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ORIGINAL RESEARCH

Prevalence of vitamin D deficiency among anaesthesia providers at an academic hospital complex in South Africa

M Booyens, BJS Diedericks

Department of Anaesthesiology, School of Clinical Medicine, Faculty of Health Sciences, University of the Free State, South Africa
Corresponding author, email: *marnusbooyens@yahoo.com*

Background: The primary source of vitamin D is skin exposure to sunlight. Vitamin D deficiency is common in people who have decreased sun exposure. Acute vitamin D deficiency symptoms are mild and non-specific, but the long-term sequelae of deficiency are extensive, severe, and easily preventable. Anaesthetists spend a large portion of their days working indoors and are at risk of developing vitamin D deficiency. This study aimed to determine the prevalence of vitamin D deficiency among anaesthetists at the Universitas Academic Hospital (UAH) complex, Bloemfontein, South Africa, and to correlate deficiency with known risk factors.

Methods: A descriptive cross-sectional study was conducted on doctors who provide anaesthesia daily at UAH. The study was explained during an academic meeting, and members were invited to participate. On the scheduled date, consent was obtained from participants. Blood was drawn for laboratory analysis. Participants completed a questionnaire regarding the risk factors. They received an informational poster and had access to their results if requested. Data were analysed, and the chi-square and Fischer's exact tests were used to determine if there was any significant association between vitamin D levels and categorical data.

Results: A total of 33 staff members from the Department of Anaesthesiology volunteered to participate in the study. An overall deficiency rate of 39.4% was found, with only one in five participants having sufficient vitamin D levels. The only factor that demonstrated a statistically significant correlation with deficiency was age ($p = 0.03$), but this study lacked sufficient power to make any conclusions.

Conclusion: Vitamin D deficiency is prevalent among anaesthetists at UAH. Awareness should be raised regarding deficiency in this group, and an increase in age is correlated with a higher risk for deficiency.

Keywords: vitamin D, deficiency, anaesthetists, sun exposure, risk factors

Introduction

Vitamin D, an essential nutrient, is a fat-soluble vitamin and hormone. It is mainly derived from exposure of the skin to sunlight. Its major role in the body is maintaining calcium homeostasis. However, every cell in the body contains receptors for vitamin D, so its effects are diverse.[1,2]

The primary source of vitamin D is sun exposure. Up to 90% of daily vitamin D production involves exposure to ultraviolet B sunrays.[3] This leads to the production of pro-vitamin D (cholecalciferol), which is converted by the liver and kidneys to its active form, 1,25-dihydroxyvitamin D.[1,2] Dietary sources of vitamin D include mushrooms, fatty fish, fish liver oils, eggs, and fortified dairy products.[4] It is absorbed from the gastrointestinal tract in the form of vitamin D_2 (ergocalciferol), which only has a third of the potency of cholecalciferol and accounts for 10–20% of daily vitamin D intake.[5]

The clinical effects of vitamin D deficiency are subtle but may be devastating in the long term, and multiple systems are affected. The acute symptoms of vitamin D deficiency are non-specific, and most patients do not seek medical attention. These symptoms include joint and muscle pain, weakness/tiredness, diarrhoea, headaches, depressed mood, recurrent infections, and delayed wound healing.[4,6] The long-term effects of vitamin D deficiency are multisystemic and can be severe. Systems where vitamin D plays a direct role in its development or affects the treatment of diseases include the skeletal, cardiovascular, and central nervous systems. It also plays a role in preventing malignancies and supporting immune function.[4,9,12-17]

The recommended daily vitamin D intake is approximately 600–800 international units (IU).[6] Certain populations may need higher levels, such as the elderly, children, and pregnant women.[2,7] The amount of sunlight needed to produce this level of vitamin D equates to one hour per day of direct exposure to sunlight on exposed limbs.[6] Dietary supplementations of vitamin D are available, but their use in South Africa is limited.[8]

