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Prevalence of Vitamin D Deficiency in Military Dependent Infants in Hawai'i

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Abstract

This study aimed to determine the prevalence of vitamin D deficiency and insufficiency among military dependent infants in the state of Hawai'i. A cross-sectional study was conducted at Tripler Army Medical Center and included samples from 30 healthy, full-term infants around 4 months of age. Serum 25-hydroxyvitamin D levels were measured, and caregivers completed questionnaires about the infant's diet, vitamin D supplementation, race/ethnicity, and military sponsor pay grade. Results revealed that 90% of infants had sufficient vitamin D levels (>20 ng/mL), with 3% deficient and 7% insufficient. The prevalence of deficiency and insufficiency was comparable to studies conducted in other regions of the United States. This is the first study to investigate infant vitamin D status in Hawai'i using serum 25-hydroxyvitamin D. Vitamin D status varied significantly by race/ethnicity. The average vitamin D level of Black or African American infants was in the insufficient range and was significantly lower than that observed in White/ Caucasian and Hispanic infants. Notably, several exclusively breastfed infants who did not receive vitamin D supplementation had sufficient vitamin D levels. While study limitations include a small sample size and cross-sectional design, the findings warrant continued investigation into the prevalence of vitamin D deficiency and insufficiency among military dependent infants in Hawai'i. Future research should explore the influence of race/ethnicity and socioeconomic status on infant vitamin D levels in Hawai'i and consider the impact of maternal vitamin D status, especially in exclusively breastfed infants. This could lead to more targeted vitamin D supplementation recommendations in clinical practice and potentially improve resource allocation.

Abbreviations and Acronyms

AAP = American Academy of Pediatrics
AI = adequate intake
EAR = estimated average requirement
IU = international units
RDA = recommended dietary allowance
TAMC = Tripler Army Medical Center
UV = ultraviolet
25(OH)D = 25-hydroxyvitamin D

Introduction

Vitamin D plays a critical role in calcium absorption, bone development, and the prevention of nutritional rickets.[1–5] In 2008, the American Academy of Pediatrics (AAP) published a clinical report recommending that all infants receive 400 international units (IU) of vitamin D daily, either through vitamin D-fortified formula or oral supplementation for exclusively breastfed infants. These recommendations were based on clinical evidence and historical safety data, emphasizing the importance of considering factors such as skin pigmentation and geographic location, as infants with darker skin or those living at northern latitudes showed higher rates of vitamin D deficiency rickets.[1] In 2012, AAP endorsed updated recommendations from the National Academy of Medicine, which continued to support an adequate intake (AI) of 400 IU/day for infants under 12 months.[3] For this age group, the report cited insufficient evidence to establish an estimated average requirement (EAR) or recommended dietary allowance (RDA), so experts used an AI level instead. In contrast, for children aged 1 to 18 years, evidence supports the establishment of both an EAR and RDA, resulting in higher recommended daily intake levels.[3] While current guidelines prioritize dietary supplementation due to the risks associated with excessive sun exposure, most vitamin D is typically synthesized in the skin after ultraviolet (UV) radiation.[1,3,6]

Despite abundant sun exposure in Hawai'i, studies have identified a high prevalence of vitamin D deficiency among adults living in the state.[7–9] A high prevalence of neonatal vitamin D deficiency has also been implicated by a 2013 study at Tripler Army Medical Center (TAMC), which found that only 7% of cord plasma 25(OH)D (25-hydroxyvitamin D) samples from military dependent newborns met the recommended vitamin D levels.[10] While cord blood reflects maternal vitamin D status, it has not been found to reliably predict infant serum levels or long-term vitamin D sufficiency.[10–12] Multiple studies have investigated infant vitamin D status in the United States (US) by measuring serum 25(OH)D, but most were conducted in areas of low UV index such as the Midwest or Northeast.[13–16] A higher UV index is associated with increased cutaneous vitamin D synthesis.[17] Another study measured serum 25(OH)D in infants 6-19 months of age in an area of relatively higher UV index – Sacramento, California.[18,19] No study has yet investigated the prevalence of vitamin D deficiency in infants living in Hawai'i by measuring serum 25(OH)D.

