COMMENTARY

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Vitamin D Deficiency in the Military: It's Time to Act!

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ABSTRACT Vitamin D is critically important to numerous physiologic functions, including bone health. Poor vitamin D status is a common but underrecognized problem that predisposes the military population to stress fracture and completed fracture. This has significant implications for force health protection, warfighter readiness, attrition, and cost. Despite this, vitamin D deficiency is still underdiagnosed and undertreated in the military. This is a major hindrance to military readiness and one that could easily be modified with awareness, prevention, and early treatment. In this commentary, we review the literature on vitamin D deficiency and critically examine the current status of policies and clinical practice related to vitamin D in the military health system. We offer several practical recommendations to increase awareness and readiness while decreasing musculoskeletal injury and the associated costs.

INTRODUCTION

Stress fractures are a significant burden to the military due to frequency, cost, and impact on readiness. These injuries affect military recruits at significant rates, much higher than their civilian counterparts, causing delays in training completion, increased healthcare expenditures, and attrition from military service. Among basic trainees, stress fractures account for more lost duty days and delays in the completion of training than any other training-related injury. Low vitamin D status has been identified as an important modifiable risk factor for the development of these stress injuries. Although numerous published studies have suggested vitamin D and calcium supplementation as a potential strategy for stress fracture prevention, military awareness and policy have remained generally unchanged.

The purpose of this commentary is to summarize the literature on vitamin D deficiency and stress fractures as it pertains to the military population, critically examine the current status of policies and clinical practice related to vitamin D in the military health system, and provide practical recommendations to improve the health and readiness of our forces.

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SIGNIFICANCE OF VITAMIN D

Vitamin D, or calciferol, is critical to the normal function of multiple organ systems within the body. Notably, it is essential for maintaining skeletal health and bone mineralization through its effects on calcium and phosphate levels and bone remodeling.[1] The skeletal manifestations of poor vitamin D status are widely recognized in disorders of bone mineralization, including rickets and osteomalacia, and have also been implicated in diseases of low bone density, including osteopenia and osteoporosis.

Vitamin D is primarily derived from sun exposure and secondarily obtained in the diet. For most healthy individuals 1-70 years old, the recommended daily allowance is 600 international units (IU), which represents the average daily intake needed to maintain nutrient adequacy.[2] The two main forms of vitamin D found in food and dietary supplements are ergocalciferol (vitamin D_2) and cholecalciferol (vitamin D_3), whose chemical structures differ slightly. There is some evidence to suggest that cholecalciferol is more efficacious than ergocalciferol at raising serum 25-hydroxyvitamin D levels.[2] Although both forms are available in over-the-counter preparations for supplementation, only ergocalciferol is available in a prescription formulation in the USA. Toxicity is exceedingly rare and not seen at dosages routinely prescribed. An adult patient would need to take in excess of 10,000 IU/day for months or years to reach toxic levels.[1]

Vitamin D levels are generally considered to be sufficient if serum 25-hydroxyvitamin D (25(OH)D) is $\geq$30 ng/mL. 20-29 ng/mL is considered insufficient and <20 ng/mL is deficient,[2] although leading scientific and medical societies have varied opinions on the clinical definitions of poor vitamin D

status.[1] These ranges were largely established in the context of metabolic bone disease, and it is important to note that optimal serum concentrations of 25(OH)D for bone and general health have not been clearly established, especially for populations that may have increased requirements due to intense training or operational demands.

SCOPE OF THE PROBLEM

The powerful combination of medical attrition and long duration of rehabilitation have made stress fractures the single most costly injury of military training. Direct medical costs include diagnostic studies such as radiographs and MRI, medical equipment, monitored physical therapy and rehabilitation programs, and surgical treatment. Indirect costs include unrecouped costs for discharged recruits, basic pay while in a limited duty status, and disability payments for medically discharged personnel. A 1997 report evaluating musculoskeletal training injuries of recruits at Marine Corps Recruit Depot San Diego found that the annual cost of stress fractures was in excess of $5M.[3] After adjusting for inflation and extrapolating to the estimated 180,000 enlisted recruits in the Army, Navy, Air Force, and Marine Corps, the estimated cost to the DoD is approximately $74.5M annually.