The prevalence of vitamin D deficiency in the general population is estimated at around 24% in the United States of America (USA), 37% in Canada, and 40% in Europe.[9,10] In the South African population, a prevalence of 5–28% has been reported, with substantial variation in the prevalence depending on the province and population groups studied.[8] It has also been documented that indoor workers generally have lower vitamin D levels than those who work outdoors.[3]

Risk factors for the development of vitamin D deficiency include decreased exposure to sunlight (indoor work, sunblock use, darker skin tones), female gender, decreased dietary intake of vitamin D, obesity, age, smoking, pregnancy and breastfeeding, chronic liver and kidney disease, and certain medications (e.g.

glucocorticoids, antiepileptics, antifungals, and antiretroviral agents).[2,4,8,9,12]

In the medical field, medical residents and students are among the groups with the lowest vitamin D levels.[3] Only one study has demonstrated the extent of the disease in the field of anaesthesia. A single-centre study conducted in Chile showed a 12% deficiency rate among their study population during the summer months, which escalated to 67% during winter.[11]

Vitamin D deficiency commonly occurs in people with decreased sunlight exposure, such as indoor workers.[3] Anaesthetists spend most of their day working indoors, without even early morning or late afternoon sun exposure. Therefore, it is logical to assume that they would be at risk of developing a deficiency of this multisystemic vitamin. This study aimed to determine the prevalence of vitamin D deficiency in the anaesthetic workforce at the Universitas Academic Hospital (UAH) in Bloemfontein, South Africa.

Methods

Ethical considerations

A descriptive cross-sectional study was conducted, for which ethical approval was obtained from the Health Sciences Research Ethics Committee of the University of the Free State (reference number: UFS-HSD2021/1216/3011). Permission for the research was provided by the Head of the Department of Anaesthesiology, University of the Free State, for including registrars (registered students), and the Free State Department of Health for including staff members. All the participants provided written, informed consent for inclusion in the study. Participation was voluntary and anonymous, with the choice to withdraw at any stage without consequences.

Methods and information distribution

Blood specimens were collected to achieve the study's primary objective, determining the vitamin D levels of anaesthesia providers at UAH and ascertaining the prevalence of deficiency. To address the study's secondary objective, determining the presence of risk factors (as identified in the literature), a questionnaire was compiled to generate information to correlate these risk factors with the blood levels of vitamin D. The questionnaire was validated on a content-basis by the authors in line with published information.

The study details were presented and discussed during a weekly academic meeting. Staff members received an explanation of the planned research and how it would be conducted and had the opportunity to sign up for the study. Members who indicated that they would participate received an email with details regarding the dates of the phlebotomy, an electronic consent form, a questionnaire, and an informational vitamin D poster.[19] The first session to collect blood samples was scheduled one week after the initial presentation. Specimen collection was performed in February 2022 during the summer season.

Inclusion and exclusion criteria

All staff members in the Department of Anaesthesiology at the University of the Free State who were involved with daily anaesthesia provision in UAH at the time of the study were eligible to participate. Convenience sampling was applied as the population was readily available and volunteered upon request to participate in the study. The size of the population was unknown due to large variations in the department's size during the data collection. No sample size calculation was required.

The exclusion criteria were the following: any person with known renal or liver disease, being on leave two weeks before blood specimen collection, refusing to participate in the study, and being younger than 18 years.

Collection and processing of blood specimens

On the day of blood sample collection, a laboratory phlebotomist set up a phlebotomy station at the Department of Anaesthesiology. Participants were then called two at a time from the academic meeting for sample collection. A blood specimen was taken from each participant after written consent was obtained. Participants also had the opportunity to complete the questionnaire if it had not already been done online. The informational poster was also on display. Blood was drawn by the phlebotomist under the supervision of the principal investigator to ensure the correct technique was applied.[20]

Each specimen and questionnaire was marked with a corresponding number. The lead investigator noted each participant's unique specimen number on a separate page for confidential safekeeping. The laboratory had no identifying information other than the unique number. Participants were given their unique specimen number and information so they could contact the laboratory or principal researcher for their results.

