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ORIGINAL RESEARCH

Association Between Vitamin D Level and Z-Score Changes of Bone Density in College-Age Saudi Girls: A Cross-Sectional Study

Omar M Al Nozha[1], Shereen El Tarhouny[2], Inass Taha[1], Intessar Sultan[3], Azza M Abdu Allah[4], Manal A Hammoda[5], Ghaidaa Elmehallawy[1], Yara Elmehallawy[6], Eman A Eysawi[7], Maha K Desouky[8]

[1]Department of Medicine, College of Medicine, Taibah University, Madinah, Saudi Arabia; [2]Department of Medical Biochemistry and Molecular Biology, College of Medicine, Zagazig University, Egypt; [3]Department of Medicine, Ibn Sina National College for Medical Studies, Jeddah, Saudi Arabia; [4]Department of Laboratory, College of Biomedical Sciences, Taibah University, Yanbu, Saudi Arabia; [5]High Quality Laboratory, Madinah, Saudi Arabia; [6]College of Medicine, Al Faisal University, Riyadh, Saudi Arabia; [7]College of Medicine, Al Rayan Colleges, Madinah, Saudi Arabia; [8]Department of Anatomy,College of Medicine, Minia University, Minia, Egypt

Correspondence: Inass Taha, Department of Medicine, College of Medicine, Taibah University, Madinah, Saudi Arabia, Tel +966505327061, Email itaha@taibahu.edu.sa

Objective: Vitamin D (VD) deficiency is a worldwide health problem. VD plays a crucial role in calcium homeostasis, phosphorus metabolism and bone health. Still much remain to understand the effect of VD deficiency on bone mass. This study aimed to evaluate the relationship between VD levels and bone mass density (BMD) among college-age Saudi females.

Methods: In a cross-sectional study, 460 females with a median age of 21 years, were enrolled, completed a comprehensive, structured questionnaire which was validated by experienced endocrinologist, a dietician, and a statistician. Body mass indexes (BMI) were calculated, and BMD was estimated through quantitative ultrasound to ankle. Serum VD, calcium, phosphate, parathyroid hormone, and alkaline phosphatase were measured using chemiluminescent immunoassay technique.

Results: VD deficiency reached up to 83.3% (66.9% insufficiency and 16.4% deficiency). Lower than normal BMD was detected in 18.3% of subjects, with only 1.1% having a non-age-matched high risk for osteoporosis. The significant independent predictors of Z-score were age of menarche, menstrual irregularities, dairy products consumption, physical activity, BMI, alkaline phosphatase, and history of previous VD supplementation.

Conclusion: VD deficiency and low BMD are highly prevalent among college-age Saudi females. Low BMD is not linked to serum level of VD but to its previous use as a supplementation. Early lifestyle changes, attention to gynecological problems, and prevention of VD deficiency are all needed to support BMD among these girls.

Keywords: vitamin D, osteoporosis, Z-score, Saudi females, bone mass density

Introduction

Vitamin D is a fat-soluble steroid hormone that has a crucial role in bone mineralization through its effect on calcium homeostasis and phosphate metabolism. In the circulation, it is bound to the vitamin D-binding protein (DBP) and undergoes the first hydroxylation in the liver, and the second hydroxylation in the kidney to form 25-hydroxy vitamin D (25(OH)D) and active hormone 1,25-dihydroxyvitamin D (1,25(OH)2D), respectively.[1]

Globally the prevalence of vitamin D deficiency is escalating into an epidemic and is considered a public health issue in many regions around the world; Saudi Arabia is not immune to these findings. Although Vitamin D can be synthesized endogenously through skin exposure to ultraviolet light (UV) and is also present in several food sources (it is plentiful in several fish and found in small amounts in milk and dairy products and other dietary supplements), there is a noticeable increase in the prevalence of vitamin D deficiency worldwide and in the Gulf region (specifically, Saudi Arabia).[2]

