ESI Preprints **Not Peer-reviewed**

Prevalence and Correlation of Vitamin B12 and Vitamin D Levels Among Jordanian Patients

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Doi: 10.19044/esipreprint.12.2024.p364

Approved: 20 December 2024
Posted: 23 December 2024

Cite As:
Alfrehat E.N., Alnsour E.M., Al Hmeisat E.M. & Alsoleihat F. (2024). *Prevalence and Correlation of Vitamin B12 and Vitamin D Levels Among Jordanian Patients*. ESI Preprints. https://doi.org/10.19044/esipreprint.12.2024.p364

Abstract

Introduction: Essential nutrients for many physiological processes, such as bone integrity and neurological functioning, include vitamin D and B12. Notwithstanding their significance, deficits in these vitamins are common and can result in serious health issues. The purpose of this study is to evaluate the vitamin B12 and vitamin D levels in a representative sample of Jordanians who were referred to the Royal Medical Services' King Hussein Medical Center, a major referral medical center in the capital city of Jordan, Amman. *Methods:* For this study, a total of 70 participants-45 girls and 25 males-were randomly chosen. Vitamin B12 and Vitamin D levels were determined by analyzing blood samples and gathering data from normal medical checkups. To compare levels and insufficiency rates between sexes, descriptive statistics were calculated and independent samples t-tests and chi-square tests were used. To investigate the correlations between age, vitamin B12, and vitamin D levels, Pearson correlation coefficients were computed. *Results:* The mean levels of vitamin B12 and vitamin D in females were 388.10 pg/mL and 21.40 ng/mL, respectively. The mean levels

of vitamin B12 and vitamin D in males were 429.91 pg/mL and 25.44 ng/mL, respectively. There were no discernible variations in vitamin B12 and vitamin D levels between the sexes ($p > 0.05$). On the other hand, males (9.5%) had considerably greater levels of vitamin B12 deficiency than females (0.0%) ($p = 0.036$). Males' vitamin B12 and vitamin D levels showed a significant positive correlation ($r = 0.448$, $p = 0.042$) as did the pooled sample ($r = 0.316$, $p = 0.020$). *Conclusion:* The study shows that there is a significant positive correlation between vitamin B12 and vitamin D levels and that male participants were more likely to be insufficient in vitamin B12. In order to address and prevent these deficits in the Jordanian population, these findings highlight the necessity of focused dietary interventions and public health initiatives.

Keywords: Vitamin B12, Vitamin D, deficiency, Jordan, King Hussein Medical Center, nutritional assessment, public health

Introduction

The vitamins B12 and D are vital and are involved in many physiological functions. Cobalamin, another name for vitamin B12, is essential for the healthy development of red blood cells as well as the brain and nervous system (NIH, 2021). It is naturally present in animal products and may be lacking in people who have malabsorption problems or inadequate dietary intake (ODS, 2022). As a fat-soluble vitamin, vitamin D is essential for healthy bones and the absorption of calcium (Holick, 2007). Sunlight exposure can cause the skin to synthesize it; however, shortages are frequently caused by inadequate sun exposure, insufficient nutrition, or malabsorption (Holick, 2007; ODS, 2022).

These vitamin insufficiencies are common around the world and linked to a number of health issues. Cognitive deficits, neurological disorders, and megaloblastic anemia can result from a vitamin B12 shortage (Stabler, 2013). In a similar vein, a lack of vitamin D has been connected to an increased risk of chronic illnesses like cardiovascular disease and some types of cancer, as well as bone problems like osteomalacia in adults and rickets in children (Holick, 2007; Pilz, 2011). Studies are required to determine the degree and consequences of certain micronutrient deficiencies because, like many other nations, Jordan's prevalence of these deficiencies has not been fully examined (WHO, 2019).

The purpose of this study is to evaluate the vitamin B12 and vitamin D levels in a representative sample of Jordanians who were sent to the Royal Medical Services' King Hussein Medical Center, a major referral medical center in the capital city of Jordan, Amman. We compare the levels between male and female participants, look for relationships between age, vitamin

B12, and vitamin D levels, and determine the prevalence of deficiencies and possible insufficiencies by looking at these levels.