The blood specimens were processed according to World Health Organization (WHO) procedures and recommendations.[18] The current classification of vitamin D deficiency proposed by the USA Endocrine Society, as shown in Table I, was used to identify deficiency.[2,6,18] The lead investigator entered the results into a Microsoft Excel (version 2016) spreadsheet along with the corresponding questionnaire answers for each specimen. The same process was repeated two weeks later to accommodate participants who could not attend the first specimen collection opportunity.

Table I: USA Endocrine Society classification of vitamin D deficiency[2,6,18]

Classification	Serum vitamin D level (ng/ml)
Deficient	< 20
Insufficient	21–29
Sufficient	> 30
Toxic	> 150

ng/ml – nanogram per millilitre

Table II: Demographic information of participants and prevalence of vitamin D deficiency

Variable	Distribution of participants per variable (*n* = 33)	Participants per variable with vitamin D deficiency
	***n* (%)**	***n* (%)**
Age (years)		
< 25	1 (3.0)	1 (100)
25–30	7 (21.2)	4 (57.1)
31–40	18 (54.5)	7 (38.9)
41–50	4 (12.1)	0 (0)
> 50	3 (9.1)	1 (33.3)
Gender		
Male	18 (54.5)	7 (38.8)
Female	15 (45.5)	6 (40.0)
Race		
African	7 (21.2)	4 (57.1)
Coloured	2 (6.1)	1 (50.0)
Indian	3 (9.1)	2 (66.7)
White	21 (63.6)	6 (28.6)
BMI (kg/m²)		
18–24.9 (normal weight)	13 (39.4)	4 (30.5)
25–29.9 (overweight)	12 (36.4)	5 (41.7)
30–34.9 (obese class I)	5 (15.2)	4 (80.0)
35–40 (obese class II)	3 (9.1)	0 (0)
Rank		
Consultant	8 (24.2)	2 (25.0)
Senior registrar	13 (39.4)	4 (30.8)
Junior registrar	6 (18.2)	4 (66.7)
Medical officer	1 (3.0)	0 (0)
Intern	5 (15.2)	3 (60.0)
Experience as anaesthetist (years)		
< 1	4 (12.1)	2 (50.0)
1–5	9 (27.3)	3 (33.3)
5–10	13 (39.4)	6 (46.2)
> 10	7 (21.2)	2 (28.6)

BMI – body mass index, kg/m² – kilogram per metre squared

Table III: Questionnaire results on factors that may influence vitamin D levels

Variable	Distribution of participants per variable (*n* = 33)	Participants per variable with vitamin D deficiency
	***n* (%)**	***n* (%)**
Smoking		
Current	4 (12.1)	3 (75.0)
Ex-smoker	2 (6.1)	0 (0)
Non-smoker	27 (81.8)	10 (37.0)
Sun exposure		
< 1 hour per day	25 (75.8)	3 (12.0)
1–3 hours per day	8 (24.4)	
Daily sunscreen use		
Yes	9 (27.3)	5 (55.6)
No	24 (72.7)	8 (33.3)
Previously tested for vitamin D levels		
Yes	9 (27.3)	2 (22.2)
No	24 (72.2)	11 (45.8)
Previous results when tested		
Deficient	5 (15.2)	1 (20.0)
Insufficient	4 (12.1)	1 (25.0)
Not applicable	24 (72.2)	11 (45.8)
Supplementation use		
Multivitamin	8 (24.2)	3 (37.5)
Vitamin D	3 (9.1)	0 (0)
None	22 (66.7)	10 (45.5)
Vitamin D supplementation (IU/day)		
0–300	6 (18.1)	3 (50.0)
301–600	4 (12.1)	0 (0)
601–800	0 (0)	0 (0)
> 800	1 (3.0)	0 (0)
None	22 (66.7)	10 (45.5)
Previously wondered about vitamin D deficiency		
In the preceding year	11 (33.3)	2 (18.2)
When tested before	7 (21.2)	2 (28.6)
Never	15 (45.5)	9 (60.0)
Food consumed		
Fish	5 (15.2)	3 (60.0)
Cod liver oil	1 (3.0)	1 (100)
Eggs	19 (57.6)	8 (42.1)
Mushrooms	14 (24.4)	4 (28.6)
Dairy	16 (48.5)	6 (37.5)

