activity level assessed as 3, walks with help (wheelchair when independent transportations) compared with the group with physical activity level assessed as 4, ambulant in the MNS ($P<0.01$). There was a positive correlation between

the levels of physical activity and the vitamin D levels, $r_s=0.18$ ($P=0.001$).

The mean 25(OH)D₃ concentration at inclusion was 40.2 nmol/l (s.d. 16.0), with no significant differences

Figure 2

Cumulative survival according to 25(OH)D₃ quartiles. Cox regression analyses were used to calculate HR for mortality in the different 25(OH)D₃ quartiles with the fourth quartile as a reference. Compared with the subjects in Q4 (25(OH)D₃ >48 nmol/l), the HR (with 95% CI) for mortality was 2.02 (1.31–3.12) in Q1 (25(OH)D₃ <29 nmol/l) ($P<0.05$), 2.03 (1.32–3.14) in Q2 (25(OH)D₃ 30–37 nmol/l) ($P<0.05$) and 1.6 (1.03–2.48) in Q3 (25(OH)D₃ 38–47 nmol/l) ($P<0.05$). 25(OH)D₃, 25-hydroxyvitamin D₃; HR, hazard ratio; Q, quartile.

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Table 3 Distribution of 25(OH)D₃ at inclusion in elderly people in nursing homes. Data are presented as percentages and (n). Differences between proportions were calculated with χ^2 -test.

Serum 25(OH)D ₃ (nmol/l)				P value
<25	26–50	51–75	>76	
14.4% (n=48)	65.8% (n=219)	15.3% (n=51)	4.5% (n=15)	P<0.001, columns 2–1, 3 and 4

Significant differences are presented with P values. 25(OH)D₃, 25-hydroxyvitamin D₃; n, number of patients.

between men and women. Table 3 shows that 80% of the patients had 25(OH)D₃ below 50 nmol/l and 14% a value below 25 nmol/l.

The vitamin D levels decreased from the baseline to the second and third measurements. As expected, there were seasonal changes in the vitamin D level during the year. Higher values were seen from May until October, compared with November until April: 39.2 vs 35.7 nmol/l ($P<0.01$), as illustrated in Fig. 3. In the analyses that compare the changes in vitamin D over time and with season, we used the vitamin D values from all three occasions of measuring. The times of the year for collections of the three blood samples were equivalently distributed.

When analysing the number of cardiovascular events, no significant differences between the quartiles of vitamin D were found, neither in the analysis of only nonfatal cardiovascular events nor when fatal cardiovascular events were included. In the analysis of the number of falls and fractures, the registered events were too few to allow statistical conclusions. No differences between the proportions of the vitamin D quartiles with cardiovascular events, fall events, fracture events or history of known falls according to interview with DFRI at inclusion were found (Table 2), but there was a difference in vitamin D levels in the female patients with a history of known falls compared with the female patients without history of known falls: 39.3 vs 44.7 nmol/l ($P<0.05$). No difference in vitamin D levels was seen between male patients with or without history of known falls.

Discussion

In this study, confined to subjects living in nursing homes without supplement with vitamin D in combination with calcium, we found that vitamin D deficiency was associated with an increased risk of mortality (Fig. 2). The risk of death during the observational time of 3 years was doubled in Q1 and Q2 compared with Q4. Also in Q3, the mortality risk was increased compared with Q4.

Increased age and reduced physical activity were also associated with an increased risk of mortality. The functional level might be of importance for the mortality risk in several ways, as a limited ability to move might be a consequence of other diseases and frailty, and might also lead to difficulties in spending time outdoors with limited sun exposure and affected vitamin D levels as a consequence.

