Urban-Rural Disparities in Serum 25-Hydroxyvitamin D Levels: A Cross-Sectional Study on Vitamin D Deficiency Prevalence in Kurdistan Region / Iraq

Azad Mohammed Aziz Ahmed1, * Musa M. Zorab2, Dara Latif Saifalddin3, Hiwa Ahmed Rahim3

1. Nursing Department, Darbandikhan Technical Institute, Sulaimani Polytechnic University, Sulaimani, KRG, Iraq
2. Department of General Science, University of Halabja, Kurdistan Region, Iraq
3. College of Physical Education and Sport Sciences, University of Halabja, Halabja, Kurdistan Region, Iraq.

E-mail: (azad.aziz@spu.edu.iq)

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Abstract

Background: In sun-rich regions like the Middle East, where cultural customs and urbanization reduce UVB exposure, Vitamin D Deficiency (VDD) is a global health issue. VDD is prevalent in Iraq, but Kurdistan Region data on urban-rural inequalities, lipid profiles, and gender differences is scarce. **Objectives:** This study aimed to evaluate blood 25-hydroxyvitamin D [25(OH)D] concentrations in urban and rural populations of Kurdistan, Iraq, while investigating correlations with lipid profiles and gender. **Material and Methods:** A cross-sectional study enrolled 214 individuals (83 men, 131 females) from urban (Sulaymaniyah) and rural regions. Serum 25(OH)D concentrations were assessed by chemiluminescence immunoassay. Demographic, anthropometric, and clinical data were gathered, and statistical analyses (Mann-Whitney U, t-tests, Pearson correlations) were performed utilizing SPSS and GraphPad. **Results:** No notable disparity in vitamin D levels between urban and rural populations was detected ($p = 0.346$). Rural residents had reduced LDL levels compared to their urban counterparts ($p = 0.025$). Males had elevated vitamin D levels compared to females (16.98 vs. 15.63 ng/mL, $p = 0.021$), with more variability observed in females. **Conclusion:** Urbanization did not forecast vitamin D levels in Kurdistan, indicating counterbalancing influences (dietary supplements against cultural practices). Gender differences underscore societal and biological determinants. The lack of vitamin D-lipid associations highlights the intricacy of metabolic processes.

Keywords: Vitamin D insufficiency, urban-rural disparities, lipid profiles, gender differences, Kurdistan Region, cross-sectional study.

Introduction

Vitamin D is an essential secosteroid hormone that significantly contributes to calcium homeostasis, bone metabolism, and immune regulation. Deficiency in this vitamin has been associated with osteoporosis, cardiovascular diseases, and autoimmune disorders (Holick, 2007). Vitamin D deficiency (VDD) is a significant global public health issue, impacting around 1 billion individuals globally (Palacios & Gonzalez, 2014). Regions characterized by ample sunlight, such as the Middle East, paradoxically show a high prevalence of vitamin D deficiency (VDD). This phenomenon is linked to cultural practices restricting skin exposure, darker skin pigmentation that diminishes UVB absorption, and inadequate dietary intake (Grant, Al Anouti, & Moukayed, 2020). This discrepancy highlights the intricate interactions among environmental, behavioral, and socioeconomic factors influencing VDD epidemiology.

Research in the Middle East indicates significant rates of vitamin D deficiency (VDD), with Saudi Arabia reporting a prevalence of 81% (Al-Daghri et al., 2017), And Iran notes a 72% deficiency, especially among urban women (Hovsepian, Amini, Aminorroaya, Amini, & Iraj, 2011). Urban-rural disparities represent a significant issue, as urban populations frequently demonstrate elevated Vitamin D deficiency due to sedentary behaviors, indoor occupations, and pollution that reduces UVB exposure (Al-Khalidi, Dima, & Stefan, 2018). In contrast, although rural communities are more involved in outdoor labor, they encounter dietary restrictions and restricted access to healthcare, which complicates the landscape of deficiencies (Bassil, Rahme, Hoteit, & Fuleihan, 2013). This variability highlights the need for region-specific analyses to clarify these complex influences.

