The Impact of Sun Exposure, MBI, and Skin Color on Serum Vitamin D Levels among Women in Western Libya

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Information of Article

Article history:
Received: Jan 2024
Revised: Feb 2024
Accepted: Mar 2024
Available online: Apr 2024

Keywords:
Sun Exposure
MBI (Body Mass Index)
Skin Color
Serum Vitamin D Levels
Women in Western Libya

ABSTRACT

This study investigates the association between vitamin D levels and various factors such as sun exposure, Body Mass Index (BMI), and skin color among women in Western Libya. Employing a quantitative cross-sectional design, the research analyzes data from 457 participants, examining serum vitamin D concentrations in relation to measured sun exposure, categorized BMI, and differentiated skin color. The results indicate a significant correlation between vitamin D levels and each of the three variables, with sun exposure and skin color showing a positive association with serum vitamin D levels, and BMI revealing an inverse relationship. The study employs Chi-Square Tests to validate these associations, all of which report p-values less than 0.05, thereby underscoring their statistical significance. These findings are in agreement with previous research and suggest that optimal vitamin D status is influenced by a complex interplay of environmental and physiological factors. The study's conclusions emphasize the need for public health strategies that account for individual and regional characteristics, advocating for tailored approaches to address vitamin D deficiency. The implications of this research are critical for the development of interventions and guidelines to improve vitamin D status, particularly in sun-rich environments where cultural and lifestyle factors may impact sun exposure and vitamin D synthesis.

1. Introduction

Globally, an estimated one billion people suffer from either vitamin D deficiency or insufficiency, posing a substantial public health challenge. Deficiencies in this crucial nutrient have been linked to an increased risk of certain cancers, cardiovascular diseases, and type 1 diabetes. Surprisingly, research has shown that regions with high levels of sunlight exposure, including Benghazi, which enjoys year-round sunny weather, are not exempt from widespread vitamin D deficiencies, highlighting a need for further study in these sun-rich locations (Mariam Omar, 2017). Vitamin D deficiency (VDD) is a prevalent issue worldwide, with studies highlighting its significant presence even in sun-drenched areas like the Near East and North Africa (NENA), encompassing Libya, challenging previous assumptions about sun exposure and vitamin D levels (Fathia Bougafa, Rema Tahir, 2021). Interestingly, a notable relationship was found between participants' age groups and their vitamin D levels, with the youngest participants showing the highest optimal vitamin D levels and the older age groups showing increased deficiency rates. This contrasts with other findings indicating a higher vitamin D deficiency rate among younger adults compared to the elderly (AlQuaiz AM, Kazi A; Fouda M; Alyousefi, Nada, 2018). The widespread nature of vitamin D insufficiency is influenced by various factors, including religious practices, cultural norms, educational background, and socioeconomic status, underscoring the importance of adequate vitamin D for health and well-being. This study focuses on the prevalence and risk factors associated with vitamin D insufficiency among Libyan women (Manal G, Marwan M, Aisha Muftah Z, Huda Al-Griw, 2020). Despite the ample sunlight in regions like Benghazi, vitamin D deficiency remains a significant concern, similar to other parts of Africa, Asia, and the Middle East. For instance, in Egypt, approximately 77% of individuals are vitamin D deficient, with only a small fraction achieving adequate levels. Comparable trends are observed in Qatar, Iran, Tunisia, and Saudi Arabia, where a substantial portion of the population suffers from vitamin D deficiency or insufficiency (Mariam Omar, 2017). Despite the moderate climate and abundant sunlight in the Middle East, conducive to outdoor activities and sun exposure, vitamin D deficiency is particularly prevalent among women. This phenomenon is likely due to a combination of factors, including lifestyle choices such as deliberate sun avoidance to maintain lighter skin tones, adherence to conservative dress codes, and restricted outdoor activity opportunities (Wedad Azhar, 2018)..

The aim of this study is to find out the impact of sun exposure, MBI, and skin color on serum vitamin D levels among women in western Libya. This research will provide a comprehensive literature review of the research variables. The following sections will show the methodology used in this research, as well as the tests and examinations used in the study. This paper will also discuss the findings of this research and include a conclusion for this research.