Satisfactory levels of vitamin D (VD) have a vital effect on bone mass in both young and old women; VD is responsible for intestinal calcium absorption, bone calcium resorption, and renal calcium reabsorption, maintaining

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calcium homeostasis and promoting skeletal mineralization. Deficiency of active vitamin D metabolites seriously affect calcification of osteoid resulting in rickets in children and adolescents or osteomalacia in adults. The skeletal manifestation of vitamin D deficiency has proven to be allied to a secondary contributing factor: hyperparathyroidism. This leads to increased bone remodeling turnover, altering calcium and phosphate metabolism and subsequently increasing the risk of osteopenia and osteoporosis.[3]

Vitamin D status is an important determinant of bone health. However, there is controversy regarding the association between 25(OH)D levels and bone mass density (BMD). By the late teen years, 90% of the peak bone mass (PBM) is mostly reached. Therefore, avoiding osteopenia and osteoporosis should begin at a young adult age, which is considered the most effective time to invest in bone health.[4]

The measurement of BMD using quantitative ultrasound (QUS) offers a low-cost, non-invasive, and easily accessible alternative to dual-emission X-ray absorptiometry (DEXA). The reliability of QUS has been confirmed.[5] Previous studies showed a high prevalence of osteoporosis and osteopenia among young Saudi females with the prevalence of 5% and 37% respectively.[6] This high prevalence of osteopenia among females highlights the urgent need for early diagnosis and intervention to reduce the risk of future osteoporosis. This aligns with recommendations made by the National Plan for Osteoporosis Prevention and Management by the Saudi Arabia's (SA) Ministry of Health that further research to reduce the onset of osteoporosis within Saudi Arabia should be undertaken.[7]

In light of the previously reported high prevalence of both vitamin D deficiency and low BMD among the Saudi population, we have assumed the presence of an association between both. This study aimed to evaluate the relationship between vitamin D levels and BMD (represented by a Z-score) among college-age Saudi females and illustrate possible contributing factors.

Subjects and Methods

Study Setting and Design

The study employed a cross-sectional design and was conducted in the female section of Taibah University, Al Rayan Colleges, Ibn Sina National College for Medical Studies, and University of Prince Mugrin, (all located at the Western Province of SA), using a structured pre-coded survey. It began during the academic year 2021/22, running from August 2021 to March 2022.

Sample Size and Sampling Technique

Our target study population consists of adult Saudi females from different colleges within the campuses (age range 18 to 26 years). G*Power software was used to estimate the sample size, taking into consideration a medium effect size of 0.25 (REF=25), an alpha error probability of 0.05, and a power of 95%. It was estimated that a sample size of at least 400 females would be needed to achieve statistical power. Thus, the study sample was 500 participants to account for any missing or incomplete data. Participants were selected using a non-randomized consecutive convenient technique through different announcement techniques. This was achieved by sending Short Mobile Messages (SMS) messages from the students' affairs unit and social media communications to the university's female students.

Exclusion criteria included pregnant and lactating women, those suffering from primary or secondary amenorrhea or chronic illnesses, and those who are currently taking medications affecting their bones other than vitamin D and/or calcium (eg, corticosteroids, hormonal contraceptives, antiepileptic medication). In addition, those who refused to participate gave incomplete or incoherent answers or did not allow blood sampling were also excluded.

Data Collection Form

The structured pre-coded questionnaire was built in Arabic language by an expert endocrine researcher. The questionnaire was available in both a paper form and an electronic Google form. The latter was used whenever possible; this was achieved either by sending the QR code through social media or through its direct scanning. The questionnaire was pilot tested through initial enrollment of 100 subjects and then revised by the endocrinologist, dietician, and a statistician member of the research team.

The first section of the questionnaire consisted of questions concerning sociodemographic data (age and marital status), smoking, menstrual and obstetric history, history of osteoporosis or fractures, vitamin D deficiency or previous intake of vitamin D and/or calcium, and family history of osteoporosis and/or fractures.