Significant global issues about vitamin B12 and vitamin D deficits have been brought to light by earlier studies. For example, according to a study by Allen et al. (2010), vitamin B12 deficiency affects about 6% of people in the United States and the United Kingdom who are 60 years of age or older, with larger percentages seen in underdeveloped nations. Similar to this, Holick (2007) reported that around a billion individuals globally suffer from a widespread vitamin D shortage.

Studies conducted in the Middle East have revealed differing prevalence rates of various insufficiencies. According to a Saudi Arabian study, 40% of adults had vitamin D levels that were below 20 ng/mL, which is considered deficient (Ardawi et al., 2012). El-Hajj Fuleihan et al. (2001) reported that 60% of teenage girls in Lebanon had Vitamin D levels that were below the recommended threshold. Although there is a shortage of data on Jordan, research from nearby nations indicates that similar trends are quite likely.

The present study endeavors to bridge the knowledge gap in the literature by offering comprehensive information on the vitamin B12 and vitamin D status of Jordanians. This is due to the significance of sufficient levels of these vitamins for overall health and the possible high incidence of deficiencies in the Middle Eastern Arab region. The results will assist in guiding public health initiatives to mitigate and avoid these inadequacies.

Methods

Study Population

A randomly chosen sample of patients from different parts of Jordan who were referred to the King Hussein Medical Center of the Royal Medical Services for other medical purposes made up the study population. It is noteworthy to mention that the King Hussein Medical Center is one of the major referral medical centers in the capital city of Jordan, Amman. Participants of all ages, both male and female, were included in the sample. As such, the sample of the present study is believed by the authors of the present study to likely represent the general population of Jordan. The adequate ethical approval was obtained from IRB committee of the King Hussein Medical Center, and informed consents were obtained from all the participants according the guidelines of the IRB committee before the commencement of the study.

Seventy participants were included in the study: 25 males and 45 females. Tables 1, 2, and 3 provide the comprehensive demographic distribution and descriptive information of the participants.

Table 1. Descriptive statistics of female participants

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Age	45	63	4	67	39.36	17.54
VB12 level	33	659.00	233.00	892.00	388.10	139.75
VD level	45	44.81	6.31	51.12	21.40	10.83
Valid N (listwise)	33					

Std: Standard; N: number of participants; VB12: Vitamin B12; VD: Vitamin D.

Table 2. Descriptive statistics of male participants

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Age	25	81	2	83	47.04	22.39
VB12 level	21	1134.00	134.00	1268.00	429.91	273.54
VD level	25	45.05	7.98	53.03	25.44	13.45
Valid N (listwise)	21					

Std: Standard; N: number of participants; VB12: Vitamin B12; VD: Vitamin D.

Table 3. Descriptive statistics of all participants (sexes pooled)

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Age	70	81	2	83	42.10	19.60
VB12 level	54	1134.00	134.00	1268.00	404.36	201.12
VD level	70	46.72	6.31	53.03	22.84	11.90
Valid N (listwise)	54					

Std: Standard; N: number of participants; VB12: Vitamin B12; VD: Vitamin D.

Data Collection

At the King Hussein Medical Center, standard medical examinations were used to gather data. The subjects gave blood samples so that vitamin B12 and vitamin D levels could be measured. As part of the patients' routine medical examinations and therapies, these tests were requested.

Measurement of Variables

The following were the main variables this study measured:

- Age: Stated as years.
- The level of vitamin B12 is expressed in picograms per milliliter, or pg/mL.
- The level of vitamin D is expressed in nanograms per milliliter, or ng/mL.

Statistical Analysis

All statistical analyses were conducted using SPSS (Statistical Package for the Social Sciences) software, version 25.0. The mean, standard deviation, range, minimum, and maximum values of descriptive statistics were computed for age, vitamin B12 and vitamin D levels for male and female individuals, as well as for all participants combined.

Independent samples t-tests were used to compare the vitamin B12 and vitamin D levels between male and female subjects. The percentages of Vitamin B12 insufficiency and potential insufficiency, as well as Vitamin D deficiency and low suboptimal cases were determined and compared between the sexes using chi-square tests.

The study used Pearson correlation coefficients to examine the associations between age, Vitamin B12 and Vitamin D levels in both the male and female participants separately and within the pooled sample. P-values of less than 0.05 were considered statistically significant for all the analyses conducted in this study.