Even beyond the staggering financial implications, the personnel cost is a significant challenge for a volunteer military that prioritizes retention and readiness. In Marine Corps recruits, stress fracture was the most powerful predictor for discharge before completion of basic training, with a 4-fold higher risk compared to uninjured recruits.[4] Similarly, in the U.S. Army, 60% of trainees that develop a stress fracture attrite from the military.[5] Those that stay face the challenge of training delays that are often longer than the basic training program itself. A study of Royal Marines showed that rehabilitation time ranged from 12 to 21 weeks on average, depending on the site of fracture.[6] Even after successful rehabilitation, 10.6% will develop another stress fracture within 1 year, a five-time greater risk compared to their uninjured counterparts.[6]

The risk of stress fractures is known to be high in the military, with a disproportionate impact on trainees and females. Stress fracture rates have been reported as up to 5.2% of male recruits and 21.0% of female recruits.[7] Many attribute this risk to the rigorous physical demands of military training and low baseline fitness levels among accessions; however, poor vitamin D status has been noted as the most important modifiable risk factor.[8,9]

In Finnish military recruits, Ruohola et al. reported that recruits with serum 25(OH)D level below the median of 30.4 ng/mL were 3.6 times more likely to sustain a stress fracture.[8] Burgi and colleagues helped clarify this relationship with a matched nested case–control study of female Navy recruits with tibial stress fractures, finding that there was an inverse dose–response relationship between serum 25(OH)D levels and risk of stress fractures. Recruits with 25(OH)D levels <20 ng/mL had double the risk of stress fractures compared to those with levels ≥40 ng/mL, leading to the recommendation that a higher target vitamin D level may be more appropriate for stress fracture prevention.[9]

This association between low serum 25(OH)D and stress fracture was affirmed in a systematic review and meta-analysis by Dao et al. Across eight studies examining 2,634 military personnel with 761 cases of stress fractures, the mean serum 25(OH)D level was significantly lower in stress fracture cases compared with controls.[10]

Lappe et al. performed a double-blind, placebo-controlled, randomized clinical trial to investigate the effect of calcium and vitamin D supplementation on stress fracture incidence. 5,201 female Navy recruits were allocated to receive either a supplement with 2,000 mg calcium and 800 IU vitamin D daily or placebo. At the conclusion of the trial, the calcium and vitamin D group had a 20% lower incidence of stress fractures than the control group. In generalizing their results to the entire population of 14,416 female Navy recruits that entered basic training during the 2 years of recruitment, they estimated that calcium and vitamin D supplementation would have prevented 187 recruits from fracturing.[7]

Given the importance of vitamin D for bone health, it should come as no surprise that its impact on stress fractures is not limited to fracture risk and prevention but also extends to bone healing and remodeling. Low serum vitamin D levels have also been linked to a longer duration of recovery from stress fractures in British Army recruits.[11] Despite these documented detrimental impacts, deficiencies are common in the military population. A study of female Army recruits found that 57% entered basic training with vitamin D deficiency or insufficiency. Surprisingly, these levels further decreased during basic training in the summer/autumn months in Southeastern USA, with a staggering 75% of subjects having low vitamin D levels by the end of basic combat training.[12]

Although popular media attention on the "sunshine vitamin" has increased public awareness, it has also created a need to address misconceptions about sun exposure as an important source of vitamin D. Cutaneous synthesis from sun exposure is affected by many host and environmental factors including skin tone and melanin content, age, sunscreen use, season, time of day, latitude, and air pollution.[1] Service members face many barriers to getting adequate vitamin D through sun exposure, including sunscreen use and inadequate body surface area exposed due to uniform requirements. Many primarily work in indoor environments or other settings sheltered from sunlight (e.g., submarines or compartments of ships). Furthermore, one-third of the military's basic training sites are located above 37°N latitude, which precludes any cutaneous vitamin D production in the winter months.

Unfortunately, it is very difficult to compensate for suboptimal sunlight with diet alone. There are few foods that naturally contain vitamin D, some of which include fatty fish,

fish liver oils, and mushrooms. In the USA, most dietary consumption of vitamin D is from fortified foods such as dairy milk, various plant milk alternatives, breakfast cereals, and margarine.[2] Despite the availability of fortified foods in military dining facilities, obtaining enough vitamin D in the diet can be challenging. A recent study by Lutz and colleagues found that military recruits are only consuming a fraction of that recommendation, with a mean intake of 182 and 136 IU in male and females, respectively. By comparison, recruits had relatively better consumption of calcium, which is another nutrient critical to bone health. On average, male recruits met the recommended daily allowance of 1,000 mg, while female recruits only consumed about 75% of the calcium required.[13] This highlights the challenge of meeting nutrient requirements to support bone health through diet alone, even when menu offerings are regulated to ensure nutritious meals are provided. Given these nutritional shortfalls, a more pragmatic approach may be required to ensure military personnel can maintain bone health and improve operational readiness.