The second section included the type and frequency of different physical activities (including walking, running, using the stairs, home activities, cycling, moderate- and high-intensity sports, and self-defense and body-building sports). This section also asked about the time spent sitting or lying down while socializing, watching TV, or using smartphones or computers.

The third section was concerned with food consumption questions for dairy products. Participants gave the frequency of their daily intake of milk, yogurt, and/or natural or processed cheese. Less than three daily servings of dairy products were considered a low intake (as per the Dietary Guidelines Advisory Committee).[8]

Ethical Considerations

The study was performed in compliance with the Helsinki Declaration and in accordance with the regulations laid down by the College of Medicine, Taibah University's ethical committee (No. TU-20-016) dated 18th February 2021. Written informed consent was obtained from all participants before their participation in the study.

The consent form was a paper form that introduced the research and researchers, outlining the research objectives and allowing the participants to give informed written consent. In addition, details of how to communicate with the researchers were given in the consent form. All data obtained were kept confidentially and safely with the principal investigator.

Measurement of Body Mass Index (BMI)

The weight of participants was measured to the nearest kilograms using a standard weight scale with weight reported. The height was measured to the nearest cm using a stadiometer. Their body mass indexes (BMIs) were then calculated using the equation: weight in kilograms divided by height in metres.[2] Based on WHO Classification of overweight/obesity in adults, participants with a BMI < 18.5 were considered to be underweight; those with a BMI ranging from 18.5–24.9 were considered lean; those with a BMI ranging from 25.0–29.9 were considered overweight; and those with BMI ≥ 30.0 were considered obese.

Bone Mineral Density Measurement

BMD measurement was performed on one leg for all the participants using QUS technique: Lunar Achilles Insight TM-GE Healthcare (a water-bath ultrasound system). The heel of the non-dominant leg (left) was placed between two ultrasonic transducers in a 37 °C water bath. The ultrasound used high-frequency sound waves to measure the heel's BMD, following which the T-score and Z-score were recorded using a standard protocol supplied by the manufacturer. The measurement results (including measurement values and fracture-risk color graphs) were displayed, stored, and printed, allowing for easy clinical assessment and visual communication with the participant.

The reliability of QUS has been confirmed as for the osteopenia, osteoporosis and fracture risk.[5,9] We elected to use it for our study as to avoid DEXA exposure for the young female subjects enrolled, some may be in their early pregnancy.

The T-score compares the subject's BMD to the mean value in a healthy and young reference population, while the Z-score compares the subject's BMD to the age-matched population. Because of the young age of the participants, we considered the Z-score rather than the T-score and relied only on the age-matched Z-score to determine normal BMD (>–2 Z-score). Moreover, in the young age group, QUS cannot be used to diagnose osteopenia or osteoporosis; therefore, according to the position statement by the International Society for Clinical Densitometry (ISCD), we categorized the T-score as a risk category. A T-score of ≥−1.0 was classified as low risk; a score <−0.1 – >−2.5 was classified as being at some risk of having osteopenia, while a T-score of ≤−2.5 was classified as being at a high risk of osteoporosis, as per the Food and Drugs Administration (FDA's) Agency approval.

Blood Sample Collection

Blood samples from participants (10 mL) were withdrawn by venipuncture in completely aseptic conditions through a puncture of an antecubital vein. Samples were left in a plain tube for 30–60 minutes to allow for spontaneous clotting at room temperature. They were then centrifuged at 3000 rpm for 10 minutes to achieve serum separation. The obtained sera were frozen immediately at -80 °C for future analysis, and the serum calcium, phosphate, and alkaline phosphatase were measured using standard analytical techniques (BECKMAN COULTER). The serum VD was measured by chemiluminescent microparticle immunoassay (CMIA; ARCHITECT, Abbott, USA). The general consensus on VD deficiency, as suggested by Endocrine Society Guidelines, is that deficiency exists when serum 25(OH)D levels are ≤20 ng/mL, insufficiency when they are 21 to 29 ng/mL, and sufficiency when they are 30–100 ng/mL.[10] Serum parathyroid hormone (PTH) was estimated using a chemiluminescent immunoassay technique (BECKMAN COULTER, ACCESS immunoassay systems). Lab technicians were blinded to the study outcomes.