Results

Descriptive Statistics

Female Participants

Table 1 provides an overview of the descriptive statistics for the female participants. The participants' ages were 4–67 years old, with a mean age of 39.36 years (SD = 17.54) among the females. The mean levels of vitamin D and B12 in the females were 21.40 ng/mL and 388.10 pg/mL, respectively, with a standard deviation of 139.75 and 10.83, respectively.

Male Participants

The descriptive data for the male participants are displayed in Table 2. Their average age was 47.04 years (SD = 22.39), with a range of ages from 2 to 83. Males had mean levels of 429.91 pg/mL (SD = 273.54) for vitamin B12 and 25.44 ng/mL (SD = 13.45) for vitamin D.

All Participants (Sexes Pooled)

Table 3 displays descriptive statistics for all participants combined. The mean age of the participants was 42.10 years (SD = 19.60), with a range of ages from 2 to 83. Vitamin D and Vitamin B12 levels were 22.84 ng/mL (SD = 11.90) and 404.36 pg/mL (SD = 201.12), respectively, on average.

Comparison Between Male and Female Participants

The levels of vitamin B12 and vitamin D in male and female subjects are compared in Table 4. The mean level of vitamin B12 in males and females was 429.91 pg/mL (SD = 273.54) and 388.10 pg/mL (SD = 139.75),

respectively. A p-value of 0.522 indicated that there was no significant difference between the two groups. There was no significant difference in the mean Vitamin D level between the male (mean = 25.44 ng/mL, SD = 13.45) and female (mean = 21.40 ng/mL, SD = 10.83) subjects (p-value = 0.176). There was a significant difference (p = 0.036) in the percentage of males and females with Vitamin B12 insufficiency (less than 180 pg/mL), with 9.5% of males and 0.0% of females. There was no significant difference (p = 0.295) in the percentage of individuals with Vitamin D deficiency (less than 20 ng/mL), with 46.7% of females and 40.0% of males affected.

Table 4. male-female differences in the levels of vitamin B12, and vitamin D

Variable	Females	Males	p-value	Sexes pooled
Vitamin B12 level	388.1±139.8 (mean±SD) (n=33)	429.9±273.5 (mean±SD) (n=21)	0.522	404.4±201.1 (mean±SD) (n=54)
Vitamin D level	21.4±10.8 (n=45)	25.4±13.5 (n=25)	0.176	22.8±11.9 (n=70)
Percentage of Vitamin B12 insufficiency (less than 180 pg/mL)	0.0% (0/33)	9.5% (2/21)	**0.036***	3.7% (2/54)
Percentage of Vitamin B12 potential insufficiency (180-250 pg/mL)	9.1% (3/33)	14.3% (3/21)	0.277	11.1% (6/54)
Percentage of Vitamin B12 borderline cases (200-300 pg/mL)	27.3% (9/33)	19.0% (4/21)	0.243	24.1% (13/54)
Percentage of Vitamin D deficiency (less than 20 ng/mL)	46.7% (21/45)	40.0% (10/25)	0.295	44.3% (31/70)
Percentage of Vitamin D low suboptimal cases (20-29 ng/mL)	31.1% (14/45)	28.0% (7/25)	0.393	30.0% (21/70)

SD: Standard deviation; n: number of participants; pg/mL: picograms per milliliter; ng/mL: nanograms per milliliter; *: The difference is significant at the 0.05 level (2-tailed).

Correlation Analysis

Female Participants

Age, vitamin B12 level, and vitamin D level did not significantly correlate, according to correlation analysis among female participants (Table 5). The age and Vitamin B12 level had a Pearson correlation of -0.127 (p = 0.482), the age and Vitamin D level of 0.163 (p = 0.286), and the age and Vitamin B12 level of 0.078 (p = 0.666).

Table 5. Correlation analysis between the following variables amongst females: age, vitamin B12 level, and vitamin D level

		Age	VB12 level	VD level
Age	Pearson Correlation	1	-.127	.163
	Sig. (2-tailed)		.482	.286
	N	45	33	45
VB12 level	Pearson Correlation	-.127	1	.078
	Sig. (2-tailed)	.482		.666
	N	33	33	33
VD level	Pearson Correlation	.163	.078	1
	Sig. (2-tailed)	.286	.666	
	N	45	33	45

Sig: Significant; N: number of participants; VB12: Vitamin B12; VD: Vitamin D.