2. Literature Review

Based on the research outlined by Ghanaati et al. (2020), BaZai (n.d.), Singh (2022), Hernandez (2023), and Baño et al. (2023), the identification of vitamin D traces back to the work of Windaus and his team in the 1920s. Edward Mellanby's investigations into the effects of vitamin D on animal health involved comparative studies between dogs with and without sun exposure. Over a two-year period, Mellanby observed significant health degeneration in the dog deprived of sunlight, particularly in its leg bones, whereas the sun-exposed dog remained healthy. This led Mellanby to hypothesize the existence of a vitamin—later identified as vitamin D—that was crucial for health and could be synthesized through sunlight exposure.

Further discoveries in the late 19th century expanded the vitamin D category to include vitamin D2 and D3, as documented by researchers including Soto- Dávila et al. (2020), Balachandar et al. (2021), Seijo (2016), Chope (2022), and Gámiz-Gracia et al. (2000). These studies also delved into the chemical behavior of vitamin D, noting its unique property of not reacting significantly with most chemical solutions except for its role in calcium absorption, a process vital for bone strengthening (Van Der Velde et al., 2014; Veldurthy et al., 2016; Chen et al., 2014; Gómez et al., 2011; Michos et al., 2021). Vitamin D has a chemical structure as shown in Figure 1.

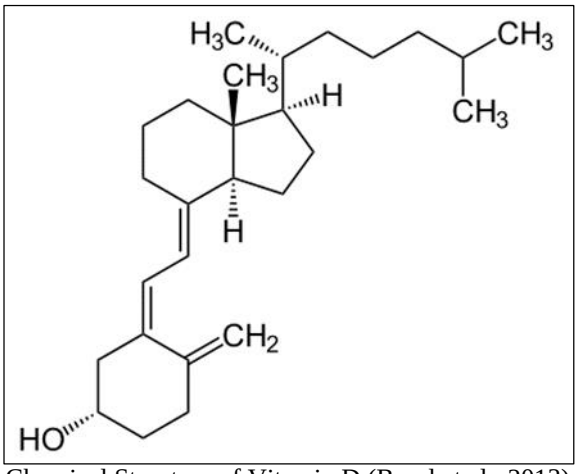


Fig. 1: Chemical Structure of Vitamin D (Borel et al., 2013)

The interaction between vitamin D and human skin, particularly in terms of absorption through sunlight exposure, has been a focus of numerous studies (Wadhwa et al., 2015; Hanel & Carlberg, 2020; Navarro- Triviño et al., 2019; Amestejani et al., 2012; Basit, 2013). These investigations highlight the critical role of sunlight in facilitating vitamin D synthesis in the skin.

The concept of vitamin D status, often measured by blood levels of 25-hydroxyvitamin D (25(OH)D), serves as an indicator of overall health and nutritional adequacy. Research such as that conducted by Stopper (2017) has linked vitamin D status inversely with BMI in diverse urban youth populations, suggesting higher BMI is associated with lower vitamin D levels. Azevedo Cabral et al. (2018) explored vitamin D deficiency in elderly men in tropical regions, noting discrepancies between sun exposure and vitamin D synthesis. Additionally, Sadat-Ali et al. (2011) examined the impact of vitamin D on bone density among patients with sickle cell anemia, while Ganie et al. (2022) investigated vitamin D deficiency in Kashmiri tribal populations. These studies collectively underscore the multifaceted relationship between vitamin D levels and various health, environmental, and demographic factors, emphasizing the need for targeted strategies to address vitamin D deficiency and enhance overall health outcomes.

3. Research Model and Hypotheses

3.1 Relationship between Sun Exposure and Serum Vitamin D Level

In their 2016 study, Krzywanski and colleagues discovered a link between sun exposure, dietary supplementation, and vitamin D levels in a cohort of 409 elite Polish athletes, who exhibited suboptimal vitamin D levels adversely affecting their health and athletic performance. The research emphasized the necessity for preventative strategies and custom interventions for elite athletes, particularly for those engaged in indoor sports, who are at a higher risk of vitamin D deficiency year-round. The study posited that optimal vitamin D status could be achieved through increased sun exposure and appropriate supplementation, noting that sun exposure during winter in lower latitude regions might be more beneficial than supplementation within recommended levels, and even superior to summer sun exposure in Poland.