In Iraq, prolonged conflict and fragmented healthcare systems have hindered thorough nutritional assessments, especially in the Kurdistan Region, which possesses unique cultural and environmental characteristics. Current research in Iraq, particularly in central and southern areas, indicates that vitamin D deficiency (VDD) rates surpass 60%, a situation worsened by veiling practices and economic instability (Mokif, Mahdi, Al-Mammori, Al-Dahmoshi, & Al-Khafaji, 2022). Data from Kurdistan is limited despite the region's distinct climatic diversity, agrarian economy, and context of post-conflict recovery. No comprehensive research has investigated urban-rural disparities in this region, characterized by significant urbanization that may have modified conventional sun exposure patterns and dietary practices. Urban centers like Erbil may reflect global trends of heightened VDD resulting from high-rise living and vehicular pollution. Despite being more agrarian, rural areas often lack access to fortified foods and supplementation programs (Arshad, Mahmood, Ahmed, Manji, & Ahuja, 2020).

This cross-sectional study evaluates serum 25-hydroxyvitamin D [25(OH)D] levels, the gold-standard biomarker, in urban and rural populations in Kurdistan, thereby addressing existing gaps in the literature. Based on regional research, we propose that urban residents demonstrate reduced levels of 25(OH)D due to lifestyle factors. Rural populations may exhibit unique risk profiles associated with dietary habits and access to healthcare. The findings seek to guide specific public health strategies, acknowledging the complex factors influencing VDD in transitioning societies. This study clarifies disparities in VDD's sociodemographic dimensions and supports the need for context-specific interventions in under-researched post-conflict areas.

Methodology

Study Design

This cross-sectional study examined the differences in serum 25-hydroxyvitamin D [25(OH)D] levels between urban and rural areas in the Kurdistan Region of Iraq. Participants were recruited from urban areas Halabja and Sulaymaniyah governorate and rural regions, categorized according to administrative boundaries and self-reported residency. The inclusion criteria included individuals aged 2 years or older who had resided in the region for at least 6 months. The exclusion criteria ruled out pregnant individuals and those with conditions that impact vitamin D metabolism, such as chronic renal or liver disease. Ethical approval was granted by the Institutional Review Board of Sulaimani Polytechnic University, and written informed consent, or parental consent for minors, was obtained before participation.

Blood Sample Collection

Fasting venous blood samples (5 mL) were obtained from participants between 8:00 and 10:00 AM to reduce diurnal variation. Samples underwent centrifugation at 3,500 rpm for 10 minutes within 2 hours post-collection to isolate serum. Aliquots were maintained at -80°C before analysis to ensure the stability of the analytes. Standardized protocols were implemented to ensure biosafety and reduce hemolysis.

Serum 25-Hydroxyvitamin D Assay

Serum 25(OH)D levels were measured using a chemiluminescence immunoassay (CLIA) with the Vitamin D concentration was measured using the VIDAS® 25 OH Vitamin D Total assay (catalog number BIM - ISIN: FR0010096479) from bioMérieux, which utilizes an enzyme-linked fluorescent assay (ELFA) technology analyzer. The assay's coefficient of variation (CV) was less than 10% for intra- and inter-assay precision. Vitamin D status was classified as deficiency (<20 ng/mL), insufficiency (20–29 ng/mL), and sufficiency (≥30 ng/mL), according to the guidelines set by the Endocrine Society(Holick et al., 2011). Quality control encompassed daily calibration and validation using internal standards.

Data Collection

Demographic (age, gender, residency), anthropometric (weight, height, BMI), lifestyle (physical activity [Sport: 1=Yes, 2=No], smoking [1=Yes, 2=No]), and clinical variables (hypertension, comorbidities) were collected via structured questionnaires and medical records. Biochemical parameters (vitamin D, blood sugar, lipid profile) were extracted from laboratory reports. Missing data (#NULL! entries) were addressed through listwise deletion, retaining only complete cases for analysis.