Vitamin D deficiency was highly prevalent, as 80% of the study population had vitamin D levels below 50 nmol/l. We found that the vitamin D levels changed over the year, with the highest values during the sunny months, which indicates the importance of sunlight on the vitamin D level. We found a decrease in vitamin D level over time, even though the women who had stayed in the nursing home <1 year gained weight during the first year. Vitamin D is stored in the adipose tissue, but the depot is not large enough to prevent seasonal changes in the plasma concentrations of 25(OH)D and PTH (3, 39). We had, however, no detailed information of the dietary calcium and vitamin D intake, other than that they all were served the same food at the nursing home. The possible reasons for the decline in vitamin D level might

Figure 3

Seasonal changes in 25(OH)D₃ in elderly people in nursing homes, presented as mean 25(OH)D₃ ± s.d. 25(OH)D₃, 25-hydroxyvitamin D₃.

be an impairment of the general condition, progression of chronic diseases or reduced sun exposure after moving into the nursing home, but this question remains to be answered in future studies.

No differences were found between the proportions of the vitamin D quartiles with a history of known falls, but the difference in vitamin D levels was significant for women. No association was seen between the vitamin D levels and the risk of cardiovascular events. The number of registered falls and fractures was too few to allow any conclusions about its association with the vitamin D levels. Thus, in this study, we cannot explain the mechanisms by which low vitamin D levels are associated with an increased risk of mortality. As the study is an observational study, we cannot rule out the possibility that low levels of vitamin D are not a cause of the mortality but an effect of other diseases.

The strength of this study is that elderly individuals in nursing homes were included and followed prospectively. This is a population category that has not been particularly well-studied previously. The elderly in nursing homes often have a high morbidity, which was evident also in this study with a total mortality of 44% during the study period. Another strength of this study is that the vitamin D levels were measured repeatedly, allowing comparison over time. In spite of the high mortality among the subjects, there was a heterogeneity in the disease panorama which made the number of reported events in each category relatively few. We had to rely on the medical records for the analysis of the events, and there might be a variation in documentation by different health care providers. There was, for example, a discrepancy between documented falls in the medical records and the history of falls according to interview. Cause of death was obtained from death certificates and these may in many cases be inaccurate. However, the Swedish Cause of Death Register has been known for maintaining high international standards of accuracy (40), showing that data on malignant neoplasms and ischemic heart disease generally are reliable (41). A variation in documentation might have contributed to the lack of clear explanation to our not being able to see any univocal explanation to the increased mortality in the people with low vitamin D levels. The observational design of this study precludes any conclusions about causality, but the clear association between low vitamin D levels and mortality calls for randomised clinical trials exploring the effects of vitamin D supplementation in elderly institutionalised subjects. A limitation of the study is that the blood samples were collected with a 1-year interval and there is a risk that the

blood samples were collected from the people with high vitamin D values during summer. This is unlikely, however, as the method of selection was the same.

Our main finding that vitamin D deficiency in elderly people living in nursing homes was associated with an increased mortality risk is in line with a study on institutionalised female patients in Austria (23). Several studies on non-institutionalised elderly have also shown a relationship between vitamin D deficiency and increased mortality (16, 17, 18, 19, 20, 21, 22). A meta-analysis of prospective observational studies shows that the mortality risk decreases when the vitamin D level rises, with optimal concentrations around 75–87.5 nmol/l (15), which are higher values than in our fourth quartile. In contrast, in a study carried out in community-dwelling American men of at least 65 years old, no association was found between low vitamin D levels and an increased risk of mortality (42). However, the vitamin D levels were generally higher and in their study only the first quartile had a vitamin D level below 50 nmol/l.

In conclusion, vitamin D deficiency has been found to be highly prevalent and has been associated with an increased risk of mortality in elderly people in nursing homes in Sweden. Our results correspond with the results of other international observational studies. There is a need for new strategies and routines to prevent and maybe treat vitamin D deficiency in the elderly in nursing homes, and the potential benefits of vitamin D supplementation need to be evaluated in randomised clinical trials.

Declaration of interest

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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Author contribution statement

S Mölsted, C J Östgren and P Midlöv contributed in study concept and design, C Lannering in acquisition of data, M Samefors, C J Östgren and A Tengblad in analysis and interpretation of the data, and M Samefors and A Tengblad in drafting of the manuscript. Critical revision of the manuscript for important intellectual content was done by A Tengblad, C J Östgren, S Mölsted and P Midlöv.

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