The role of sun exposure as the primary source of vitamin D synthesis in the body is well recognized, with UVB radiation catalyzing the conversion of 7-dehydrocholesterol in the skin into vitamin D3, which then becomes active vitamin D3 (Holick, 2007). Several studies have underscored the positive correlation between sun exposure and serum vitamin D levels. Aris et al. (2021), in their investigation among Malay women, identified a significant link between moderate sun exposure and increased serum 25-hydroxyvitamin D levels. Similarly, research by Dix et al. (2017) demonstrated that individuals with greater sun exposure had higher serum vitamin D levels, underscoring the vital role of sun exposure in maintaining adequate vitamin D levels. These findings collectively underscore the direct relationship between sun exposure and serum vitamin D levels, highlighting the critical importance of sunlight in the synthesis of vitamin D and its subsequent levels in the serum. Hence this paper proposes the following hypothesis:

H1: There is a posistve and significant relationship between sun exposure and serum Vitamin D level among Women in Western Libya.

3.2 Relationship between (BMI) and Serum Vitamin D Level

A recurring observation in research is the inverse relationship between BMI and the levels of vitamin D in the bloodstream. Studies by Bindayel (2021) and Sadat-Ali et al. (2011) have consistently noted this pattern. The underlying reasons for this connection are complex, possibly involving the storage of vitamin D in adipose tissue, reduced vitamin D availability due to its dilution in larger body volumes, and altered vitamin D processing in individuals with higher body fat percentages (Sadat-Ali et al., 2011). Additionally, individuals with higher BMI often engage in less outdoor activity and receive less sun exposure, further exacerbating vitamin D deficiency (Sadat-Ali et al., 2011). Consequently, a higher BMI is inversely associated with serum vitamin D concentrations, positioning obesity as a significant factor in the risk of vitamin D deficiency. Hence this paper proposes the following hypothesis:

H2: There is a posistve and significant relationship between BMI and serum Vitamin D level among Women in Western Libya.

3.3 Relationship between Skin Color and Serum Vitamin D Level

Melanin concentration in the skin, which dictates skin color, is a crucial factor in the synthesis of vitamin D, with individuals possessing darker skin tones typically exhibiting reduced vitamin D production in the skin. This reduction is attributed to melanin's natural sunscreen properties, which inhibit the penetration of UVB rays necessary for vitamin D synthesis (Holick, 2007). Research indicates a clear correlation between skin color and serum vitamin D levels, where darker-skinned individuals tend to have a higher prevalence of vitamin D deficiency compared to their lighter-skinned counterparts (Gaksch et al., 2017; Aris et al., 2021). Therefore, there's an inverse relationship between skin color and serum vitamin D levels, underscoring the influence of melanin on the synthesis of vitamin D and its concentration in the serum.

Skin pigmentation varies widely across individuals and is primarily determined by melanin, which provides protection against the harmful effects of UV radiation from the sun. However, increased melanin levels in darker skin reduce the skin's ability to produce vitamin D from sunlight exposure. Studies have delved into the relationship between skin pigmentation and vitamin D status and its health implications. For instance, Dix et al. (2017) examined how skin color affects vitamin D levels in obese individuals, finding a negative correlation where darker skin is associated with lower levels of vitamin D, regardless of sun exposure and BMI. Similarly, Hussein et al. (2021) investigated the relationship between vitamin D levels, socioeconomic status, and BMI in overweight individuals, noting a significant link between skin color and vitamin D levels, which suggests that darker skin may contribute to vitamin D deficiency, particularly in individuals with obesity. These findings underscore the significant impact of skin pigmentation on vitamin D status, although factors such as sun exposure, BMI, and socioeconomic status can also influence this relationship. Hence this paper proposes the following hypothesis:

H3: There is a posistve and significant relationship between skin color and serum Vitamin D level among Women in Western Libya.