IU/day – international units per day

Data collection and analysis

The data sheet with the final specimen results and corresponding questionnaire answers was processed and analysed by the Department of Biostatistics, University of the Free State. Descriptive statistics were determined. Blood levels of vitamin D and categorical data were expressed as frequencies and percentages. The vitamin D levels were then compared with responses to the questionnaire items to identify any associations between risk factors and vitamin D levels. The data were subjected to chi-square and Fischer's exact tests to analyse categorical data to determine whether any significant association occurred between vitamin D levels and categorical data. Significance was expressed as a *p*-value of less than 0.05. The Kolmogorov–Smirnov test was used to determine whether the data were normally distributed. The statistical software package used for analysis was SAS version 9.4 (SAS Institute, Cary, USA).

Results

A total of 33 out of a potential 42 staff members participated in the study, giving a response rate of 78%. Of the 33 participants,

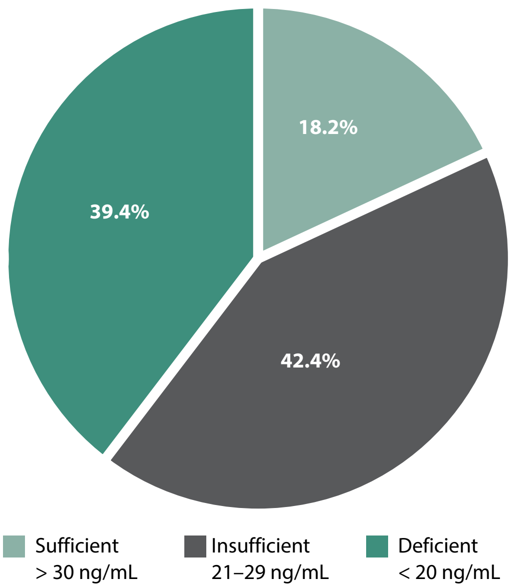

Figure 1: Distribution of participants (n = 33) according to vitamin D levels; toxic levels of vitamin D (> 150 ng/ml) were not observed in any of the participants

13 (39.4%) had deficient vitamin D levels (confidence interval 0.22 to 0.56). Only six (18.2%) participants had sufficient vitamin D levels. The mean vitamin D plasma level was 22.7 ng/ml, with a standard deviation of 7.7 ng/ml. The lowest recorded value was 10.5 ng/ml, and the highest was 41.9 ng/ml.

Figure 1 illustrates the distribution of participants according to the classification of vitamin D levels. Tables II and III summarise the participants' demographic information, the prevalence of vitamin D deficiency, and the questionnaire results. Table IV shows associations between risk factors and vitamin D deficiency.

Discussion

The prevalence of vitamin D deficiency in this study population was 39.4% (Figure 1), which was in keeping with findings reported for the general population (not necessarily high-risk groups) in the USA, Canada, and Europe (range 28–40%).[9,10] However, the prevalence was notably higher than recorded in previous South African studies, with ranges of 5–28.6%.[8] Our data were collected in the summer, during February. By implication, generally higher levels of vitamin D would be expected because of the potentially increased exposure to sunlight, a major factor in vitamin D synthesis. Therefore, it was concerning to find deficiency values similar to or lower than those in the other studies. These studies involved the general population and not necessarily high-risk groups, the medical community, or anaesthetists, which complicated the comparison and relating of the results.[8-10] There was also a variation in the units in which vitamin D levels were measured, leading to difficulty in comparison.