Statistical Analysis

Data analyses were performed using SPSS statistical software Version 27.0 (SPSS Inc., Chicago, IL, USA) and GraphPad Prism 10.1 (GraphPad Software Inc., San Diego, CA, USA). The Mann-Whitney U test was used to compare vitamin D levels between rural and urban populations and between men and women. Independent samples t-tests were conducted to assess blood vitamin D and lipid profile biomarkers between urban and rural groups. A significance level of $p < 0.001$, and data was expressed as the mean ± Standard deviation of the mean (SD).

Ethical Considerations

The study adhered to the Declaration of Helsinki. Confidentiality was maintained through anonymized data coding, and participants received individualized vitamin D reports with medical recommendations if deficient.

Result

Descriptive Statistics of Study Variables

The table below (Table 1) displays the descriptive statistics for the demographic, anthropometric, and biochemical variables of the study participants (N = 214). Continuous variables are expressed as mean ± standard deviation (SD), while categorical variables (Gender, Residence) are summarized by proportions.

Table1: Demographic, anthropometric, and biochemical variables of the study

Variable	N	Range	Min	Max	Mean ± SD	Variance
Demographics						
Gender	83 (1)	38.8%	1	2	1.61 ± 0.49	0.24
(1: Male, 2: Female)	131(2)	61.2%	1	2	1.61 ± 0.49	0.24
Age (years)	214	95	2	97	40.62 ± 16.14	260.52
Anthropometrics						
Weight (kg)	214	91.00	10.00	101.00	67.66 ± 14.75	217.63
Height (m)	214	1.36	0.60	1.96	1.63 ± 0.16	0.03
BMI (kg/m²)	214	25.10	12.40	37.50	25.28 ± 3.98	15.82
Residence	29(1)	13.6%	1	2	1.14 ± 0.34	0.12
(1: Village, 2: Urban)	185(2)	86.4%	1	2	1.14 ± 0.34	0.12
Biochemical						
Vitamin D (ng/mL)	214	69.90	2.10	72.00	16.15 ± 11.20	125.45
Blood Sugar (mg/dL)	59	222.00	78.00	300.00	119.19 ± 46.64	2175.60
Cholesterol (mg/dL)	92	341.00	90.00	431.00	169.57 ± 51.51	2652.84
Triglycerides (mg/dL)	92	663.00	47.00	710.00	194.60 ± 130.62	17061.30
HDL (mg/dL)	80	53.00	27.00	80.00	42.80 ± 11.66	135.94
LDL (mg/dL)	79	185.00	25.00	210.00	103.11 ± 40.43	1634.95

There is a difference in serum vitamin D levels between urban and rural populations.

The non-parametric test was correctly utilized, supposing non-normality in the data. The Mann-Whitney U test analyzed vitamin D levels between rural and urban populations. The urban group exhibited a mean rank of 105.92, but the village group demonstrated a superior mean rank of 117.57. The test statistic findings ($U = 2390.50$, $W = 19595.50$, $Z = -0.942$) produced a non-significant p-value of .346 (two-tailed). No statistically significant difference exists in vitamin D levels between rural and urban populations ($p > .05$) (Figure 1).

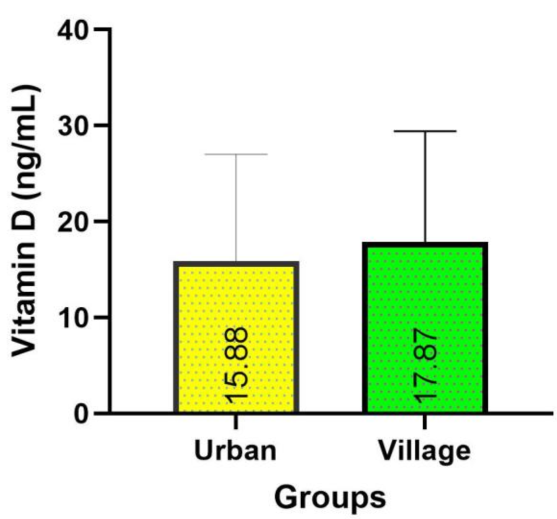

Figure 1. The relationship between urban and village populations and serum vitamin D levels Data are expressed as mean ±SD.