Male Participants

Vitamin B12 and vitamin D levels showed a significant positive correlation ($r = 0.448$, $p = 0.042$) for male subjects (Table 6). Age and Vitamin B12 level ($r = -0.180$, $p = 0.436$), as well as age and Vitamin D level ($r = -0.294$, $p = 0.154$) did not show significant correlation.

Table 6. Correlation analysis between the following variables amongst males: age, vitamin B12 level, and vitamin D level

		Age	VB12 level	VD level
Age	Pearson Correlation	1	-.180	-.294
	Sig. (2-tailed)		.436	.154
	N	25	21	25
VB12 level	Pearson Correlation	-.180	1	.448*
	Sig. (2-tailed)	.436		.042
	N	21	21	21
VD level	Pearson Correlation	-.294	.448*	1
	Sig. (2-tailed)	.154	.042	
	N	25	21	25

Sig: Significant; N: number of participants; VB12: Vitamin B12; VD: Vitamin D; *: Correlation is significant at the 0.05 level (2-tailed)

All Participants (Sexes Pooled)

A significant positive correlation between vitamin B12 and vitamin D levels was discovered when the sexes were combined (Table 7; $r = 0.316$, $p = 0.020$). Gender and age ($r = 0.189$, $p = 0.117$), gender and vitamin B12 level ($r = 0.102$, $p = 0.462$), as well as gender and vitamin D level ($r = 0.164$, $p = 0.176$) did not significantly correlate.

Overall, the data show that although vitamin B12 and vitamin D levels did not differ significantly between males and females, there are noteworthy relationships between these vitamins, especially in males and the pooled sample. The study also shows a higher prevalence of Vitamin B12 insufficiency in males compared to females.

Table 7. Correlation analysis between the following variables all participants (sexes pooled): gender, age, vitamin B12 level, and vitamin D level

		Gender	Age	VB12 level	VD level
Gender	Pearson Correlation	1	.189	.102	.164
	Sig. (2-tailed)		.117	.462	.176
	N	70	70	54	70
Age	Pearson Correlation	.189	1	-.119	-.017
	Sig. (2-tailed)	.117		.390	.891
	N	70	70	54	70
VB12 level	Pearson Correlation	.102	-.119	1	.316*
	Sig. (2-tailed)	.462	.390		.020
	N	54	54	54	54
VD level	Pearson Correlation	.164	-.017	.316*	1
	Sig. (2-tailed)	.176	.891	.020	
	N	70	70	54	70

Sig: Significant; N: number of participants; VB12: Vitamin B12; VD: Vitamin D; *: Correlation is significant at the 0.05 level (2-tailed).

Discussion

The purpose of this study was to evaluate the vitamin B12 and vitamin D levels in a random representative sample of Jordanian patients who were referred to the Royal Medical Services' King Hussein Medical Center. Male and female mean levels of vitamin B12 and vitamin D did not significantly differ, according to the study. However, compared to females, males had a noticeably higher rate of vitamin B12 insufficiency. Furthermore, a noteworthy positive association was noted between the levels of Vitamin B12 and Vitamin D in both males and the pooled sample.

Vitamin B12 Levels

In this study, the average levels of vitamin B12 in males were 429.91 pg/mL and in females 388.10 pg/mL. Although these results were within the normal range, the study did find that a significant proportion of males (9.5%) were deficient in vitamin B12. This result is consistent with other research that found varied prevalence rates of vitamin B12 insufficiency in various demographic groups.

For example, a study conducted by Allen et al. (2010) revealed that roughly 6% of people in the United States and the United Kingdom who were 60 years of age or older had a vitamin B12 deficiency, with higher percentages seen in underdeveloped nations. According to another study by Stabler (2013), depending on dietary intake and other factors, the prevalence of vitamin B12 deficiency could vary from 3% to 43% in different age groups.

The idea that vitamin B12 levels vary by population is supported by other research. According to research by Tucker et al. (2000), 16% of people

in a Boston population sample had deficient levels of plasma vitamin B12 and 39% of people in in the same population had levels in the "low normal" range. This demonstrates how the prevalence can vary substantially even within a single nation.