Compared to the Chilean study on anaesthetists reporting a deficiency rate of 12% during the summer months, we found a notably higher prevalence.[11] However, this comparison did not consider the difference in altitude between the two countries. As Chile has a higher altitude (1 871 m above sea level, consequently closer to the sun with less dense air), it might have played a role in the fact that they found a lower prevalence of vitamin D deficiency compared to Bloemfontein (1 395 m above sea level). This explanation is echoed by the systematic review of South African studies, reporting that coastal provinces (at lower altitudes) tended to have a higher prevalence of vitamin D deficiency than inland provinces (at higher altitudes).[8]

An increase of 55% in the deficiency rate to 67% was reported when studies were repeated in the winter months.[8] A South African study conducted during winter demonstrated a deficiency rate of 57.3%.[21] As this study used a different classification system for deficiencies, no direct comparison could be made with our results, although it is likely that a potentially increased prevalence would be observed in winter.[21] Consequently, it could be concluded that anaesthetists working in this hospital complex are at risk of developing vitamin D deficiency. Awareness should be raised to alert anaesthetists to the potential risk. It may also be true for other specialities working under similar conditions, i.e. starting work early in the morning and only leaving the building at night or late afternoon on working days, including some weekends.

Table II shows that 54.5% of the participants were male and in the 31–40 age group. In the group of participants with vitamin D deficiency, 53.8% were male. Age was statistically associated with vitamin D deficiency (p = 0.03). According to the literature, vitamin D deficiency is more prevalent among the elderly, although not many participants in our study were in this category.[2] Most participants were aged 18–29 years (n = 25, 75.8%), which could have led to some bias regarding the results. A steady increase in the number of deficient participants was observed with increasing age (Table II). The sudden drop in the prevalence of vitamin D deficiency after age 40 could mainly be attributed to the lack of data. Thus, it is prudent to repeat the study with more anaesthetists in advanced age groups and to raise awareness in this subgroup.

Most participants (63.6%) identified themselves as white (Table II), the skin colour that permits more sunlight to penetrate the skin and allows for increased vitamin D production.[6] Darker skin tones are more likely to have vitamin D deficiency.[2,4,6,8,9,12] However, the few participants from darker race groups and the lack of power in the data resulted in insufficient data, preventing corroboration of our findings with previously published findings. Furthermore, race as a surrogate for skin tone is not always accurate.

Most participants classified themselves as having a normal body mass index (BMI) of 18–24.9 kg/m^2. Obese individuals are at a higher risk of developing vitamin D deficiency.[2,4,8,9,12,14] The group with the highest percentage of vitamin D deficient participants was the 25–29.9 kg/m^2 BMI group. This study did not perform formal weight and height measurements to calculate participants' BMI; they were requested to select their BMI category on the questionnaire, which might have led to biased results.

Most participants were senior staff members (consultants and senior registrars) or had more than five years of experience in anaesthesia. Their prolonged indoor work could have contributed to developing chronic complications of vitamin D deficiency. However, as shown in Table II, more deficient levels occurred in the registrar group (both senior and junior) and participants with 5–10 years' experience in the field.

Of the 27 non-smokers in this study, 10 had vitamin D deficiency (Table IV). Although smoking increases the risk for vitamin D deficiency, no significant association was found in this group ($p = 0.39$).[14]

Three-quarters of participants indicated exposure to sunlight for less than one hour per day (Table III), the minimum amount of sun exposure needed to produce sufficient levels of vitamin D.[6] None of the participants indicated that they had more than three hours of direct sun exposure a day. An association was expected because sun exposure is the main contributor to vitamin D production. Participants might have been more exposed to sunlight than they noticed (driving to work or weekend outdoor activities). The questionnaire did not further probe sun exposure, and it was not objectively measured. The study was also conducted during the summer, with longer daylight time, increasing the potential of sun exposure. Most participants do not apply sunscreen daily (72.7%). Deficiency was higher in the group that did use sunscreen daily.