There is a relationship between lipid profiles and serum vitamin D levels.

Based on the Shapiro-Wilk test for normality and Levene's test for homogeneity of variances, we compare the outcomes of independent samples t-tests for blood vitamin D and lipid profile biomarkers between urban and rural groups.

No substantial difference in vitamin D levels was detected between the groups (t (212) = -0.891, p = 0.374; Mean Difference = -1.99, 95% CI: [-6.41, 2.42]). Cholesterol levels exhibited no significant difference (t (90) = -1.246, p = 0.216; Mean Difference = -29.43, 95% CI: [-76.35, 17.48]). No notable difference in triglyceride levels (t (90) = 0.266, p = 0.791; Mean Difference = 14.72, 95% CI: [-95.41, 124.86]). HDL levels exhibited no significant difference between groups (t (78) = -0.316, p = 0.753; Mean Difference = -1.71, 95% CI: [-12.49, 9.07]). A statistically significant difference in LDL levels was identified (t (77) = -2.294, p = 0.025; Mean Difference = -41.73, 95% CI: [-77.95, -5.50]). Rural individuals had reduced LDL levels compared to their urban counterparts (Figure 2A).

The Pearson correlation coefficients for the biomarkers are presented in Figure 2B. Vitamin D had no significant associations with cholesterol (r = -0.044, p = 0.678), TG (r = 0.007, p = 0.945), HDL (r = 0.030, p = 0.794), or LDL (r = -0.063, p = 0.584).

Significant positive relationships were identified between cholesterol and triglycerides (r = 0.532, p < 0.001) as well as between cholesterol and LDL (r = 0.767, p < 0.001). Triglycerides exhibited a positive correlation with LDL (r = 0.341, p = 0.002) and an inverse correlation with HDL (r = -0.313, p = 0.005). HDL had no significant correlation with LDL (r = -0.118, p = 0.299).

This research underscores clinically significant relationships, notably the robust correlation among cholesterol, triglycerides, and LDL, indicating interconnected metabolic pathways. The negative connection between triglycerides and HDL highlights the intricacies of lipid metabolism.

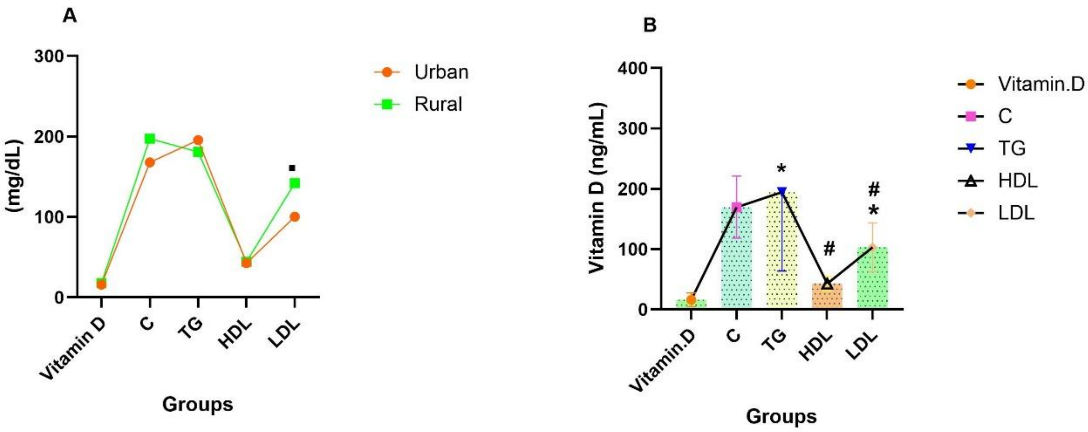

Figure2: Relationship between lipid profile and serum vitamin D levels.