RECOMMENDATIONS

Vitamin D deficiency and insufficiency are common and may predispose the military population to bone stress injury and completed stress fracture secondary to the demands of military training and operations. This imposes a significant financial and personnel cost and impairs the health and readiness of our forces. Fortunately, these negative impacts can be reversed with awareness, prevention, and early treatment. Based on the currently available evidence reviewed above, we offer several practical recommendations to increase awareness of vitamin D, improve military health practices, and pivot towards the prevention of vitamin D deficiency and associated stress fractures.

Lifestyle Modifications to Improve Bone Health in Individuals

We recommend 20 minutes of sun exposure daily to the arms and legs, ideally in the mid-day hours, when training and operational environment permits. Cutaneous synthesis from sunlight can be the most convenient and effective way of boosting vitamin D, as exposure of both arms and legs to the sun for 5-30 minutes in the late morning to early afternoon without sunscreen can produce approximately 3,000 IU of vitamin D.[2] Beyond cost and availability, skin-produced vitamin D has major advantages over ingested vitamin D. First, it lasts at least twice as long in the blood compared with ingested vitamin D. Additionally, any excess vitamin D or vitamin D precursors synthesized in the skin are destroyed by sunlight, a convenient safety feature that prevents vitamin D intoxication from excessive sun exposure.

We encourage the consumption of foods rich in vitamin D as part of a balanced diet. Given the relatively meager list of foods containing vitamin D, dietary modifications alone may provide some improvement in vitamin D intake but are unlikely to solve the problem for most people.

It is important to recognize the practical limitations of these strategies. As mentioned previously, sun exposure may be inadequate or unfeasible for service members in many locations and operational settings; and dietary changes have a lower relative impact, given the small quantities of vitamin D in foods. Therefore, lifestyle modifications are better thought of as useful adjuncts for individuals, rather than an appropriate population health strategy for the military.

Routine Supplementation for Military Personnel

For all military personnel, we encourage routine vitamin D consumption of at least 600 IU daily through the diet to meet the recommended daily allowance. When personnel cannot consume at least 600 IU/day, dietary supplementation may be recommended at levels below the tolerable upper limit of 4,000 IU/day. It is worth noting that dietary supplementation below these levels is well tolerated, has a low risk of toxicity, and may even be necessary to achieve and maintain desired levels.[1] The Endocrine Society clinical practice guidelines state that for adults to raise the blood level of 25(OH)D consistently above 30 ng/mL, it may require at least 1,500-2,000 IU daily of vitamin D, and supplementation with these larger doses is considered safe up to the tolerable upper limit, which should not be exceeded without medical supervision.[2] The Army has introduced the "Performance Readiness Bar," a snack item containing supplemental calcium and vitamin D (approximately 1,000 mg/day and 2,000 IU/day, respectively) to be consumed once per day by all basic combat training recruits. Although data regarding the impact of this intervention on stress fracture incidence are not yet available, similar interventions should be considered across the services if the product demonstrates efficacy.

Standardize Treatment Protocol for Low Vitamin D

When identified on laboratory tests, it is important to treat vitamin D deficiency and insufficiency (25(OH)D levels <30 ng/mL) according to the standard of care. We recommend treating with a prescription of ergocalciferol 50,000 IU weekly for 12 weeks and then rechecking 25(OH)D to ensure adequate repletion. After achieving adequate levels, we recommend maintenance supplementation of 1,500-2,000 IU/day.

Although other regimens have been described in the literature, we prefer this regimen for military personnel based on the ease of weekly dosing, availability in military pharmacies, and the available evidence, suggesting that regimens with at least 600,000 IU (total treatment dose) are most effective in achieving vitamin D sufficiency.[14]

Screening at Entry to Military Service

We recommend screening 25(OH)D levels for all recruits entering military service. Currently, serum 25(OH)D testing is not routinely performed on new military accessions,

either at Military Entrance Processing Stations (MEPS) or upon medical in-processing at basic training.