Only nine participants had previous vitamin D testing done, five of whom had previously been diagnosed with deficiency, while the remaining four had insufficient levels. Of the participants, 11 used dietary supplementation, eight took multivitamins, and three specifically used vitamin D supplements. Only five of these supplementations contained adequate amounts of vitamin D (> 600 IU/tablet/day, Table III). However, the deficiency prevalence increased as less supplemental vitamin D was taken, and a significant association might have been observed in a larger study population.

Nearly half of the participants (45.5%) had never considered their vitamin D status before the study, while a third started wondering in the preceding year (Table III). The questionnaire responses were limited and could have influenced the results.

Eggs were the most consumed vitamin D-containing food, followed by fortified dairy products and mushrooms. The least consumed food group was cod liver oil, with two participants indicating they did not know what it was. The lower intake of fish-based food could be attributed to the study population being from an inland province with limited access to fresh fish produce (Table III).

Study limitations

The study population was small, limiting the ability to significantly associate possible contributing factors with vitamin D deficiency. Age showed a significant association, but the lack of data among participants aged 40 years and older and the lack of powering of data restricted the interpretation. The study was conducted in summer with no comparative winter data. It is likely that a higher prevalence of deficiency will occur in winter.

The study population only consisted of doctors working in the public sector in Bloemfontein and did not include private sector practitioners or anaesthesia providers in other locations. Literature about the extent of deficiency is limited in this specific field of medicine. Furthermore, this study only focused on anaesthetists and did not include other medical specialities or axillary staff who may have similar deficiencies. Medication use, which could be a potential risk factor, was not considered.

The limited options provided on the questionnaire might have restricted it in an effort to increase compliance. Expansion of the questionnaire may yield improved responses and data distribution. Initially, the aim was to determine a correlation between vitamin D levels and risk factors as a secondary objective; however, this was not possible due to our small sample size and the inability to power the study due to variations in the size of the population during data collection.

Recommendations for future research

The study should be repeated during winter to assess the effect of seasons on this specific population. Other hospitals (including the private sector) in the province/country should be recruited to increase the study population and the data pool to determine associations between vitamin D deficiency and possible risks. Research can also be performed to investigate vitamin D deficiency symptoms in this population and its associated long-term complications.

Other branches of medicine can be approached to participate in a similar study to determine whether the entire medical community is at risk of developing deficiency, or if certain specialities are at higher or lesser risk (e.g. radiologists who exclusively work indoors and specialities working shorter hours indoors).

The questionnaire should be expanded to obtain more information regarding the risks of developing vitamin D deficiency. A follow-up study should be conducted to reassess the vitamin D status of department staff after they were exposed to an awareness campaign, such as the informational poster, to assess the effectiveness of this method in preventing vitamin D deficiency.

Conclusion

Anaesthetists in this academic hospital complex are at risk of developing vitamin D deficiency, with only one in five having sufficient vitamin D levels. The prevalence of deficiency was higher (39.4%) than previously reported in Chile (12%), the general population of the USA (24%), and South Africa (5–28%). The prevalence was in keeping with findings in European and Canadian studies. A potential association between vitamin D deficiency and an increase in age was observed, but adequately powered data are needed to make further conclusions. Thus, it is imperative to raise awareness regarding the signs, symptoms, and prevention of vitamin D deficiency amongst anaesthetists to prevent the consequences of long-term deficiency and related subsequent medical conditions.

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Conflict of interest

The authors declare no conflict of interest.

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Ethical approval

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ORCID

M Booyens https://orcid.org/0000-0002-2688-0208

BJS Diedericks https://orcid.org/0000-0003-2543-2996

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