Cholesterol, C; Triglyceride, TG; High-density lipoprotein, HDL; Low-density lipoprotein, LDL:

*vs. C; #vs. TG. ($p \leq 0.001$). Data are expressed as mean ±SD.

There are differences in serum vitamin D levels between men and women.

This research analyzed serum vitamin D concentrations in male and female participants through an independent sample design. Descriptive statistics revealed that males (N = 83) exhibited a higher mean vitamin D level (M = 16.98, SD = 9.29, range: 3.97–53.30) than females (N = 131; M = 15.63, SD = 12.26, range: 2.10–72.00). The coefficient of variation for females was 0.785, exceeding the 0.547 observed for males, indicating increased variability within the female group.

Assumption checks indicated that the residuals for vitamin D levels were not normally distributed (Shapiro-Wilk test: W = 0.834, p < .001). The Mann-Whitney U test was utilized as a non-parametric alternative to the independent samples t-test. The analysis revealed a statistically significant difference between the groups (U = 6455.50, p = .021). Levene's test for equality of variances yielded a non-significant result (F (1, 212) = 3.276, p = .072), thereby supporting the assumption of homogeneity of variances.

The findings indicate that males demonstrated significantly elevated vitamin D levels relative to females, accompanied by moderate effect sizes and considerable variability, especially within the female group. Because of normality violations, applying non-parametric methods was warranted, ensuring a robust statistical interpretation (Figure 3).

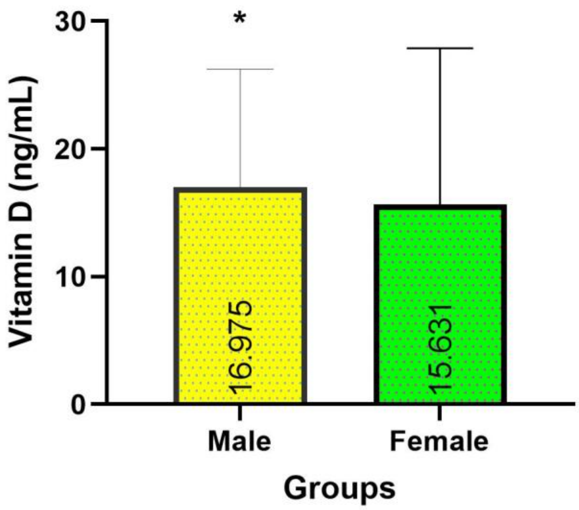

Figure 3. There are differences in serum vitamin D levels between men and women. *vs. Female (p ≤0.05). Data are expressed as mean ±SD

Discussion

This study examined three hypotheses about blood vitamin D levels and their correlations with urban-rural residency, lipid profiles, and gender disparities. The results indicated no notable urban-rural difference in vitamin D levels, an absence of a link between vitamin D and most lipid biomarkers (except inter-lipid correlations), and a statistically significant gender discrepancy favoring men. This discourse situates these findings within the current literature, examines mechanical interpretations, and confronts discrepancies and constraints. The Mann-Whitney U test indicated no statistically significant difference in vitamin D levels between urban and rural people (U = 2390.50, p = 0.346). Still, rural persons demonstrated a slightly higher mean rank (117.57 vs. 105.92) (Figure 1).

The lack of a substantial difference corresponds with research indicating that urbanization does not consistently forecast vitamin D levels. A van Schoor and Lips (Gaksch et al., 2017), Meta-analysis identified inconsistent urban-rural disparities across areas, attributing this heterogeneity to confounding variables such as dietary fortification, supplement consumption, and cultural customs. In specific contexts, urban inhabitants mitigate diminished sun exposure by consuming vitamin D-enriched diets or pills, offsetting the benefits of outdoor exercise in rural areas(Holick, 2007).