Statistical Analysis

The data were analyzed using the Statistical Package for the Social Sciences (SPSS; IBM Corp. Released 2013, IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY, USA). The reliability of the questionnaire (content validity) was tested by SPSS using Cronbach's alpha (r=0.87). Categorical variables were represented as percentages and frequencies, while numerical variables were summarized by calculating the median and interquartile range (IQR) due to their skewed distribution. The correlation between laboratory data and both the T-scores and Z-scores was performed using the Spearman non-parametric test. Multiple linear regression analysis was used to identify the independent predictors affecting the participants' Z-scores. All results were considered statistically significant at a P-value < 0.05.

Results

All demographic data and clinical characteristics are summarized in Table 1. The median age of the study participants was 21 years, with an IQR of 3. About 72.5% of the participants menstruated regularly, 21.7% were married, and 20.9% had given birth previously. Additionally, 36.7% had a previous diagnosis of VD deficiency. Most girls in the studied population had a normal Z-score that matched their age (98%), with a median Z-score of -0.1 (IQR 1.4), with scores ranging from -5.4 to 4.5. Similarly, most participants had a normal median T-score of 0.00 (IQR 1.4), with scores ranging from -5.4 to 4.5. Some participants (n = 84) showed some risk of osteoporosis (18.3%) while very few (n = 5) were high risk. Only nine participants had a non-age-matched Z-score (four in the "some risk" group and five in the high-risk group).

An analysis of the estimated BMIs of all the enrolled participants indicated that a significant proportion (47.9%) were categorized as "lean". In addition, an analysis of the participants' dietary habits indicated that 80.7% of the girls consumed an inadequate amount of dairy (less than three servings daily), and that 86.3% engaged in physical activity. Weight categories and lifestyle habits are summarized in Table 2.

Serum calcium and phosphate levels were within the reference range for most of our patients, as were serum alkaline phosphatase and PTH. However, the serum level of 25(OH)D was only within the sufficiency range for 12.9% of participants. The laboratory findings are given in Table 3.

Among the participants, there were small but significantly positive correlations between alkaline phosphatase and both the T-score (r = 0.112; p = 0.016) and the Z-score (r = 0.113; p = 0.015): Table 4. However, there were no statistically significant correlations between VD level and either T-scores (0.037; p = 0.425) or Z-scores (r = 0.032; p = 0.495: Table 4).

However, in the regression analysis, all demographic, lifestyle, clinical, and biochemical data (including VD levels) showed a significant Z-score prediction model. There was a normal distribution of error terms without autocorrelation between residuals (the Durbin–Watson statistic was 0.964) or collinearity (the variance inflation factor [VIF] was < 4). This could explain 16.5% of variability (F = 2.825 [16: 212]; p = 0.000; adjusted R^2: 16.5%). After controlling for all factors, the independent significant predictors of Z-score among college-age Saudi girls were age of menarche (OR: 0.188; 95% CI: 0.028–0.206; p = 0.010), menstrual irregularities (OR: -0.184; 95% CI: -0.383–-0.051; p = 0.011), history of VD supplementation (OR: 0.188; 95% CI: 0.028–0.206; p = 0.010), dairy intake (OR: -0.141; 95% CI: -0.715–0.025; p =

Table 1 Demographic Data and Clinical Characteristics Among College-Age Saudi Girls