The potential consequences of vitamin D deficiency, which include fractures and rickets, underscore the importance of preventive measures.[4] Although no cases of infantile vitamin D deficiency rickets have been reported in Hawai'i, it is routine practice at TAMC to prescribe oral vitamin D supplementation to all newborns. This practice follows national guidelines, despite unknown parental adherence to vitamin D supplementation. A 2020 study showed that up to 73% of US parents do not administer vitamin D supplements to their infants as advised.[20]

The utility of routine supplementation has recently been challenged. A 2023 randomized controlled trial involving Mongolian children aged 6 to 13 years found no difference in fracture rates between children who received vitamin D supplements and those in the placebo-supplementation group.[4] Combined with low adherence, the lack of vitamin D deficiency-related rickets in Hawai'i, and abundant sun exposure, this raises doubts about the effectiveness and necessity of universal supplementation in the infant population.

To inform future clinical decision-making and resource distribution, this study aims to determine the prevalence of vitamin D deficiency among military dependent infants in the TAMC patient population. TAMC pharmacy purchases vitamin D drops so that supplementation may begin at birth, then transitions that cost to TRICARE, the US military's health care program, after the first bottle. At $6.24 per bottle and an average of 115 deliveries each month, TAMC and TRICARE, spend approximately $8800 and $63 000, respectively, on annual vitamin D supplements for infants of military families born in the state of Hawai'i. Annual medical funding at TAMC is $420 million, so the cost of vitamin D supplementation accounts for less than 1% of TAMC's medical budget but is still an important consideration in terms of cost efficiency. Understanding the local vitamin D status is crucial for evaluating the value and necessity of this practice.

The study population is unique due to its connection with the US military. All participants in this study were dependents of an active-duty military service member. A legal guardian or caregiver with military sponsor status makes an infant eligible for TRICARE and qualifies them to receive care at TAMC. All military service members are assigned a pay grade based on their rank. Pay grades are standardized across all military branches as enlisted (E1-E9), warrant (W1-W5), or officer (O1-O10), with pay increasing at each higher grade or rank. Enlisted service members typically join the Army with a high school diploma, while officers are college graduates who receive a commission; this key educational distinction separates enlisted personnel from officers. Warrant officers, positioned between enlisted members and officers, are technical experts who are usually promoted from the enlisted ranks and receive specialized leadership training. Pay grade was ultimately included in the questionnaire as a proxy for socioeconomic status. The caregiver who completed the survey may or may not have been the military sponsor whose pay grade was recorded.

Methods

Study Design: This study employed a cross-sectional design to investigate vitamin D levels in military dependent infants at TAMC at approximately 4 months of age. The study protocol was approved by the Madigan Army Medical Center Institutional Review Board, approval #224073. Investigators adhered to the policies for protection of human subjects as prescribed in 45 Code of Federal Regulation 46.

Study Participants: A total of 40 infants were recruited and consented at the TAMC General Pediatrics Clinic during routine well-child visits between May 2024 and April 2025. Exclusion criteria included a history of prematurity (<37 weeks of gestation), birth weight less than 2000 grams, chronological age less than 3.5 months or greater than 4.5 months at the time of blood sample collection, presence of a chronic disease, or use of medications known to affect vitamin D metabolism during the first 4 months of life. Recruitment typically occurred on the same day as consent and sample collection. Most often, pediatric providers at TAMC who were not members of the research team would mention the study to their patients, and if they expressed interest the provider would notify the research team prior to the patient being discharged from the clinic. A research team member would then present to the clinic to discuss the study further in person. In a few cases, recruitment occurred days or weeks prior to the well-child visit via caregiver outreach using contact information included in the study advertisement flyer. Consent and sample collection occurred on the same day regardless of the recruitment method, during or after completion of the well-child visit. After sample collection, 8 infants were excluded due to inadequate blood samples for laboratory analysis. Additionally, 2 more infants were excluded due to laboratory processing errors. A total of 30 infants had adequate blood samples and were included in the final data analysis.

