Original research

Vitamin D levels in Portuguese Navy military personnel: a cross-sectional study

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ABSTRACT

Objectives Evaluate vitamin D levels in Portuguese active-duty Navy military personnel during winter and explore the relationship between Navy occupational settings and vitamin D levels, as well as between vitamin D levels and fatigue, sleep health, and burnout.

Methods All active-duty Navy military personnel who collected a blood sample at the Naval Medicine Centre during the winter of 2023–2024 were included in a cross-sectional study. Serum 25-hydroxy-vitamin D (25(OH)D), calcium, phosphorus and parathyroid hormone were added to their analysis request. They were asked to complete a questionnaire that included questions about work, sun exposure, vitamin D-rich foods and/or vitamin D supplements or medication intake, fatigue, sleep health and burnout. Blood samples were processed at the Clinical Pathology Service of the Portuguese Armed Forces Hospital. T-test/median test and z-test were applied to compare homologous means/medians and prevalences, respectively.

Results Of the 735 participants, 42.2%, 41.1% and 16.7% were vitamin D deficient, insufficient and sufficient, respectively. The median serum 25(OH)D level was significantly lower (p<0.001), and vitamin D deficiency prevalence was significantly higher (p=0.000) in 'onboard' and 'indoors' groups, as well as in the 'mixed shifts' group (p=0.030; p=0.004). Median serum 25(OH)D level was not statistically different between groups with and without fatigue, poor sleep health, and personal or work-related burnout.

Conclusions The high prevalence of vitamin D deficiency in a sample of Portuguese active-duty Navy military personnel, during winter, especially those working onboard, indoors and with mixed shifts, must be addressed by Navy occupational health services. Future research should include submariners.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Vitamin D's role in maintaining active-duty military personnel's health is a widely discussed research topic. The prevalence of vitamin D deficiency is high both in the Portuguese population and in Navy occupational settings; what about in the Portuguese Navy?

WHAT THIS STUDY ADDS

⇒ The prevalence of vitamin D deficiency was high in a sample of Portuguese active-duty Navy military personnel (significantly higher in 'onboard', 'indoors', and 'mixed shifts' groups); meanwhile, the prevalence of fatigue, poor sleep health and burnout was low.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Portuguese Navy occupational health services must implement new policies and review field practices to improve vitamin D levels in active-duty military personnel.

INTRODUCTION

War has returned to Europe recently, and military personnel's health is a significant concern. Active-duty service members face incredibly demanding physical and psychological stressors not generally experienced in typical civilian jobs. They can be healthier than the general population, but, paradoxically, they have a higher risk of fatigue, poor sleep quality and burnout.[1–3]

Vitamin D's role in maintaining skeletal and extra-skeletal health, including mental health, is still a common research topic.[4–6] The relationship between vitamin D and fatigue, sleep quality or burnout has been studied in recent years.[7–9]

Vitamin D deficiency prevalence in Portugal is high, and blood sample collection during winter is associated with a higher risk of deficiency.[10] Working indoors is also a well-known risk factor for vitamin D deficiency.[11] A previous study with Portuguese active-duty military personnel (n=1744) revealed a vitamin D deficiency prevalence of 34.6% (37.1% in 555 Navy military personnel).[12] Furthermore, a recent systematic review on vitamin D status in active-duty Navy military personnel reported a high prevalence of vitamin D deficiency in the Navy and proposed further research on this topic, as their occupational settings can be particularly detrimental to endogenous vitamin D synthesis.[13]

The (American) Endocrine Society recently published a new clinical practice guideline on vitamin D for disease prevention and no longer endorses the target 25-hydroxy-vitamin D (25(OH)D) level of 30 ng/mL nor does it endorse a specific 25(OH)D level to define vitamin D sufficiency, insufficiency and deficiency.[14] The Guideline Development Panel did not find clinical trial evidence supporting the establishment of distinct 25(OH)D thresholds tied to outcome-specific benefits in the populations examined.[14] Even so, Portuguese health authorities and laboratories still distinguish 25(OH)D levels as follows: deficiency (<20 ng/

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mL), insufficiency (≥20 ng/mL and<30 ng/mL) and sufficiency (≥30 ng/mL).[15]

The main objective of this study is to evaluate vitamin D levels in a sample of Portuguese active-duty Navy military personnel during winter. Besides that, it will explore the relationship between Navy occupational settings and vitamin D levels, as well as between vitamin D levels and fatigue, sleep health, and burnout.