Based on the above arguments this paper propse the following conceptual framework:

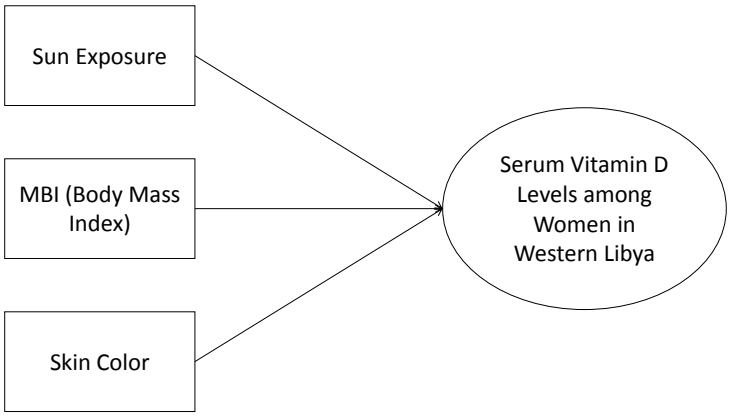


Fig. 2. Research conceptual model.

4. METHODOLOGY

This study employs a quantitative cross-sectional design to assess the prevalence of vitamin D deficiency and explore its associations with sun exposure, skin color, and BMI among women in Western Libya. The methodology encompasses a systematic approach to gather reliable and valid data. The research is concentrated at Zuwara Hospital, located on the western coast of Libya in the city of Zuwara. This hospital serves a significant patient population and is equipped with qualified staff and advanced medical facilities, ensuring accurate sample results. The study's geographical setting shares common climatic features with the majority of Libya, making the findings relevant to a broader audience.

Participants include 457 women residing on the west coast of Libya, specifically in Zwara. To protect privacy, personal details such as contact numbers and names are not required, and all participant information is kept confidential. Participants are asked to complete a questionnaire and provide a blood sample for analysis. The study ensures no collection of unrelated personal information. A random sampling technique is utilized, ensuring each potential participant within the hospital's catchment area has an equal chance of selection, thus minimizing selection bias and enhancing the study's external validity. The catchment area, including Zuwara and neighboring regions, is estimated to have a population of around 45,000 individuals. The sample size of 457 was determined using a statistical formula that accounts for the confidence level, population proportion, population size, and margin of error, with an additional 20% added for reliability, balancing statistical integrity with practical constraints. The primary research instrument is a questionnaire designed to investigate various factors influencing vitamin D levels. Statistical analysis of the collected data involves multiple steps, including data cleaning, descriptive analysis, and bivariate analysis, with the chi-squared test used to examine the relationship between dependent and independent variables. A p-value of 0.05 or less indicates statistical significance. The analysis aims to identify significant associations and factors contributing to vitamin D deficiency among the study population, enhancing the understanding of this public health issue in Western Libya.

5. Data Analysis and Results

The data analysis section of this paper delves into the exploration of potential associations between various factors and serum vitamin D levels among women in Western Libya. Employing Chi-Square Tests, the study rigorously examines the relationships between sun exposure duration, Body Mass Index (BMI), and skin color with serum vitamin D concentrations. This statistical approach enables the identification of any significant links between the categorical independent variables—sun exposure minutes, BMI categories, and skin color classifications—and the dichotomous outcome variable representing vitamin D levels (deficient or sufficient). By meticulously analyzing these associations, the research aims to shed light on the intricate interplay between environmental, physiological, and demographic factors and their impact on vitamin D status within the target population. Through this analytical process, the study seeks to contribute valuable insights into public health strategies tailored to the unique needs and characteristics of women in Western Libya.

5.1 Association between Sun exposure and serum vitamin D level

Table 1 outlines the relationship between sun exposure and serum vitamin D levels among women in Western Libya. The categorization of sun exposure duration reveals a stark contrast in vitamin D levels. A majority of the participants with less than 120 minutes of sun exposure exhibit deficient vitamin D levels, which is significantly high at 95.3%. In the group with 60 minutes of sun exposure, the deficiency is even more pronounced, with 100% of participants falling into the deficient category. However, among those with only 30 minutes of sun exposure, the spread across different vitamin

D levels is more equitable, with a notable portion having sufficient levels. Overall, the data indicate that deficient vitamin D levels are prevalent in 60% of the total 457 participants surveyed, suggesting a public health concern regarding vitamin D insufficiency.