Contrarily, some studies indicate reduced vitamin D levels in urban residents attributed to air pollution (e.g., particulate matter obstructing UVB sunlight) and sedentary habits (Manicourt & Devogelaer, 2008). Rural communities in sun-abundant areas frequently have elevated vitamin D levels, as a Turkish study indicates that rural inhabitants had 25(OH)D concentrations 8 ng/mL more than their urban counterparts (Mobini, Kashi, Akha, Khani, & Bahar).

The production of Vitamin D is contingent upon UVB radiation, which urban settings may restrict owing to pollution or indoor employment. Nonetheless, rural communities may encounter obstacles such as dress customs (e.g., veiling) or nutritional inadequacies (Wahl et al., 2017). The null finding may indicate balanced trade-offs: Urban supplements compensate for less solar exposure, and rural inhabitants encounter dietary or cultural constraints.

The study did not assess direct UVB exposure, dietary habits, or supplement consumption, allowing for potential unmeasured confounders. Seasonal fluctuations in sampling may obscure genuine disparities. Neither cholesterol ($r = -0.044$, $p = 0.678$), triglycerides (TG; $r = 0.007$, $p = 0.945$), HDL ($r = 0.030$, $p = 0.794$), nor LDL ($r = -0.063$, $p = 0.584$) were found to be significantly correlated with vitamin D. Mean Difference = -41.73, $p = 0.025$) indicates that LDL levels were much lower in rural areas compared to metropolitan centers. There were significant connections between different types of lipids, such as the inverse link between TG and HDL ($r = -0.313$, $p = 0.005$) and the cholesterol-LDL ($r = 0.767$, $p < 0.001$) association (Figure 2 A, B).

The absence of a correlation between vitamin D and lipids is consistent with extensive research like the Framingham Offspring Study, which identified no relationship after controlling for BMI and physical activity(Ning, Wang, & Giovannucci, 2010). A meta-analysis by Dibaba (2014) also indicated relatively minor correlations, indicating that the significance of vitamin D in lipid metabolism may be exaggerated in observational research. In contrast, experimental investigations suggest processes that connect vitamin D to lipid control. Vitamin D receptors (VDRs) in hepatocytes regulate genes associated with cholesterol production (e.g., CYP7A1), and calcitriol may suppress lipoprotein lipase, hence diminishing triglyceride clearance (Hoseini, Rahim, & Ahmed, 2022a; Jorde & Grimnes, 2011). Epidemiological research, including NHANES, has documented inverse relationships between vitamin D and LDL (Forrest & Stuhldreher, 2011).

The null findings may indicate factors specific to the population studied. Rural participants' reduced LDL levels may be attributed to diets with lower saturated fat content or increased physical activity—variables not assessed in this study. The robust inter-lipid correlations highlight common metabolic pathways, notably the impact of hepatic VLDL secretion on TG and LDL (Feingold & Grunfeld, 2022; Hoseini, Rahim, & Ahmed, 2022b). The cross-sectional design limits the ability to draw causal inferences. Residual confounding factors, such as dietary habits, genetics, and limited sample sizes for subgroup analyses (e.g., LDL: n = 77), may hinder identifying actual effects. Males demonstrated significantly elevated vitamin D levels compared to females (16.98 vs. 15.63 ng/mL, U = 6455.50, p = 0.021), with females exhibiting more significant variability (CV = 0.785 vs. 0.547) (Figure 3).

This corresponds with global trends indicating that males often exhibit elevated vitamin D levels due to increased outdoor activity, a more significant body surface area for UVB absorption, and hormonal factors. Hagenau et al (Hagenau et al., 2009), Males exhibited 4–5 ng/mL elevated levels of 25(OH)D across 195 investigations, partially attributable to occupational sun exposure. While some studies do find gender differences, others see no differences at all after controlling for factors like clothing or sunscreen use. Seasonal and behavioral factors may explain why men and women in the finish population had comparable vitamin D levels in the winter (Kauppi et al., 2009).