METHODS

A cross-sectional study was conducted including all Portuguese active-duty Navy military personnel (inclusion criteria) who collected a blood sample at the Naval Medicine Centre between 22 December 2023 and 20 March 2024. Exclusion criteria included civilian or militarised personnel. Four blood parameters (serum 25(OH)D, calcium, phosphorus and parathyroid hormone (PTH)) were added to their analysis request. In addition, they were invited to complete a questionnaire. Personal data, such as sex, age, and military category (officer vs sergeant vs seaman), were retrieved from the analytical results form.

Questionnaire

An original questionnaire (online supplemental questionnaire S1) included questions about (1) the reason for carrying out analyses (occupational vs routine vs disease); (2) occupational setting (ashore vs onboard; indoors vs outdoors; day shift vs night shift vs mixed shift); (3) skin type (Fitzpatrick scale); (4) sun exposure (≥30 min, 09:00–15:00, wearing only a t-shirt and shorts, without sunscreen), vitamin D-rich food intake (eg, cod liver oil, fatty fish, oysters, liver, eggs, butter and/or milk fortified with vitamin D) and vitamin D supplements or medication intake (number of days in the last 30 days; 4-point Likert scale—0 days, 1–10 days, 11–20 days and 21–30 days); (5) fatigue (Fatigue Assessment Scale; considering fatigue if the score is ≥30, in 10–50 possible); (6) sleep health (Regulatory Satisfaction Alertness Timing Efficiency Duration; considering poor sleep health if the score is ≤6, in 0–12 possible); and (7) burnout (Copenhagen Burnout Inventory; personal and work-related dimensions; considering burnout if the score is ≥50, in 0–100 possible). The three scales used are validated for the Portuguese population.[16–18] Missing or duplicate responses were verified by email or phone.

Blood sample analysis

Blood samples were processed at the Clinical Pathology Service (Lisbon) of the Portuguese Armed Forces Hospital. Chemiluminescence was used to perform 25(OH)D and PTH assays on the Alinity equipment (Abbott; certified by the Centers for Disease Control and Prevention – Vitamin D Standardization-Certification Program). The o-cresolphthalein complexone and phosphomolybdate ultraviolet (UV) methods were applied to measure calcium and phosphorus levels, respectively, using the Cobas c501 equipment (Roche). The laboratory reference values for calcium, phosphorus and PTH ranged from 8.1 to 10.4 mg/dL, 2.7–4.5 mg/dL and 15–68.3 pg/mL, respectively.

Regarding the determination method of 25(OH)D serum levels, the Alinity i 25-OH Vitamin D Reagent Kit is a delayed one-step immunoassay using chemiluminescent microparticle immunoassay technology for the quantitative determination of 25(OH)D. This assay is standardised against the National Institute of Standards & Technology Standard Reference Material 2972 and the Clinical and Laboratory Standards Institute. Results were compared with those of isotope dilution liquid chromatography with tandem mass spectrometry for validation. The functional sensitivity of the assay is 3.5 ng/mL and the linearity through the measurement range is between 3.5 ng/mL and 154.2 ng/mL. The analytical specificity expressed through a percentage of cross-reactivity with other metabolites is 98.6%–101.1% for $25(OH)D_3$, 80.5%–82.4% for $25(OH)D_2$, 101.9%–189.2% for $24.25(OH)_2D_3$ and 71.4%–114.2% for $24.25(OH)_2D_2$. The cross-reactivity with the C3 epimer of $25(OH)D_3$ and $25(OH)D_2$ is 1.3% and 0.8%, respectively.