Clinical Data: The investigators conducted a chart review of the participant's medical records to gather clinical information, including the infant's age in days, sex, birth weight, and estimated gestational age at birth.

Laboratory Measurements: A single blood sample (0.5 mL was collected from each participant in the TAMC General Pediatrics Clinic treatment room. The TAMC Core Laboratory measured serum levels using the Abbott Architect assay. Investigators reviewed the participants' medical records to obtain lab results and communicated the findings to caregivers by phone.

Nutritional and Demographic Data: At the time of sample collection, participants' caregivers completed a questionnaire through the institutional version of the online survey tool SurveyMonkey (SurveyMonkey, Inc, San Mateo, CA). The questionnaire collected information about the infant's diet (exclusive breastfeeding, formula feeding, or a combination), frequency of vitamin D supplementation, race/ethnicity, and the military sponsor's pay grade. If an infant had more than one caregiver who qualified as a military sponsor, the higher pay grade was recorded. Caregivers classified the infant's race/ethnicity using predefined categories: American Indian or Alaskan Native, Asian/Pacific Islander, Black or African American, Hispanic, White/Caucasian, Multiple Ethnicity/Other. The study collected racial and ethnic data following current pediatric guidelines, which recommend considering skin pigmentation in vitamin D supplementation practices for infants, due to the higher prevalence of rickets from vitamin D deficiency among infants identified as Black.

Results

A total of 30 subjects provided sufficient blood volume for analysis (**Table 1**). The most frequently reported diet was exclusive breastfeeding (n=12, 40%), while the remaining subjects were evenly divided between formula-fed (n=9, 30%) and combination formula-breastfed (n=9, 30%). Among caregivers, 25% reported providing the recommended daily vitamin D supplementation, whereas 40% reported providing no supplementation.

The most frequently reported race/ethnicity was White/Caucasian (n=14, 47%), while the least frequent was Black or African American (n=2, 7%). Enlisted service members comprised 66% (n=20) of the infant's military sponsors, with the remainder consisting of officers. The average participant age was 125 days old (SD=4), with a mean estimated gestational age of 39 weeks (SD=1) and a mean birth weight of 3348.8 grams (SD=538).

Vitamin D status was classified in this study as deficient (< 12 ng/mL or < 30 nmol/L), insufficient (12-19 ng/mL or 30-49 nmol/L), or sufficient (>20 ng/mL or >50 nmol/L). The mean serum 25(OH)D was 47.32 ng/mL (SD=20.18). Vitamin D deficiency was identified in 3% (n=1) of infants, insufficiency in 7% (n=2), and sufficiency in 90% (n=27). Serum 25(OH)D levels varied by race/ethnicity (ANOVA, F=3.81, *P*=.015) and sponsor pay grade (ANOVA, F=7.16, *P*<.001) (**Figure 1**, **Table 2**). No other variables demonstrated statistically significant differences.