Biological and sociocultural factors may account for the disparity. Estrogen enhances the expression of vitamin D-binding protein, which may decrease free vitamin D levels in women (Ross et al., 2011). Sociocultural practices, including wearing modest clothing by females, further restrict sun exposure in specific populations (Al-Mogbel, 2012). The increased variability observed in females may indicate influences from the menstrual cycle or pregnancy-related fluctuations that this analysis has not considered. The study failed to account for hormonal status, clothing habits, or sunscreen use, essential mediators of gender differences.

Conclusion

This research provides detailed insights into the epidemiology of vitamin D. The lack of urban-rural disparities underscores the intricate nature of environmental and behavioral interactions. The absence of associations between vitamin D and lipids complicates straightforward mechanistic models, highlighting the necessity for randomized trials. The gender disparity highlights the significance of sociocultural and biological factors in determining vitamin D status. Future research must incorporate direct assessments of sun exposure, dietary habits, and hormonal factors to elucidate these relationships.

Authors' Contributions

All authors read and approved the manuscript, performed procedures and data analysis, and contributed to its writing conception and design.

Conflict of Interests

Conflicts of interest: The authors declare no conflicts of interest.

In this manuscript, all tables and figures have been authored by us.

The authors signed the ethical consideration's approval.

Ethical clearance: The scientific and ethical committee at the Sulaimani Polytechnic University (SPU) has approved our work.

Consent for publications

All authors read and approved the final manuscript for publication.

Ethics approval and consent to participate

Availability of data and material

The data that support the findings of this study are available from the corresponding author upon reasonable request

Authors' contribution statement:

All authors of this study participated equally in all stages of the writing process; they also reviewed and approved the submission of this work

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References:

Al-Daghri, N. M., Al-Saleh, Y., Aljohani, N., Sulimani, R., Al-Othman, A. M., Alfawaz, H., . . . Alharbi, M. (2017). Vitamin D status correction in Saudi Arabia: an experts' consensus under the auspices of the European Society for Clinical and Economic Aspects of Osteoporosis, Osteoarthritis, and Musculoskeletal Diseases (ESCEO). *Archives of osteoporosis, 12*, 1-8.

Al-Khalidi, J., Dima, M., & Stefan, S. (2018). Large-scale modes impact on Iraq climate variability. *Theoretical and applied climatology, 133*, 179-190.

Al-Mogbel, E. S. (2012). Vitamin D status among adult Saudi females visiting primary health care clinics. *International journal of health sciences, 6*(2), 116.

Arshad, A., Mahmood, S. B. Z., Ahmed, A., Manji, A. A. K., & Ahuja, A. K. (2020). Association of vitamin D deficiency and disease activity in systemic lupus erythematosus patients: Two-year follow-up study. *Archives of Rheumatology, 36*(1), 101.

Bassil, D., Rahme, M., Hoteit, M., & Fuleihan, G. E.-H. (2013). Hypovitaminosis D in the Middle East and North Africa: prevalence, risk factors and impact on outcomes. *Dermato-endocrinology, 5*(2), 274-298.

Feingold, K. R., & Grunfeld, C. (2022). The effect of inflammation and infection on lipids and lipoproteins. *Endotext [internet]*.

Forrest, K. Y., & Stuhldreher, W. L. (2011). Prevalence and correlates of vitamin D deficiency in US adults. *Nutrition research, 31*(1), 48-54.

Gaksch, M., Jorde, R., Grimnes, G., Joakimsen, R., Schirmer, H., Wilsgaard, T., . . . März, W. (2017). Vitamin D and mortality: Individual participant data meta-analysis of standardized 25-hydroxyvitamin D in 26916 individuals from a European consortium. *PloS one, 12*(2), e0170791.

Grant, W. B., Al Anouti, F., & Moukayed, M. (2020). Targeted 25-hydroxyvitamin D concentration measurements and vitamin D3 supplementation can have important patient and public health benefits. *European journal of clinical nutrition, 74*(3), 366-376.