Statistical analysis

Categorical variables were presented as absolute and relative frequency, and continuous variables as mean and SD or median and IQR depending on whether they followed a normal or non-normal distribution confirmed with Kolmogorov-Smirnov and Shapiro-Wilk tests. The sample means comparison test (t-test) and the median test (also with Yates correction or with Bonferroni correction for multiple tests) were used to compare homologous means and medians, respectively. The U of Mann-Whitney (2 samples) or Kruskal-Wallis (>2 samples) non-parametric test for independent samples (also with Bonferroni correction for multiple tests) was used to compare distributions, being at least one of them non-normal. When statistically significant differences were found in median 25(OH)D values, a proportion comparison test (z-test) was used to compare homologous prevalences of vitamin D deficiency, insufficiency and sufficiency, according to the national definition. Pearson's correlation was used to evaluate correlations between continuous variables. The considered significance level was 5%. The program IBM SPSS Statistics V.29 was used for statistical analysis.

RESULTS

Overall, 735 Portuguese active-duty Navy military personnel (38.27±9.5 years old mean age; range 20–64 years old) were included in this study baseline (95.3% participation rate). Table 1 presents the distribution of study participants by personal characteristics and winter period.

In this sample, the median (IQR) [Min.; Max.] 25(OH)D, calcium and PTH levels were, respectively, 21.8 (16.3–27.5) [5.3; 65.4] ng/mL, 9.8 (9.6–10.0) [7.8; 10.9] mg/dL and 51.3 (37.8–65.4) [11.9; 144.0] pg/mL. Mean±SD [Min.; Max.] phosphorus levels were 3.23±0.45 [1.60; 5.10] mg/dL. Online supplemental table S2 includes parameter levels according to each personal characteristic and winter period. The median calcium and mean phosphorus levels significantly differed between males

Table 1 Study participants (n=750) distribution by personal characteristics and winter period

		N (%)
Gender	Male	651 (88.6)
	Female	84 (11.4)
Age	<30 years old	176 (23.9)
	30–39 years old	188 (25.6)
	40–49 years old	275 (37.4)
	≥50 years old	96 (13.1)
Category	Officer	159 (21.6)
	Sergeant	231 (31.4)
	Seaman	345 (46.9)
Winter period	22 December to 20 January	127 (17.3)
	21 January to 20 February	386 (52.5)
	21 February to 20 March	222 (30.2)