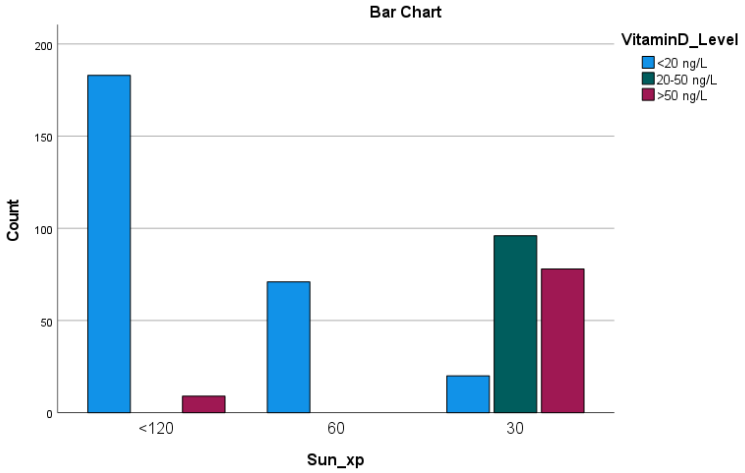
Table 1: Association between Sun exposure and serum vitamin D level

			VitaminD_Level			
			<20 ng/L	20-50 ng/L	>50 ng/L	Total
Sun_xp	<120	Count	183	0	9	192
		% within Sun_xp	95.3%	0.0%	4.7%	100.0%
	60	Count	71	0	0	71
		% within Sun_xp	100.0%	0.0%	0.0%	100.0%
	30	Count	20	96	78	194
		% within Sun_xp	10.3%	49.5%	40.2%	100.0%
Total		Count	274	96	87	457
		% within Sun_xp	60.0%	21.0%	19.0%	100.0%

In Table 2, the Chi-Square Tests provide a statistical validation of the observations from Table 1. The Pearson Chi-Square value, Likelihood Ratio, and Linear-by-Linear Association all report significant values with p-values less than 0.001, underscoring the strength of the association between sun exposure and serum vitamin D levels. The Pearson Chi-Square and Likelihood Ratio, with 4 degrees of freedom, support the hypothesis that the level of sun exposure is strongly associated with vitamin D levels. The Linear-by-Linear Association confirms a significant linear relationship, implying that increased sun exposure correlates with a change in vitamin D levels. Collectively, these statistical results affirm that the association observed is not coincidental but a reflection of the impact sun exposure has on vitamin D status in this population. The consistency of the findings across different statistical measures lends robustness to the conclusion that sun exposure is a critical factor in determining serum vitamin D levels among the studied group. To sum it up, the study found out that sun exposure measured results P-value less than 0.05 that is mean there is significance association between level of vitamin D and Sun exposure. The final outcomes of the study indicate significant associations across three variables with respect to serum vitamin D levels. The P-value for sun exposure is less than 0.05, which implies a significant association between the duration of sun exposure and vitamin D levels. This suggests that the amount of sun exposure is a determinant factor in the serum vitamin D status of the individuals studied.

Table 2: Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	348.869[a]	4	.000
Likelihood Ratio	427.789	4	.000
Linear-by-Linear Association	195.599	1	.000
N of Valid Cases	457		



5.2 Association between BMI and serum vitamin D level

Table 3 in the study explores the association between BMI categories and serum vitamin D levels. It categorizes BMI into normal, overweight, and obese groups and correlates these with serum vitamin D levels split into deficient, insufficient, and sufficient categories. The analysis shows that all individuals with a normal BMI have sufficient vitamin D levels, as evidenced by the 100% figure in the corresponding category. Among the overweight participants, the majority, 88.7%, have deficient vitamin D levels, while 11.3% fall into the insufficient category, with none displaying sufficient levels. The obese group presents a more varied distribution: nearly half are deficient, a substantial 36.1% are insufficient, and a minority of 14.1% have sufficient vitamin D levels. Across the total sample size of 457 individuals, 60% have deficient vitamin D levels, while 21% and 19% have insufficient and sufficient levels, respectively, pointing towards a potential trend that suggests higher BMI categories might be associated with lower vitamin D levels.