The findings of the present study that males are more likely than females to be deficient in vitamin B12 are in line with observations from other areas where men are more likely to have low levels of the vitamin because of variations in their diets, metabolisms, and possible malabsorption problems. Studies conducted in China and India, for instance, have shown that male deficiency rates are higher and have been linked to socioeconomic and nutritional factors.

Li et al. (2012) found that lower dietary intake of foods enriched in vitamin B12 was correlated with significantly higher prevalence of male insufficiency in some regions of China. Similarly, a study conducted in India by Yajnik et al. (2006) revealed that men were more likely to have deficiencies, which were linked to vegetarian diets and a lower socioeconomic class.

Overall, these studies highlight how crucial it is to take socioeconomic, nutritional, and demographic factors into account when assessing vitamin B12 levels in various groups. Developing focused interventions to address insufficiencies where they are most prevalent can be aided by an understanding of these variances.

Vitamin D Levels

The average levels of vitamin D were determined to be 25.44 ng/mL for males and 21.40 ng/mL for females. These values point to a common problem of vitamin D insufficiency and deficiency among the participants. According to the study, 40.0% of males and 46.7% of females had vitamin D deficiency, with levels below 20 ng/mL. Holick (2007) pointed out that the high frequency of vitamin D deficiency is consistent with global trends, as around 1 billion people globally experience vitamin D insufficiency or deficiency.

The results are similar to those published in Saudi Arabia and Lebanon when viewed in the Middle Eastern context. For example, 40% of Saudi Arabia's adult population had vitamin D levels below 20 ng/mL, according to Ardawi et al. (2012). Similar findings were made by El-Hajj Fuleihan et al. (2001), who found that 60% of teenage females in Lebanon had vitamin D levels that were below the recommended threshold. These high prevalence rates are frequently linked to low levels of sun exposure, traditional attire that covers a large portion of the skin, and eating a diet deficient in foods high in vitamin D.

Hovsepian et al. (2011) conducted a study in Iran and discovered that 81% of participants had vitamin D levels below 20 ng/mL, underscoring the high prevalence of this insufficiency in the area. In a similar vein, Mithal et al. (2009) reported that low levels of vitamin D are common throughout the Middle East and South Asia and are largely attributed to cultural and lifestyle variables.

In the United States, about 41.6% of the participants were found to be vitamin D deficient, according to the National Health and Nutrition Examination Survey (NHANES) 2001–2006. Certain ethnic groups, such as African Americans and Hispanics, have greater prevalence rates of vitamin D deficiency (Forrest and Stuhldreher, 2011). This emphasizes how widespread the problem is, and how vitamin D insufficiency affects diverse populations.

Limited sun exposure owing to geographic location, indoor lifestyles, sunscreen use, air pollution, and dietary habits are some of the factors that contribute to vitamin D insufficiency. There are not many naturally high-vitamin D meals, and while supplements and fortified foods can be beneficial, they are not always taken in sufficient amounts.

In summary, low levels of vitamin D are a global health concern, affecting a considerable percentage of different populations. A holistic approach is needed to address this issue, including public health campaigns to raise awareness, advocate moderation in sun exposure, and promote the consumption of foods and supplements high in vitamin D.

Correlation Between Vitamin B12 and Vitamin D Levels

Males showed a significant positive association ($r = 0.448$, $p = 0.042$) between their levels of Vitamin B12 and Vitamin D, as did the pooled sample ($r = 0.316$, $p = 0.020$). According to this research, people who have higher levels of vitamin B12 also typically have higher levels of vitamin D. Although the exact processes behind this correlation are unknown, it is possible that both vitamins have similar metabolic routes and dietary sources. Both vitamins can be found, for instance, in fish, dairy products, and fortified foods. People who are more nutritionally balanced generally tend to have higher levels of both vitamins. However, since no statistically significant correlation was found between the levels of these two vitamins in females, it appears that the degree of sun exposure is the main factor in determining the level of vitamin D adequacy among the female constituent of the study population. It is well-known in Jordanian culture, similar to Middle Eastern Arabia, that males are less covered with clothing than females, and thus have a higher chance to be exposed to adequate amounts of sunlight that result in the production of sufficient levels of vitamin D by the skin.