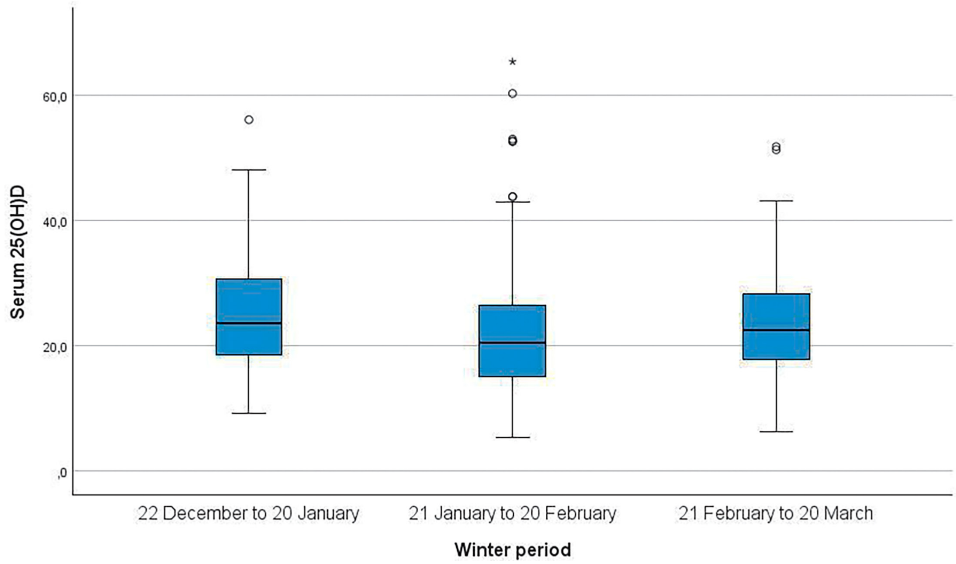

Figure 1 Distribution of serum 25(OH)D level by winter period. Box plots: the bottom and top of the box are, respectively, the 25th and 75th percentiles, and the horizontal line inside the box is the median (50th percentile). The lower and upper ends of the whiskers are the minimum and maximum, respectively, without outliers. Outliers and extreme outliers are marked with a circle and an asterisk, respectively. After Bonferroni correction for multiple tests (median test for independent samples), 25(OH)D median value was only statistically different between the '22 December to 20 January' and '21 January to 20 February' groups (p=0.007) and between the '21 January to 20 February' and '21 February to 20 March' groups (p=0.029).

and females (p<0.001; p=0.000). The median 25(OH)D level was significantly lower in the middle of winter (figure 1), and the median PTH level was significantly higher at the beginning of winter (p=0.000). The youngest group's median PTH value was significantly lower than all older group's median PTH value (p=0.000). PTH values were negatively correlated with 25(OH) D, calcium and phosphorus values, with statistical significance (p<0.001).

Considering vitamin D status, 310 (42.2%) had vitamin D deficiency (21 (2.9%) subjects with 25(OH)D <10 ng/mL) and only 123 (16.7%) had vitamin D sufficiency. Despite the difference between 25(OH)D median value of 'Sergeant' and 'Seaman' groups (p=0.021), there was no statistical difference in vitamin D deficiency, insufficiency or sufficiency prevalences. In the first third of the winter, vitamin D sufficiency prevalence was significantly higher, and vitamin D deficiency prevalence was significantly lower only than in the second third (table 2).

Of all participants, 609 agreed to complete the questionnaire (82.9% response rate). Table 3 presents the study participants' distribution by vitamin D-related occupational and personal characteristics. Most of them (83.9%) underwent testing for occupational purposes and only 33 (5.4%) reported a disease under study. Two (0.3%) work at night shift and none reported skin type VI on the Fitzpatrick scale.

Online supplemental table S3 presents parameter levels by vitamin D-related occupational and personal characteristics. The median 25(OH)D level was significantly different between the workplace (p<0.001), workstation (p<0.001) and work shift ('day shift' vs 'mixed shift'; p=0.030) groups, with lower levels observed in the 'onboard', 'indoors' and 'mixed shift' groups (figure 2). The median 25(OH)D level consistently increased with sun exposure and vitamin D-rich food intake. Concerning vitamin D supplements or medication intake, the '0 days' group's 25(OH)D value distribution was significantly different than in the other groups. The median PTH level was significantly different between workplace groups, with higher levels in the 'ashore' group. The median PTH level consistently decreased with sun exposure and vitamin D-rich food intake.

When merging workstation or work shift with workplace, a lower median 25(OH)D level was revealed in the 'onboard' groups compared with 'ashore' groups: indoors (19.0 ng/mL vs 22.8 ng/mL); outdoors (24.2 ng/mL vs 25.8 ng/mL); day shift (20.1 ng/mL vs 23.7 ng/mL); and mixed shift (18.9 ng/mL vs 24.3 ng/mL).

Concerning vitamin D status by vitamin D-related occupational characteristics (online supplemental table S4), in the 'onboard' group, vitamin D deficiency prevalence was significantly higher (p=0.000), and vitamin D sufficiency and insufficiency

Table 2 Vitamin D status by winter period (n=735)

Vitamin D status	Winter period 22 December to 20 January N (%)	21 January to 20 February N (%)	21 February to 20 March N (%)	P_1 value*	P_2 value*
Deficiency	39 (30.7)	185 (47.9)	86 (38.7)	0.002	NSD
Insufficiency	52 (40.9)	151 (39.1)	99 (44.6)	NSD	NSD
Sufficiency	36 (28.3)	50 (13)	37 (16.7)	0.000	0.030

P_1 = '22 December to 20 January' vs '21 January to 20 February'. P_2 = '22 December to 20 January' vs '21 February to 20 March'.
*Proportion comparison test (z-test).
NSD, no statistical difference between groups.