		N (%) N= 460
Age: median years (IQR)[a]	21 (3)	
Menarche: median years	13 (2)	
Menstruation	Regular	316 (72.5%)
	Irregular	120 (27.5%)
Marital status	Single	360 (78.3%)
	Married	100 (21.7%)
Previous labor		96 (20.9%)
History of Fractures		24 (5.5%)
History of Osteoporosis		14 (3.2%)
History of Vitamin D Deficiency		160 (36.7%)
Vitamin D ± calcium intake		121 (27.8%)
Family history of Osteoporosis/ fracture		73 (16.7%)
T-Score median (IQR): MIN-MAX		0.000 (1.4) -5.4–4.5
T-Score Category	Low risk (≥-0.1)	371 (80.7%)
	Some risk (<-0.1 - > -2.4)	84 (18.3%)
	High risk (≤ -2.5)	5 (1.1%)
Z-Score median (IQR): MIN-MAX		-0.1 (1.4) -5.4–4.6
Z-Score Category	Age Matched (>–2).	451 (98%)
	Non-age matched (≤2)	9 (2%)

Note: [a]Interquartile Range.

0.035), physical activity (OR: 0.353; 95% CI: 0.118–0.283, p < 0.001), BMI (OR: 0.187; 95% CI: 0.009–0.067; p = 0.011), and alkaline phosphatase (OR: 0.163; 95% CI: 0.002–0.020; p = 0.020). VD level was a statistically insignificant predictor of Z-score if measured as a sole factor. (OR: 0.104, 95% CI: -0.004–0.027; p = 0.150: Table 5).

Discussion

In The current study we found that VD deficiency among college-age Saudi females is very prevalent, reaching up to 83.3% (66.9% insufficiency and 16.4% deficiency). Only 12.7% of the participants showed a normal level of 25(OH)D, which is the best clinical indicator of VD status in the blood.

Studies measuring VD in the Saudi population started to appear in the late 1980s; most of the results proved that there was a deficiency in this hormone among the Saudi population,[11] with a greater deficiency seen during the summer months. Since then, studies have been conducted that focus on different age and gender groups, with escalating reports of VD deficiency reaching up to 83.6%.[12]

Our study was conducted in the western province of Saudi Arabia, with a latitude of 24.4 °N. Sunlight is plentiful throughout the year, so it was expected that its residents would have a lower prevalence of VD deficiency than people living in high-altitude cities; however, our results revealed a very high prevalence of VD deficiency among young females of college age in this region.

Table 2 Weight Categories and Lifestyle Habits Among College-Age Saudi Girls

		N (%) N= 460
BMI[a]: median (IQR)[b]: kg/m 2		22.52 (7.47)
Weight categories	Underweight	80 (17.4%)
	Lean	220 (47.9%)
	Overweight	96 (20.7%)
	Obese	64 (14%)
Smoking		47 (10.8%)
Physical activity	No	3 (13.7)
	Yes	397 (86.3)
Daily TV/computer time median (IQR): hours		3 (3)
Dairy products	< 3 servings daily	371 (80.7%)
	≥ 3 servings daily	89 (19.3%)

Notes: [a]Body Mass Index, [b]Interquartile Range.

Table 3 Laboratory Findings

Serum Level (Reference Range)	Median (IQR)[a]
Serum calcium (8.6–10.3 mg/dl)	9.4 (0.6)
Serum phosphate (2.8–4.5 mg/dl)	4 (0.4)
Alkaline phosphatase (44–147 U/L)	62 (18)
Parathyroid hormone (PTH) (10–55 pg/mL)	37.78 (27.33)
Serum 25 hydroxy vitamin D (25(OH)D) (ng/mL); Sufficiency level (30–100 ng/mL) Insufficiency level (21 to 29 ng/mL) Low level (≤20 ng/mL)	16.4 (11.63) 60 (13%) 315 (68.5%) 85 (18.5%)

Note: [a]Interquartile Range.