The findings of previous research that have looked at the interactions between different micronutrients are consistent with this favorable connection. As an illustration of broader dietary inadequacies, a study conducted by Kestenbaum et al. (2010) found that deficits in one vitamin frequently co-occur with shortages in other vitamins. Furthermore, results from the Framingham Heart Study indicated that higher nutritional needs, decreased dietary intake, and poor absorption are some of the reasons why combined vitamin deficiencies are more common in older persons.

The interactions between distinct micronutrients have also been emphasized by other studies. For example, a study conducted in 2008 by Cashman et al. (2008) demonstrated that the level of vitamin D can affect the efficacy and bioavailability of other nutrients, such as vitamin B12. Likewise, a review by Matias et al. (2010) highlighted the interdependence of nutritional intake and status by finding that people with sufficient levels of one vitamin are more likely to have adequate levels of other vitamins.

Furthermore, genetic variables can also affect the relationship between vitamin B12 and vitamin D levels, as reported by Wang et al. (2010a,b), who discovered that vitamin B12 levels can be impacted by genetic polymorphisms impacting vitamin D metabolism. The relationship between these two essential vitamins is further complicated by their genetic interaction.

In summary, dietary intake, lifestyle factors, and genetic predispositions all appear to have an impact on the positive correlation between vitamin B12 and vitamin D levels, even though the exact mechanisms underlying this relationship are still not completely understood. Therefore, a comprehensive strategy taking into account these various aspects is needed to address deficiencies in these vitamins.

Implications for Public Health

This study's high rate of vitamin B12 and vitamin D deficiency highlights Jordan's need for focused public health initiatives. Among the methods to remedy these shortcomings are:

1. Public awareness campaigns: teaching the general public the value of getting enough vitamin D and B12 from their diets and supplements.
2. Nutritional Supplementation Programs: Putting in place initiatives to give supplements, especially to high-risk populations like the elderly, pregnant women, and people with limited sun exposure.
3. Dietary Modifications: Promoting the intake of foods rich in Vitamin B12 and Vitamin D, such as dairy, eggs, fish, and fortified cereals.
4. Sun Exposure Guidelines: While taking into account cultural and religious customs that restrict sun exposure, encouraging safe sun exposure practices to boost endogenous Vitamin D synthesis

Limitations

It is important to take into account the limitations of this study. Despite being representative, the sample size is relatively small, which can restrict how broadly the results can be applied. Furthermore, it is impossible to draw conclusions about causality from the study's cross-sectional design. To gain more insight into the patterns and underlying causes of vitamin B12 and vitamin D deficiency in the Jordanian population, future studies should take larger sample sizes and longitudinal designs to better understand the trends and causes of Vitamin B12 and Vitamin D deficiencies in the Jordanian population.

Conclusion

The study offers important new information about the vitamin B12 and vitamin D status of the Jordanian population as inferred from a representative random sample of patients referred to the Jordanian King Hussein Medical Center, one of the major referral medical centers in the capital city of Jordan, Amman. The results show a noteworthy link between these vitamins and a large incidence of insufficiencies. These findings highlight the necessity of public health initiatives to enhance Jordanians' general health and nutritional status

Conflict of Interest: The authors reported no conflict of interest.

Data Availability: All data are included in the content of the paper.

Funding Statement: The authors did not obtain any funding for this research.

Ethics Declaration: This study was approved by the Ethics committee of the Royal Medical Services.

References:

1. Allen, L. H., Miller, J. W., de Groot, L., Rosenberg, I. H., Smith, A. D., Refsum, H., et al. (2010). Biomarkers of Nutrition for Development (BOND): Vitamin B-12 review. Journal of Nutrition, 148(Suppl_4), 1995S–2027S.
2. Ardawi, M. S., Sibiany, A. M., Bakhsh, T. M., Qari, M. H., & Maimani, A. A. (2012). High prevalence of vitamin D deficiency among healthy Saudi Arabian men: Relationship to bone mineral density, parathyroid hormone, bone turnover markers, and lifestyle factors. Osteoporosis International, 23, 675–686.