Table 3 Study participants (n=609) distribution by vitamin D-related occupational and personal characteristics

		N (%)
Workplace	Ashore	338 (55.5)
	Onboard	271 (44.5)
Workstation	Indoors	411 (67.5)
	Outdoors	158 (25.9)
	Unknown	40 (6.6)
Work shift	Day shift	293 (48.1)
	Mixed shift	302 (49.6)
	Night shift	2 (0.3)
	Unknown	12 (2.0)
Skin type	I	18 (3.0)
	II	136 (22.3)
	III	288 (47.3)
	IV	140 (23.0)
	V	18 (3.0)
	VI	0 (0)
	Unknown	9 (1.5)
Sun exposure	0 days	232 (38.1)
	1–10 days	286 (47.0)
	11–20 days	55 (9.0)
	21–30 days	36 (5.9)
Vitamin D-rich food intake	0 days	31 (5.1)
	1–10 days	452 (74.2)
	11–20 days	75 (12.3)
	21–30 days	51 (8.4)
Vitamin D supplements or medication intake	0 days	464 (76.2)
	1–10 days	84 (13.8)
	11–20 days	17 (2.8)
	21–30 days	42 (6.9)
	Unknown	2 (0.3)

prevalences were significantly lower (p=0.000 and p=0.003, respectively). In the 'indoors' group, vitamin D deficiency prevalence was significantly higher (p=0.000), and vitamin D sufficiency prevalence was significantly lower (p=0.001). In the 'mixed shift' group, vitamin D deficiency prevalence was significantly higher (p=0.004), and vitamin D insufficiency prevalence was significantly lower (p=0.040). Although there was no statistical difference in the median 25(OH)D value across 'vitamin D-rich food intake' groups, in the '21–30 days intake' group, vitamin D sufficiency prevalence was significantly higher than in the '1–10 days intake' group (p=0.036). In the '21–30 days intake of vitamin D supplements or medication' group, vitamin D sufficiency prevalence was significantly higher than in the 'no intake' group (p=0.002).

Online supplemental table S5 presents a more detailed analysis of vitamin D status by workplace, combining workstation or work shift with workplace. In the 'indoors' group, vitamin D deficiency prevalence was significantly higher in the 'onboard' group (p=0.000), and vitamin D insufficiency and sufficiency prevalences were significantly higher in the 'ashore' group (p=0.009 and p=0.005, respectively). In the 'mixed shift' group, vitamin D deficiency prevalence was significantly higher in the 'onboard' group (p=0.000), and vitamin D insufficiency and sufficiency prevalences were significantly higher in the 'ashore' group (p=0.030 and p=0.000, respectively). Even in the 'day shift' group, vitamin D deficiency prevalence was significantly higher in the 'onboard' group (p=0.001), and vitamin D sufficiency prevalence was significantly higher in the 'ashore' group (p=0.038).

The proportion of Portuguese active-duty Navy military personnel that revealed fatigue (2%; n=587), poor sleep health (11.7%; n=608), and personal or work-related burnout (8.5%; n=602 and 17.1%; n=608, respectively) was small, and none of these groups exhibited significant differences in the median 25(OH)D level compared with their counterparts (online supplemental table S6).

DISCUSSION

This study included a convenience sample of 735 subjects from the 6493 Portuguese active-duty Navy military personnel (11.3%; reference date 31 December 2023). As anticipated, males (88.6%) and younger personnel (86.8% with <50 years old) were predominant. Most of the participants were otherwise healthy and underwent testing for occupational purposes (eg, pre-mission). Among those who reported a disease under study, none had a direct relation to vitamin D metabolism, except for one pregnant woman. In the Portuguese Navy, working permanent night shifts is uncommon, and the number of Black ethnicity military personnel is probably low—skin pigmentation negatively influences vitamin D synthesis. In 2023, for the first time, ethnic self-identity was addressed in the Survey on Living Conditions, Origins, and Trajectories, and only 2.8% of the 4.8 million residents in Portugal with ages between 18 and 54 years self-identify with the Black ethnic group.