Discussion

This study investigated vitamin D levels in a cohort of 30 healthy, full-term infants at TAMC in the state of Hawai'i. The average serum 25(OH)D level was 47.32 ng/mL, compared to 35.2 ng/mL in 4-month-old infants in Massachusetts, where the UV index ranges from 1-8 compared to the typical UV index range of 7-13 in the state of Hawai'i.[15,16] The difference in UV index may explain, in part, the difference between 25(OH)D levels in similarly-aged healthy populations. The 25(OH)D level found in Hawai'i is also higher than the 85 nmol/l (approximately 34 ng/mL) discovered in infants aged 6-19 months in California, a state of relatively high sun exposure.[18] Vitamin D deficiency was found in 3% of the infants, and insufficiency in 7%, while 90% had sufficient levels. The combined 10% deficiency and insufficiency was like other studies (11% Liang et al, 11.9% Merewood et al). Prior to the study, a prevalence threshold of ⩾5% deficiency and/or insufficiency was determined to be clinically significant. This level was based on the World Health Organization's (WHO) prevalence cut-off value for public health significance regarding anemia, which was determined to be analogous to vitamin D deficiency since the WHO has not published prevalence cut-off values for the public health significance of vitamin D deficiency.[21] If this determination is viewed as appropriate, this study shows that the military-dependent infant population in Hawai'i has a mild vitamin D deficiency and insufficiency population-level problem.[21] Despite the prevalence reaching clinical significance, it is far below the previously reported prevalence of 93% in the TAMC neonatal population.[10] Cord blood vitamin D levels likely do not accurately reflect postnatal vitamin D status due to maternal contribution and physiological changes after birth. Measuring serum 25(OH)D in infants offers a more precise assessment of their current vitamin D status.

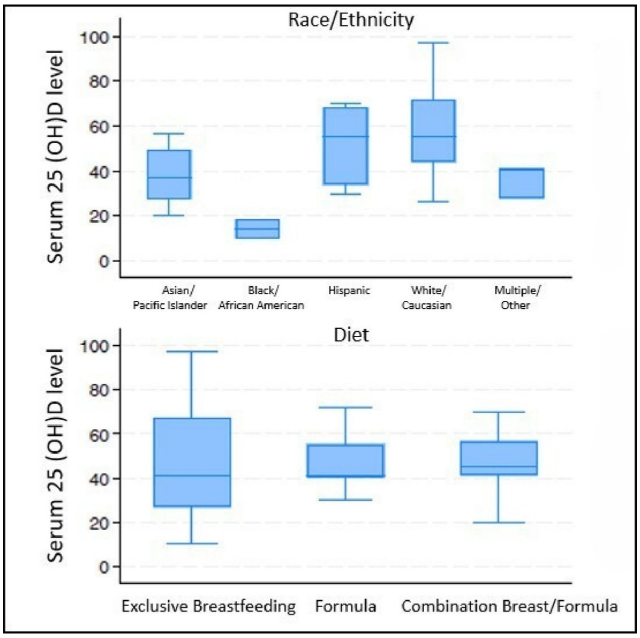

Figure 1. Serum 25-Hydroxyvitamin D (25(OH)D) Levels among Infants by Demographic and Clinical Variables, Tripler Army Medical Center, May 2024-April 2025[a]

Box plots comparing serum 25(OH)D levels in ng/mL across race/ethnicity and diet. Boxes represent interquartile range; horizontal lines indicate medians; whiskers show the range within 1.5-times interquartile range (IQR).

[a]The average serum 25(OH)D level for Black or African American infants was in the insufficiency range and was significantly lower than levels observed in White/Caucasian and Hispanic infants (ANOVA, F=3.81, *P*=.015).

Differences in mean vitamin D levels were observed among racial and ethnic groups. Black or African American infants had the lowest average serum 25(OH)D level (14.15 ng/mL), which approached the deficiency threshold and was markedly lower than levels observed in White/Caucasian (56.97 ng/mL) and Hispanic (51.38 ng/mL) infants. This disparity is likely attributable to increased melanin pigmentation in darker skin, which can reduce the efficiency of cutaneous vitamin D synthesis as significantly more sun exposure is required to generate adequate levels.[1] In a sun-rich environment like Hawai'i, these findings suggest that other factors, such as cultural practices, clothing habits, and outdoor time, may also influence vitamin D levels.