Hagenau, T., Vest, R., Gissel, T., Poulsen, C., Erlandsen, M., Mosekilde, L., & Vestergaard, P. (2009). Global vitamin D levels in relation to age, gender, skin pigmentation and latitude: an ecologic meta-regression analysis. *Osteoporosis international, 20*, 133-140.

Holick, M. F. (2007). Vitamin D deficiency. *New England journal of medicine, 357*(3), 266-281.

Holick, M. F., Binkley, N. C., Bischoff-Ferrari, H. A., Gordon, C. M., Hanley, D. A., Heaney, R. P., . . . Weaver, C. M. (2011). Evaluation, treatment, and prevention of vitamin D deficiency: an Endocrine Society clinical practice guideline. *The Journal of clinical endocrinology & metabolism, 96*(7), 1911-1930.

Hoseini, R., Rahim, H. A., & Ahmed, J. K. (2022a). Concurrent alteration in inflammatory biomarker gene expression and oxidative stress: how aerobic training and vitamin D improve T2DM. *BMC Complementary Medicine and Therapies, 22*(1), 165.

Hoseini, R., Rahim, H. A., & Ahmed, J. K. (2022b). Decreased inflammatory gene expression accompanies the improvement of liver enzyme and lipid profile following aerobic training and vitamin D supplementation in T2DM patients. *BMC Endocrine Disorders, 22*(1), 245.

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.

Jorde, R., & Grimnes, G. (2011). Vitamin D and metabolic health with special reference to the effect of vitamin D on serum lipids. *Progress in lipid research, 50*(4), 303-312.

Kauppi, M. J., Neva, M. H., Laiho, K., Kautiainen, H., Luukkainen, R., Karjalainen, A., . . . Ilva, K. (2009). Rheumatoid atlantoaxial subluxation can be prevented by intensive use of traditional disease modifying antirheumatic drugs. *The Journal of Rheumatology, 36*(2), 273-278.

Manicourt, D.-H., & Devogelaer, J.-P. (2008). Urban tropospheric ozone increases the prevalence of vitamin D deficiency among Belgian postmenopausal women with outdoor activities during summer. *The Journal of clinical endocrinology & metabolism, 93*(10), 3893-3899.

Mobini, M., Kashi, Z., Akha, O., Khani, S., & Bahar, A. Comparing the Serum Levels of 25-hydroxyvitamin D after Taking Intramuscular and Oral Vitamin D in Patients with Vitamin D Insufficiency.

Mokif, T. A., Mahdi, Z. A.-A., Al-Mammori, R. T. O., Al-Dahmoshi, H. O. M., & Al-Khafaji, N. S. K. (2022). Correlation of Vitamin D3, PAI-1, and HCG Hormone in Pre-and Post-Menopausal in Babylon Province. *Reports of Biochemistry & Molecular Biology, 11*(1), 36.

Ning, Y., Wang, L., & Giovannucci, E. (2010). A quantitative analysis of body mass index and colorectal cancer: findings from 56 observational studies. *Obesity reviews, 11*(1), 19-30.

Palacios, C., & Gonzalez, L. (2014). Is vitamin D deficiency a major global public health problem? *The Journal of steroid biochemistry and molecular biology, 144*, 138-145.

Ross, A. C., Manson, J. E., Abrams, S. A., Aloia, J. F., Brannon, P. M., Clinton, S. K., . . . Jones, G. (2011). The 2011 report on dietary reference intakes for calcium and vitamin D from the Institute of Medicine: what clinicians need to know. *The Journal of clinical endocrinology & metabolism, 96*(1), 53-58.

Wahl, D. R., Villinger, K., König, L. M., Ziesemer, K., Schupp, H. T., & Renner, B. (2017). Healthy food choices are happy food choices: Evidence from a real life sample using smartphone based assessments. *Scientific reports, 7*(1), 17069.