Vitamin D levels

The median serum 25(OH)D value was below 30 ng/mL considering all participants and across all characteristic subdivisions, and it was significantly lower in the middle of winter. Considering that cutaneous synthesis of vitamin D—the main vitamin D source—depends on exposure to solar ultraviolet B (UVB) photons and that vitamin D winter duration in Lisbon (Portugal) may vary over the years because of climate changes, it is important to crosscheck vitamin D and atmospheric data.[19] According to

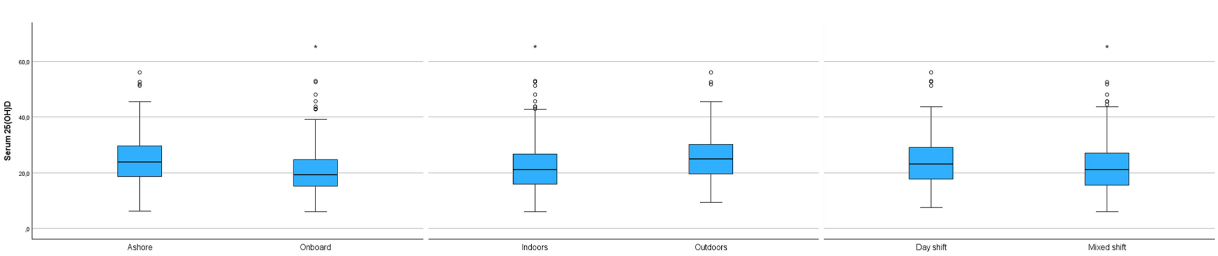

Figure 2 Distribution of serum 25(OH)D by workplace, workstation and work shift. Box plots: the bottom and top of the box are, respectively, the 25th and 75th percentiles, and the horizontal line inside the box is the median (50th percentile). The lower and upper ends of the whiskers are the minimum and maximum, respectively, without outliers. Outliers and extreme outliers are marked with a circle and an asterisk, respectively.

the Portuguese Institute of the Sea and Atmosphere, total energy from UVB radiation received throughout the day (measured in minimum erythema dose (MED); 1 MED=210 J/m^2) in Lisbon increased substantially after 17 January 2024 (online supplemental figure S7). However, we must take into account that the effect of sun exposure on circulating 25(OH)D levels has a time lag, and serum 25(OH)D has a half-life of 21–30 days.[20 21]

Vitamin D and PTH form a tightly regulated feedback cycle, and both play a crucial role in maintaining calcium and phosphate homeostasis: calcium and phosphorus serum levels were within reference intervals in 95.8% and 87.8% of the Portuguese active-duty Navy military personnel, respectively. The strength of the negative correlation between physiologically related hormones and/or electrolytes serum values was weak but statistically significant. We highlight the notable number of cases with PTH value above the reference interval (154 in 730; 21.1%), which may indicate a biological effort to improve calcium and vitamin D serum levels. Differences in median calcium, mean phosphorus and median PTH levels according to sex and/or age were found, as expected, according to previously published studies.[22 23]

Vitamin D status

The prevalence of vitamin D sufficiency in this Portuguese active-duty Navy military personnel sample was low (16.7%) and significantly higher at the beginning of winter. On the other hand, the prevalence of vitamin D deficiency was 42.2% (2.9% of subjects had serum 25(OH)D value <10 ng/mL). However, we must acknowledge that Portugal is among the countries with the highest prevalence of vitamin D deficiency. The estimated prevalence of vitamin D deficiency in the adult Portuguese population (2011–2013) during winter was 76% (prevalence of levels of 25(OH)D ≤10 ng/mL was 24.3%).[10] This reality underscores the need to implement occupational and population-wide interventions before and during winter, both at the individual and community levels.

Additionally, a previous study reported that Portuguese military personnel are not at higher risk of vitamin D inadequacy than civilians and that the prevalence of vitamin D deficiency during winter was not statistically different between active-duty Navy military personnel and civilians (60.7% vs 56.7%, but it was between active-duty Navy and Army military (60.7% vs 47.6%; p=0.017)).[12] Although we may assume a similar risk of vitamin D deficiency between civilians and active-duty Navy military personnel, considering adjustments applied for season, age and gender, and recognising the existence of a variety of similar occupations, some Navy occupational settings may pose a higher risk and should be specially addressed by Navy occupational health services.