Table 1. Demographic and Neonatal Characteristics of Infant Vitamin D Study Participants, Tripler Army Medical Center, May 2024-April 2025

	# of Participants (% of total)
Total Participants	30 (100%)
Race/Ethnicity	
Asian/Pacific Islander	6 (20%)
Black or African American	2 (7%)
Hispanic	5 (17%)
White/Caucasian	14 (47%)
Multiple Ethnicity / Other	3 (10%)
Sex	
Male	11 (37%)
Female	19 (63%)
Military Sponsor's Pay grade (Monthly Basic Pay)[a]	
E3 ($2733.00)	2 (7%)
E4 ($3027.30)	6 (21%)
E5 ($3220.50)	3 (11%)
E6 ($3276.60)	7 (25%)
E7 ($3788.10)	2 (7%)
O2 ($4606.80)	1 (4%)
O3 ($5331.60)	4 (14%)
O4 ($6064.20)	2 (7%)
O5 ($7028.40)	1 (4%)
Diet	
Exclusive Breastfeeding	12 (40%)
Formula Fed	9 (30%)
Combination Breast and Formula	9 (30%)
Caregiver-Reported Days per Week of Vitamin D Administration[b]	
0	12 (40%)
1	4 (13%)
4	3 (10%)
5	2 (7%)
6	1 (3%)
7	8 (27%)
Vitamin D Status	
Deficient	1 (3%)
Insufficient	2 (7%)
Sufficient	27 (90%)
Perinatal/Neonatal Characteristics	**Mean (SD)**
Birthweight in Grams	3348.8 (538)
Estimated Gestational Age at Birth in Weeks	39 (1)
Age at 25 (OH)D Testing in Days	125 (4)

[a]No participants reported a pay grade of E1, E2, E8, E9, O1, or O6-O10. Enlisted ranks start with the letter "E" with more senior level indicated by higher number in comparison to more junior level indicated by lower number. Similar for officer ranks that start with the letter "O". Fiscal Year 2025 Monthly Basic Pay Rates for Active-duty service members with 2 or less Cumulative Years of Service are included after each pay grade in parentheses.
[b]No caregivers reported vitamin D administration on average 2 or 3 days per week.

Infants identified as Asian/Pacific Islander and Multiple/Other demonstrated intermediate vitamin D levels, underscoring the heterogeneity within these broad categories and the complexity of the relationship between race/ethnicity and vitamin D levels. Within the Asian/Pacific Islander designation, considerable variation in skin pigmentation and cultural practices likely contribute to the observed variability and intermediate average. The "Multiple/Other" category is too broad to draw specific conclusions from the results.

A major limitation of this study is its small sample size, particularly within subgroup analyses. The extremely low number of Black or African American participants limits the generalizability of findings to the broader population of Black or African American infants in Hawaiʻi. Further studies with larger and more representative samples are crucial.

Table 2. Mean Serum 25(OH)D Levels Among Infant Vitamin D Study Participants by Demographic and Clinical Variables ,Tripler Army Medical Center, May 2024-April 2025

Variable	Mean 25 (OH)D (ng/mL)[a]	Standard deviation
All Participants	47.32	20.18
Diet		
Exclusive Breastfeeding	46.85	27.35
Formula Fed	47.73	14.60
Combination Breast and Formula	47.53	15.30
Race/Ethnicity		
Asian/Pacific Islander	37.91	13.66
Black or African American	*14.15	5.86
Hispanic	51.38	18.67
White/Caucasian	56.97	19.33
Multiple Ethnicity / Other	36.43	7.65
Caregiver-Reported Days per Week of Vitamin D Administration[b]		
0	45.60	24.69
1	36.47	7.50
4	42.4	24.88
5	60.7	28.99
6	63.8	-
7	51.75	14.59
Military Sponsor's Pay grade[c]		
E3	36.95	9.97
E4	33.36	16.91
E5	25	4.41
E6	53.54	12.52
E7	29.7	4.80
O2	71.5	-
O3	61.97	9.12
O4	89.25	11.38
O5	40.5	-
Sex		
Male	40.16	17.40
Female	51.46	20.94

[a]Mean 25 (OH)D level falls within insufficient category (12-19 ng/mL).
[b]No caregivers reported vitamin D administration on average 2 or 3 days per week
[c]No participants reported a pay grade of E1, E2, E8, E9, O1, or O6-O10.