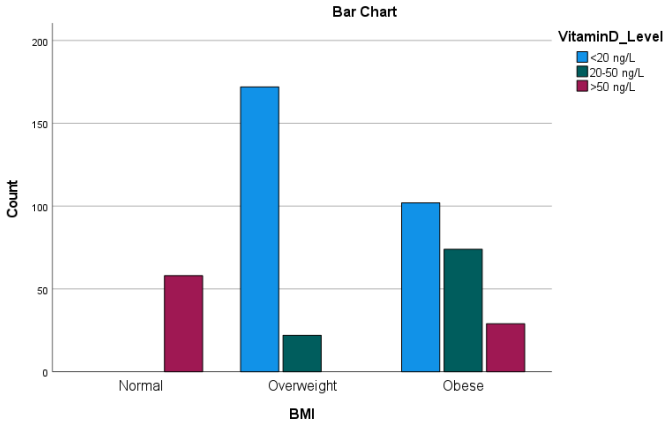
Table 3: Association between BMI and serum vitamin D level

			VitaminD_Level			
			<20 ng/L	20-50 ng/L	>50 ng/L	Total
BMI	Normal	Count	0	0	58	58
		% within BMI	0.0%	0.0%	100.0%	100.0%
	Overweight	Count	172	22	0	194
		% within BMI	88.7%	11.3%	0.0%	100.0%
	Obese	Count	102	74	29	205
		% within BMI	49.8%	36.1%	14.1%	100.0%
Total		Count	274	96	87	457
		% within BMI	60.0%	21.0%	19.0%	100.0%

Table 4 details the statistical significance of these observations using the Chi-Square Tests. With a Pearson Chi-Square value of 347.245 and a Likelihood Ratio of 324.724, both with 4 degrees of freedom, and a p-value of less than 0.001, the results indicate a highly significant association between BMI and serum vitamin D levels. The Linear-by-Linear Association further corroborates this finding, with a value of 37.299 and 1 degree of freedom, also showing a p-value of less than 0.001. These statistical tests strongly suggest that the association observed between BMI and serum vitamin D levels is not due to chance, and that as BMI increases, there is a notable change in the distribution of vitamin D levels. The results from the Chi-Square Tests affirm the hypothesis that BMI is an influential factor in determining serum vitamin D status among the population studied. To sum it up, the study found out that Body mass index (BMI) is another variable also significance to measure the level of vitamin D, because P-value less than 0.05. The Body Mass Index (BMI) variable also demonstrates significance in its relation to vitamin D levels, as the P-value is again less than 0.05. This indicates that BMI is a predictor of vitamin D status, with different BMI categories correlating with varying levels of serum vitamin D.

Table 4: Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	347.245[a]	4	.000
Likelihood Ratio	324.724	4	.000
Linear-by-Linear Association	37.299	1	.000
N of Valid Cases	457		



5.3 Association between skin color and serum vitamin D level

Table 5 elucidates the connection between skin color and serum vitamin D levels. The data categorize individuals across six different skin color categories, labeled I through VI, and correlate these with serum vitamin D level categories: deficient, insufficient, and sufficient. The study reveals a distinct trend: categories I and II, presumably representing the lightest skin tones, have 100% vitamin D deficiency. As the skin color categories progress, a shift is seen in vitamin D levels. Category III has a significant number still in the deficient range but also shows a small proportion with insufficient levels. Notably, categories IV through VI, which might represent darker skin tones, show a transition to higher vitamin D levels, with category IV having a majority in the insufficient range and categories V and VI showing all individuals with sufficient vitamin D levels. This distribution suggests that serum vitamin D levels may increase with darker skin tones within the sampled population, with a total of 60% being deficient, 21% insufficient, and 19% having sufficient vitamin D levels across the 457 individuals assessed.