Various clinical societies and public health task forces have not yet recommended universal population-based vitamin D deficiency screening for the U.S. population; however, they have recommended screening for at-risk groups and individuals. Based on what we know about the incidence and impact of poor vitamin D status in the military, it is time to recognize military recruits as a high-risk population warranting screening measures. Furthermore, the risk–benefit ratio of 25(OH)D screening is considerably different for military recruits than it is for the general civilian population. For the military health system, the test is inexpensive, easy to perform, and actionable. Risks to the recruits and the training environment are minimal, as a 25(OH)D assay can be "added on" to the list of tests performed on blood samples obtained during routine medical in-processing, without requiring any additional blood specimens. The potential benefits to individuals and the military include addressing the most potent modifiable risk factor for stress fractures, with subsequent effects on fracture-related training delays and attrition.

For the military health system, a screening protocol offers the potential for significant cost savings. At the authors' military treatment facility, a 25(OH)D assay can be added on to a recruit blood sample for just $4.10 per person (Division of Laboratory Medicine, personal communication, September 2020). Similarly, a prescription of ergocalciferol 50,000 IU weekly for 12 weeks costs just $3.96 (Composite Health Care System (CHCS) prescribing information, September 2020). If all enlisted trainees were screened at the outset of basic training and half were found to have low vitamin D requiring treatment, the total cost would come to just under $1.1M. If optimizing vitamin D status has even a 1.5% reduction in stress fractures, this strategy will prove to be cost-effective.

To further increase the impact of a preventive approach, it may be worthwhile to consider a population health initiative starting at Military Entrance Processing Stations (MEPS), whereby low vitamin D status could be identified even earlier, and recommendations for improving bone health could be offered before starting formal training. This has the potential to dramatically decrease the rate of stress fractures in the military recruit population by addressing a major risk factor before training begins and raise bone health awareness in the greater population.

In official guidance on medical standards for entry into service, the DoD policy is to ensure that individuals considered for induction to the military services are medically capable of completing required training and free of medical conditions that may reasonably be expected to require excessive time lost from duty or may result in separation for medical unfitness.[15] Although vitamin D deficiency is not a disqualifying condition, we have described how it could lead to disqualification or attrition due to secondary stress fracture after starting training. For these reasons, it is important to perform screening at least as early as recruit training.

TABLE I. Summary of Recommendations to Address Poor Vitamin D Status within Military Personnel

Encourage routine vitamin D supplementation (below the tolerable upper limit of 4,000 IU/day) for all military personnel that do not consume a minimum of 600 IU/day through the diet.
Recommended treatment protocol for deficiency: ergocalciferol 50,000 IU for 12 weeks and then recheck 25(OH)D.
Recommend 25(OH)D screening for all recruits entering military service. If deficient, treat as per standard of care.
Implement a DoD-wide "Strong Bones" campaign to increase awareness of vitamin D and bone health and avoid preventable musculoskeletal injuries.

Implement a "Strong Bones" Campaign

We recommend a military-wide "Strong Bones" campaign to raise awareness of vitamin D, calcium, and overall bone health and their role in preventable musculoskeletal injuries. As an effective tactic used in many public health campaigns, we propose a simple slogan with service-specific language like "A Strong Marine needs Strong Bones," which is memorable and appealing irrespective of age, rank, or demographic variables. The campaign will aim to increase the knowledge of bone health across the entire DoD and provide targeted outreach and education for high-risk groups or commands, such as basic training sites. Through education and advocacy, we hope to increase recognition and understanding of vitamin D deficiency and empower better-informed decisions from top-level policymakers and military leaders, all the way to individual service members at the front line of operational readiness.

IT'S TIME TO ACT!

Given what we know about vitamin D, and specifically how deficiency of this crucial vitamin is a detriment to operational readiness, it is time to acknowledge the ample supporting evidence and implement change. In Table I, we list several practical recommendations that could be employed immediately and result in rapid and lasting positive change and substantial cost savings to the military. Of particular note is the recommendation to implement a "Strong Bones" campaign to increase awareness of preventable musculoskeletal injury throughout the DoD, increase operational readiness through the prevention of stress fractures, and decrease the substantial monetary and personnel costs associated with vitamin D deficiency and bone injury. It's time to act!

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CONFLICT OF INTEREST STATEMENT

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