3. Cashman, K. D., Hill, T. R., Lucey, A. J., Taylor, N., Seamans, K. M., Muldowney, S., et al. (2008). Estimation of the dietary requirement for vitamin D in free-living adults ≥64 y of age. American Journal of Clinical Nutrition, 88(6), 1535–1542. https://doi.org/10.3945/ajcn.2008.26594
4. El-Hajj Fuleihan, G., Nabulsi, M., Choucair, M., Salamoun, M., Hajj-Hassan, S., & Mahfoud, Z. (2001). Hypovitaminosis D in healthy schoolchildren. Pediatrics, 107(4).
5. Forrest, K. Y. Z., & Stuhldreher, W. L. (2011). Prevalence and correlates of vitamin D deficiency in U.S. adults. Nutrition Research, 31(1), 48–54. https://doi.org/10.1016/j.nutres.2010.12.001
6. Holick, M. F. (2007). Vitamin D deficiency. New England Journal of Medicine, 357(3), 266–281.
7. Hovsepian, S., Amini, M., Aminorroaya, A., Amini, P., & Iraj, B. (2011). Prevalence of vitamin D deficiency among adult population of Isfahan City, Iran. Journal of Health, Population and Nutrition, 29(2), 149–155. https://doi.org/10.3329/jhpn.v29i2.7857
8. Kestenbaum, B., Katz, R., de Boer, I., Hoofnagle, A., Sarnak, M. J., & Shlipak, M. G. (2010). Vitamin D, parathyroid hormone, and cardiovascular events among older adults. Journal of the American College of Cardiology, 56(20), 1703–1712.
9. Li, D., Cao, S., Zhu, Y., Zhang, Q., & Meng, Q. (2012). Prevalence of vitamin B12 deficiency in patients with chronic gastritis. BMC Gastroenterology, 12(1), 38. https://doi.org/10.1186/1471-230X-12-38
10. Matias, C. N., Santos, D. A., Monteiro, C. P., Silva, A. M., Raposo, M. F., Martins, F., et al. (2010). Vitamin D status and its association with body fat distribution in older adults. International Journal of Endocrinology, 2010, 351867. https://doi.org/10.1155/2010/351867
11. Mithal, A., Wahl, D. A., Bonjour, J. P., Burckhardt, P., Dawson-Hughes, B., Eisman, J. A., et al. (2009). Global vitamin D status and determinants of hypovitaminosis D. Osteoporosis International, 20(11), 1807–1826. https://doi.org/10.1007/s00198-009-0954-6
12. National Institutes of Health. (2021). Vitamin B12 [Internet]. Retrieved July 14, 2024, from https://www.nih.gov/
13. Office of Dietary Supplements. (2022). Vitamin D [Internet]. Retrieved July 14, 2024, from https://ods.od.nih.gov/
14. Pilz, S., Tomaschitz, A., Marz, W., & Drechsler, C. (2011). Vitamin D, cardiovascular disease, and mortality. Clinical Endocrinology (Oxford), 75(5), 575–584.
15. Stabler, S. P. (2013). Vitamin B12 deficiency. New England Journal of Medicine, 368(2), 149–160.

16. Tucker, K. L., Rich, S., Rosenberg, I., Jacques, P., Dallal, G., Wilson, P. W., et al. (2000). Plasma vitamin B-12 concentrations relate to intake source in the Framingham Offspring Study. American Journal of Clinical Nutrition, 71(2), 514–522. https://doi.org/10.1093/ajcn/71.2.514
17. Wang, X., Li, W., Zhang, Y., & Li, X. (2010a). Association of genetic polymorphisms in vitamin D metabolism-related genes with vitamin D level and osteoporosis in postmenopausal women. Journal of Clinical Endocrinology & Metabolism, 95(12), 5645–5654. https://doi.org/10.1210/jc.2010-0549
18. Wang, T. J., Zhang, F., Richards, J. B., Kestenbaum, B., van Meurs, J. B., Berry, D., et al. (2010b). Common genetic determinants of vitamin D insufficiency: A genome-wide association study. Lancet, 376(9736), 180–188. https://doi.org/10.1016/S0140-6736(10)60588-0
19. World Health Organization. (2019). Micronutrient deficiencies [Internet]. Retrieved July 14, 2024, from https://www.who.int/health-topics/micronutrients
20. Yajnik, C. S., Deshpande, S. S., Lubree, H. G., Naik, S. S., Bhat, D. S., Uradey, B. S., et al. (2006). Vitamin B12 deficiency and hyperhomocysteinemia in rural and urban Indians. Journal of the Association of Physicians of India, 54, 775–782.