Table 5: Association between skin color and serum vitamin D level

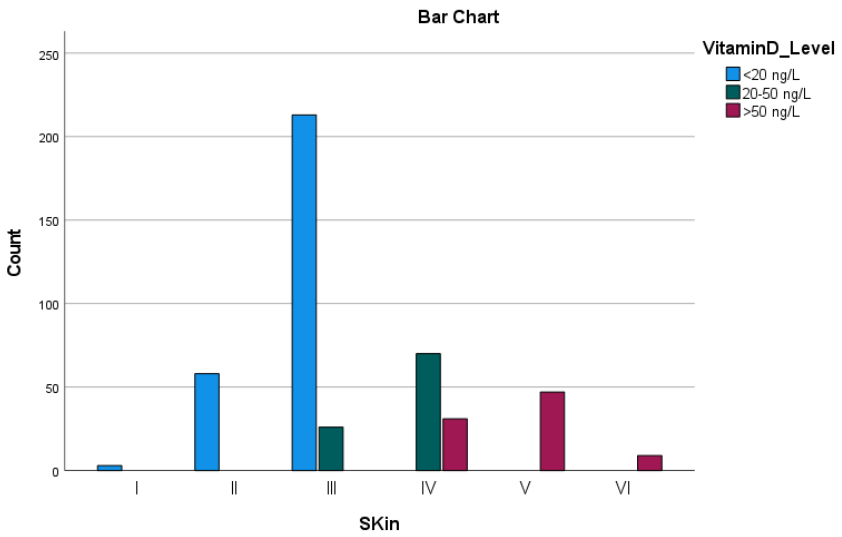
			VitaminD_Level			
			<20 ng/L	20-50 ng/L	>50 ng/L	Total
SKin	I	Count	3	0	0	3
		% within SKin	100.0%	0.0%	0.0%	100.0%
	II	Count	58	0	0	58
		% within SKin	100.0%	0.0%	0.0%	100.0%
	III	Count	213	26	0	239
		% within SKin	89.1%	10.9%	0.0%	100.0%
	IV	Count	0	70	31	101
		% within SKin	0.0%	69.3%	30.7%	100.0%
	V	Count	0	0	47	47
		% within SKin	0.0%	0.0%	100.0%	100.0%

	VI	Count	0	0	9	9
		% within SKin	0.0%	0.0%	100.0%	100.0%
Total		Count	274	96	87	457
		% within SKin	60.0%	21.0%	19.0%	100.0%

Table 6 presents the Chi-Square Test results, which evaluate the statistical significance of the observed associations. The Pearson Chi-Square value of 549.909 and the Likelihood Ratio of 579.568, both with 10 degrees of freedom, indicate a highly significant association with a p-value of less than 0.001. Similarly, the Linear-by-Linear Association shows a significant value, suggesting a strong linear relationship between skin color categories and serum vitamin D levels. These compelling statistical figures reinforce the hypothesis that skin color significantly influences serum vitamin D status. The substantial p-values across the board underscore that these associations are highly unlikely to occur by chance, affirming the relationship's validity. The study, thus, provides strong evidence that skin color plays a critical role in determining vitamin D levels among the women surveyed in Western Libya. To sum it up, the study found out that Skin color measured results P-value less than 0.05 that is mean there is significance association between level of vitamin D and Skin color. Furthermore, skin color also presents a significant association with vitamin D levels, evidenced by a P-value less than 0.05. This outcome highlights that skin color, which affects the synthesis of vitamin D due to its influence on ultraviolet radiation absorption, is an important variable in determining the serum levels of vitamin D.