For nonpregnant adults <50 years of age without established indications for vitamin D treatment, the (American) Endocrine Society's current guidelines suggest against empirical vitamin D supplementation, assuming that these adults follow the Recommended Daily Allowance (15 µg daily).[14] However, the estimated mean vitamin D dietary intake (excluding dietary supplements) in the Portuguese adult population (18–64 years old) is 3.54 µg/day, and only 5.7% have a vitamin D intake above 10 µg/day (estimated average requirement).[24] These findings advocate the need to implement vitamin D food fortification policies in Portugal. Despite this, to prevent vitamin D inadequacy, special attention should be given to people living/working indoors, especially during months near winter solstice. Even though the optimal level of 25(OH)D to prevent disease likely depends on the clinical outcomes being evaluated, 10 to 20 µg of vitamin D per day may be adequate to avoid clinical vitamin D deficiency and maintain calcium homeostasis in healthy individuals.[14 25] Vitamin D supplementation should be specific to age group, body weight and ethnicity (skin type).[25] Daily oral supplementation of cholecalciferol is the preferred method to supplement vitamin D as it is effective, simple and safe—cholecalciferol can maintain physiological serum 25(OH)D levels between 30 and 50 ng/mL for a long time due to its pharmacokinetic profile characterised by prolonged storage and release on demand according to physiological needs.[25]

For generally healthy adults without established indications for 25(OH)D testing, the (American) Endocrine Society's new guidelines do not recommend routine 25(OH)D level screening to guide decision-making about vitamin D supplementation, as well as routine 25(OH)D level follow-up testing to guide vitamin D dosing.[14] However, people working long hours indoors are still at risk of vitamin D deficiency according to a clinical approach that probably counteracts the downward trend on screening in the general population, as it is not informative and has a considerable economic burden.[25] So, rather than test in all situations that can be reasonable, it may be better to test only high-risk individuals.[25] In the Portuguese Navy, there are various indoor occupational settings (eg, submarines vs warships vs office), and, especially for the submariners, 25(OH)D level screening should be considered case by case. Among the Portuguese active-duty Navy military personnel, we may admit the excuse of 25(OH)D testing if empirical vitamin D supplementation became generalised, as it is a safe treatment—vitamin D toxicity prevalence is so rare that there is no explicit cut-off value above which it occurs and below which it does not—with no need for routine monitoring for long-term maintenance vitamin D doses of ≤50 µg/day.[25] Unfortunately, an expressive number of participants reported no vitamin D supplements or medication intake.

Vitamin D levels and Navy occupational settings

In this study, the median 25(OH)D level was significantly lower among indoor workers (as well as onboard workers, indeed because 86.9% of them were also indoor workers) and in mixed shift workers (65.8% of mixed shift workers were also indoor workers; as were 78.2% of day shift workers) as found in recent systematic reviews.[11 26] Vitamin D deficiency prevalence was also significantly higher in the 'onboard', 'indoors' and 'mixed shift' groups. On the other hand, the median 25(OH)D level increased consistently with sun exposure and vitamin D-rich food intake. It was statistically higher with vitamin D supplements or medication intake ('21–30 days' vs '0 days'). The same pattern was generally shown for vitamin D sufficiency prevalence. That is why these three recommendations—sun exposure, dietary intake and supplementation—in sequence or preferably together, should be taken into account for the Portuguese active-duty Navy military personnel who are usually integrated into indoor occupational settings, despite the workplace and the kind of shift work. The use of low-dose UVB exposure using a home-based lighting solution to maintain healthy serum 25(OH)D in indoor workers may also be an option in the future.

Onboard workers should be addressed specifically in the Portuguese Navy occupational health service recommendations regarding vitamin D intake, knowing that they presented a lower median 25(OH)D level, as well as a significantly higher vitamin D deficiency prevalence among indoor workers and mixed shift workers. It is crucial to remember that these personnel often live 24/7 aboard warships or, more critically, in submerged submarines. Future studies should focus on submariners.