Despite this limitation, these findings support the need for routine vitamin D supplementation and increased awareness of potential vitamin D insufficiency and deficiency in high-risk groups, including Black or African American infants, even in regions with abundant sunlight. Health care providers should consider these disparities when evaluating and treating infants.

Although significant variation in vitamin D levels was observed among sponsor pay grade groups, a clear linear trend was not identified. Some officer ranks (ie, O3, O4) showed significantly higher vitamin D levels compared to enlisted ranks, while others (ie, O5) did not. Similarly, vitamin D levels varied within the enlisted ranks. The distribution of race/ethnicity within each pay grade might not be uniform. A disproportionate number of participants from certain race/ethnic groups in lower pay grades could explain why this group has lower vitamin D levels. The small number of participants in each pay grade, especially at the officer ranks, and the potential interaction between race/ethnicity and pay grade make it difficult to draw definitive conclusions about socioeconomic influences. To properly analyze the effects of race/ethnicity and pay grade on an infant's vitamin D status, a statistical analysis controlling for both variables at the same time is necessary but was not conducted in this study. Larger studies with sufficient sample sizes within each pay grade are needed to better understand the interaction between these 2 variables.

Notably, several exclusively breastfed infants, including 5 reported as White/Caucasian and 1 as Multiple Ethnicity/Other, had sufficient vitamin D levels despite not receiving the recommended vitamin D supplementation. This observation raises questions regarding the necessity and cost-effectiveness of universal supplementation at TAMC. While universal supplementation may contribute to the overall high sufficiency rate observed in this cohort, a more targeted approach could be more resource efficient.

Despite the low prevalence of vitamin D deficiency and insufficiency, these conditions can have long-term effects on bone health and growth. Even mild deficiency raises the risk of rickets, osteomalacia, and fractures later in life. Therefore, continuous monitoring and targeted interventions for at-risk infants remain crucial.

Strengths of this study include its focus on a specific pediatric population with unique environmental and demographic characteristics, the use of serum 25(OH)D as a direct measure of vitamin D status, and standardized data collection methods. However, as mentioned, generalizability is limited due to the small sample size. Other limitations include the cross-sectional design, which precludes causal inferences. Potential biases related to participant recruitment, such as voluntary participation and possible differences in health-seeking behaviors, may have influenced the results. Additionally, parental reporting of supplementation practices could introduce recall bias.

Future research should include longitudinal studies to monitor vitamin D status over time and assess the long-term impact of various supplementation strategies. Investigating parental knowledge, beliefs, and adherence to supplemental guidelines, as well as environmental and behavioral factors affecting sun exposure, would provide further insight.

The findings suggest that the practice of universal vitamin D supplementation at TAMC may warrant re-evaluation. A more tailored approach that targets infants at higher risk, based on factors such as race/ethnicity and/or sponsor pay grade, could provide a more cost-effective strategy. Enhanced parental education on vitamin D and supplementation guidelines might also help optimize infant health outcomes. In the end, a personalized strategy that considers individual risk factors is crucial for making informed decisions about vitamin D supplementation.

Conclusion

Most infants in this study had sufficient vitamin D levels despite low adherence to supplementation recommendations. Significant variability observed in vitamin D levels across demographic groups raises questions about the need for universal supplementation in this population. A small sample size limits the ability to generalize the findings, and the cross-sectional design prevents determining causality. Future studies examining maternal serum 25(OH)D levels, especially in exclusively breastfed infants, may offer further insights for refining supplementation recommendations as many exclusively breastfed infants without supplementation in this study were found to be vitamin D replete.

Conflict of Interest Statement

The authors have no competing interests or conflicts of interest to disclose.

Disclaimer

The views expressed in this brief report reflect the results of research conducted by the authors and do not necessarily reflect the official policy or position of the Defense Health Agency, Department of Defense, nor the US Government.

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