Table 6: Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	549.909[a]	10	.000
Likelihood Ratio	579.568	10	.000
Linear-by-Linear Association	327.616	1	.000
N of Valid Cases	457		



6. Discussion and implications

The current paper's findings on the significant association between sun exposure and vitamin D levels resonate with previous research by Aris et al. (2021), who also observed a notable relationship between sunlight exposure and serum

25-hydroxyvitamin D concentrations. This study contributes to the growing body of evidence that suggests optimal sun exposure is critical for maintaining sufficient vitamin D levels, a fact that is particularly pertinent in regions with abundant sunlight, such as Western Libya. In discussing BMI, the results align with Bindayel (2021) and Sadat-Ali et al. (2011), who found an inverse relationship between BMI and serum vitamin D levels. The findings underscore the potential for higher BMI to be associated with lower vitamin D levels due to factors such as the sequestration of vitamin D in adipose tissue and possible lifestyle differences related to outdoor activities and sun exposure. This suggests that obesity may present a complex challenge to maintaining adequate vitamin D levels, with implications for public health interventions focusing on nutrition and physical activity.

The significant association observed between skin color and vitamin D levels in this paper is echoed in the study by Hussein et al. (2021), which reported darker skin pigmentation as a risk factor for vitamin D deficiency. The implications here extend to considerations of melanin's role in inhibiting UVB radiation absorption, which is crucial for the cutaneous synthesis of vitamin D. This has broader implications for dietary recommendations and potential fortification strategies, particularly for those with darker skin living in sun-rich regions. The findings also bring to light Cork's study (2017), which highlighted the influence of environmental and lifestyle factors on vitamin D status. While sun exposure remains a primary source of vitamin D, lifestyle choices, including sun-avoiding behaviors, could counteract the benefits of a sunny environment. This points to the need for public health policies that encourage safe sun exposure practices, particularly in regions where cultural or religious practices may limit direct sunlight exposure.

Khulood Othman (2019) and Ibrahim M. (2017) have contributed to the understanding of vitamin D metabolism and the various factors influencing its levels in the human body. Their studies underscore the importance of a holistic approach to vitamin D research, considering not only biological factors but also socio-cultural dynamics that may influence an individual's vitamin D status. Keila Valente (2022) adds to this discourse by emphasizing the significance of public health strategies tailored to address the multifactorial nature of vitamin D deficiency. The current study's findings suggest that such strategies should consider variations in sun exposure habits, BMI, and skin color when formulating vitamin D supplementation guidelines and recommendations for dietary intake. Collectively, these studies and the current paper underscore the intricate web of factors influencing vitamin D levels. They highlight the need for individualized approaches to addressing vitamin D deficiency, taking into account personal attributes such as BMI and skin color, as well as environmental factors like sun exposure. The implications for practice are clear: there is a need for nuanced public health messaging that can address these variables in promoting optimal vitamin D levels for diverse populations.

7. Conclusion

The study's rigorous analysis offers a conclusive insight into the multifaceted determinants of serum vitamin D levels among women in Western Libya. The significant associations observed with sun exposure, BMI, and skin color provide a nuanced understanding of the factors contributing to vitamin D status. This is consistent with previous findings that highlight the role of sunlight in synthesizing vitamin D, the impact of BMI on its serum levels, and the influence of melanin content related to skin color on its cutaneous production.

The implications of these findings are substantial, suggesting targeted public health strategies are essential. For instance, encouraging optimal sun exposure, particularly in sunny regions, could enhance vitamin D synthesis. However, strategies must balance the need for sun exposure with the risk of skin damage and take into account cultural practices related to sun avoidance. Furthermore, the link between higher BMI and lower vitamin D levels underscores the importance of addressing obesity as part of vitamin D deficiency prevention strategies. Considering the risk of vitamin D sequestration in adipose tissue, weight management initiatives could play a crucial role in improving overall vitamin D status.

Finally, the stark difference in vitamin D levels across skin color categories highlights a need for personalized dietary and supplementation advice, particularly for those with higher melanin levels who may require more significant vitamin D intake to reach optimal serum levels. In conclusion, this study reaffirms the complex interplay between environmental, physiological, and lifestyle factors in determining vitamin D levels, emphasizing the importance of a multifactorial approach in addressing vitamin D deficiency. Future interventions and policies should be crafted to reflect these diverse influences, ensuring they are culturally sensitive, scientifically sound, and effectively tailored to improve vitamin D status among at-risk populations.

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