Vitamin D levels and fatigue, sleep health or burnout

In this study, very few Portuguese active-duty Navy military personnel reported fatigue, poor sleep health, and personal or work-related burnout, so it was difficult to establish any relation with serum 25(OH)D levels. Notably, active-duty service members are exposed to job demands that result in physical, mental and emotional fatigue in each one of the four broad military work settings revealed by crossing deployment status (non-deployed vs deployed) and mission type (combat vs non-combat).[1 27] They are also especially prone to sleep loss and sleep disruption, in both operational and non-operational times, due to several occupational, cultural and psychosocial factors—this population tends to sleep less and have poorer sleep quality than the general civilian population.[28] Previous studies have documented pronounced levels of poor sleep quality and sleep problems, which convince military leaders to value sleep along with physical activity and nutrition (eg, US Army's Performance Triad) because they recognise that without adequate sleep, service member's health and performance, and, ultimately, the mission may be compromised.[2 29] Last but not least, previous studies confirmed that they are vulnerable to burnout (high burnout prevalence ranged from 0.9% to 40%) due to the high-pressure nature inherent in their profession, characterised by long working hours, heavy workloads and a high level of responsibility.[3 30] For example, the prevalence of burnout syndrome among Royal Thai Navy male ship officers (n=424) was 22.4% (Maslach burnout inventory—Thai version), with younger and lower ranked ship officers at higher risk, and the prevalence of moderate to high degree of job burnout in Iranian Navy personnel (n=130) was 65.3% (standard Goldard questionnaire).[31 32]

Vitamin D administration has been reported to be associated with improvements in fatigue across various populations. However, scarce data on the impact of supplementation on fatigue as an outcome have been collected until now, despite documented evidence of a positive response to vitamin D supplementation in multiple sclerosis patients experiencing fatigue.[33 34] The literature evidence suggests a beneficial role of vitamin D supplementation in enhancing sleep quality, but its effect on sleep disorders remains to be explored in future adequate studies.[35] McCarthy *et al* observed a significant improvement in fatigue ($p<0.001$) and sleep ($p=0.01$) with vitamin D supplementation in active-duty warfighters.[36] In the military, fatigue assessment as a measure for overuse injury prevention, with special attention to vitamin D biomarkers, is a recent research topic.[37 38] Although there is some evidence that vitamin D supplementation may reduce depressive symptoms and a relationship between depression and burnout is often assumed, supplementation of vitamin D, with or without calcium, was not associated with overall burnout or any of its dimensions in anaesthesiologists.[39–41] Future studies should investigate this relationship in military populations.

Study strengths and limitations

This is the first study addressing the vitamin D levels in Portuguese active-duty Navy military personnel. However, it is based on a convenience sample, which is not representative of the entire population, and is limited to a single blood test conducted during winter, so it does not reflect long-term vitamin D status. Other limitations that should be considered include the respondents' attention, as seven participants answered 'never' to all fatigue-related questions, despite two of them being inversely coded, and recall bias, as the questionnaire required participants to recall information about sun exposure, vitamin D-rich food intake and vitamin D supplements or medication intake over the past 30 days.

CONCLUSIONS

During the winter, a sample of Portuguese active-duty Navy military personnel had a median serum 25(OH)D level below 30 ng/mL, with a vitamin D deficiency prevalence of 42.2%. The median serum 25(OH)D level and the prevalence of vitamin D deficiency were significantly different across workplace, workstation and work shift groups, with the worse values observed in the 'onboard', 'indoors' and 'mixed shift' groups. The low prevalence of fatigue, poor sleep health and burnout in this sample prevented the exploration of possible relationships with vitamin D levels. Portuguese Navy occupational health services must implement measures to promote optimal vitamin D levels for all military personnel. Future research should focus on submariners.

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Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and the study protocol was approved by the Public Health National School (n.º 11/2022, 19 April 2023) and Portuguese Armed Forces Hospital (n.º 04/2022, 6 December 2022) Ethical Committees. Participants gave informed consent to participate in the study before taking part.

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