This could be explained by a conservative lifestyle, a fully concealed dress code that covers most of the body, very low outdoor social activities, and very hot weather throughout the year, with temperatures reaching above 50 °C (122 °F) in summer (an obstacle for outdoor activity). All these factors decrease exposure to sunlight, thereby reducing UVB-induced VD synthesis in the skin. Dietary habits and genetic variants may also be considered.[13]

Our result was in concordance with Anouti et al findings, who stated that VD deficiency among immigrants in the United Arab Emirates (UAE) is over 80%.[14] The variables used by Anouti et al were; low dietary intake of VD, obesity, avoidance of sun exposure, and a covered dress style (either due to cultural or religious reasons).

Several other studies targeting the young age population show similar results related to VD deficiency. A UAE study of 208 students reported normal VD levels in only three students.[15] An Italian study shows that 49.9% of the adolescent sample population had VD deficiency and 32.3% had VD insufficiency.[16] In addition, results reported by Kardelen et al indicate that only 8.8% of medical students in Istanbul, Turkey, have sufficient VD levels.[17]

Table 4 Correlations Between Serum Laboratory Levels and Both T- and Z-Score Among College-Age Saudi Girls

		T-Score	Z-Score
Serum calcium	R	-0.017	-0.018
	P	0.719	0.699
Serum 25(OH) VIT D	R	0.037	0.032
	P	0.425	0.495
Serum Parathyroid hormone	R	0.023	0.028
	P	0.618	0.547
Serum Phosphate	R	0.092*	0.091
	P	0.050	0.050
Serum Alkaline phosphatase	R	0.112	0.113
	P	0.016[a]	0.015[a]

Note: [a]Differences were considered statistically significant at p value < 0.05.

Table 5 Predictors of Z-Score Among College-Age Girls

	Standardized Coefficients	P	95.0% Confidence Interval for B[a]	
	OR		Lower Bound	Upper Bound
Marital status	-0.126	0.083	-0.454	0.028
Menstrual Irregularities	-0.184	***0.011***[b]	-0.383	-0.051
TV/computer use (hours)	-0.002	0.976	-0.293	0.285
Smoking	0.012	0.851	-0.225	0.272
History of Vitamin D Intake	-0.204	***0.004***[b]	-0.782	-0.156
History of Vitamin D Deficiency	0.084	0.239	-0.063	0.249
Dairy products	-0.141	***0.035***[b]	-0.715	-0.025
Age	-0.016	0.826	-0.047	0.038
Age of menarche	0.188	***0.010***[b]	0.028	0.206
Alkaline Phosphatase	0.163	***0.020***[b]	0.002	0.020
Body Mass Index	0.187	***0.011***[b]	0.009	0.067
Serum phosphate	0.116	0.086	-0.033	0.495
Physical Activity	0.353	***0.000***[b]	0.118	0.283
Parathyroid hormone	-0.029	0.694	-0.008	0.005
Serum Calcium	-0.099	0.153	-0.302	0.048
Serum 25 OH VIT D	0.104	0.150	-0.004	0.027

Notes: [a]Lower and upper limits of 95% Wald confidence interval. [b]Italic and bold text indicates statistically significant values.

College-age is considered the golden period for bone mineralization, at which point about 90% of the bone mineral mass is completed. Together with other genetic factors, physical activity, and diet, VD is assumed to be one of the most important factors for PBM.[18]

This study's most pertinent finding is that, despite the prevalent low VD level among the sample population of college-age Saudi girls (83.3%), alone, it has no statistically significant association with either the T-score or Z-score. Instead, the participants' Z-scores were significantly dependent on their menstrual regularity, BMI, dietary habits, and physical activities, and were primarily predicted by alkaline phosphatase rather than serum levels of calcium, phosphate, 25(OH)D, or PTH. The link between bone turn-over, alkaline phosphatase, and BMD is explained by its function as a biomarker of bone osteoblastic activity, which varies with age and gender and is much increased during rapid growth phases such as puberty.[19] VD serum level was included in the significant regression model of Z-score variability. However, only its previous use as supplementation was an independent significant predictor of age-matched Z-score. This discrepancy could be explained by the longer time taking by VD supplementation to impact the BMD Z-score which was not reflected as a serum VD level at time of screening.

Our results showed an 18.3% prevalence of low BMD with some risk of osteoporosis, and only 1.1% had high risk of osteoporosis. The prevalence rate of low BMD among young Saudi girls detected by QUS was much lower (6% for osteopenia and 3% for osteoporosis) than what was reported in an earlier, similar study from Al Madinah.[20] Other Studies from other areas of the SA have reported a higher prevalence: a study based in Al-Khobar returned 24% for osteopenia and 11.9% for osteoporosis,[21] while the one from Riyadh returned 30.1% for osteopenia and 6.5% for osteoporosis.[22] The main reason of difference may be the different range of age of participating women. However, our prevalence rates felt within the reported ranges of studies that used the gold-standard DEXA scan among women at the age of peak BMD; from 18% to 41% for osteopenia and from 0% to 7% for osteoporosis (≤ 31 years).[23]

Discrepancies in the relationship between VD and BMD are observed. Some studies have reported a positive association between serum 25(OH)D levels and BMD, while others have found no association.[24] The reasons for this discrepancy could be attributed to differences in population, the selected age group, gender, dietary habits, and style of clothes. Data from within the KSA are also debatable and could have a geographical pattern. Study performed in the city of Jeddah, also on the western province of Saudi Arabia; have reported a significant correlation between VD and bone mineral density.[25] In Al Khobar, a city on the Gulf coast, a similar association between VD and BMD has been proven among different male and female age groups.[26] Another study has reported a positive correlation between serum 25(OH) D_3 and BMD for gestational diabetes mellitus patients during mid to late pregnancy; these subjects were prone to VD deficiency and bone loss.[27] Our results agreed with the study done by Alkhanzian et al, who reported absence of significant correlation between VD levels and bone mineral density among Saudi and non-Saudi adults residing Riyadh.[28] The same results were also proved by Ghannam et al in 1999, who found no significant correlation between VD levels and BMD among lactating and pregnant Saudi females.[23] Also in agreement with our results were findings by Sayed Hassan et al, who found no significant relationship between serum VD and BMD among the Syrian population and who assumed that, after adjustment for potential predictors, PTH explains about 3% of the variation in total hip BMD.[29]

Our result is also consistent with work by Wei et al on the Chinese population, which revealed no association between serum 25(OH)D levels and the BMD of young and middle-aged women and in middle-aged and elderly men.[30] However, in the same study, the researchers found a positive correlation between serum VD and BMD in old women and young men. PTH has no correlation in this study.

Recently, a comprehensive study by Segheto et al has, through systematic review and meta-analysis, analyzed the association between VD level and bone health in adults. The majority of the results showed a positive correlation.[31]

In our study, we measured only the total 25(OH)D. The free VD is a portion of VD in circulation that is unbound to protein. Around 85–90% of the total VD in circulation is bound to its specific binding protein (DBP) and (weakly) to plasma albumin (10–15%), leaving a small fraction (< 1%) in its "free form". This explanation could be the cause of the non-significant correlation between total VD and BMD.

Strengths and Limitations

This study of the prevalence of VD deficiency and its relation to BMD among the college-aged group has a valuable implication related to the global health of this young population. A parallel assessment of VD and BMD at college age is a great help to address this health problem. Early diagnosis and treatment would prevent further effects on bone health. Additionally, an estimation of free VD could explain some of our results and provide recommendations for further study.

Conclusion

VD deficiency and low BMD are highly prevalent among college-age Saudi females, whom VD supplementation may enhance the development of an age-matched Z-score.

There is, therefore, an urgent need for the early detection and prevention of both low BMD and low VD among these girls.

The strategies for the prevention of low BMD among young adult Saudi women should consider; VD supplementation, management of menstrual irregularities, increase dairy intake, and starting physical exercise early in adult life.

Interventional clinical trials are needed to evaluate the effectiveness of these mitigating strategies.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis, and interpretation, or in all areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agree on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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