

Prevalence of vitamin D deficiency and its associated factors in three regions of Saudi Arabia

A cross-sectional study

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ABSTRACT

الأهداف: قياس انتشار نقص فيتامين (د) في المملكة العربية السعودية، والكشف عن نمط الحياة والعادات الغذائية فضلاً عن تحديد عوامل الخطر المحتملة.

الطريقة: تم إجراء مسح مدرسي يستهدف طلاب المدارس السعودية وموظفيها خلال الفترة من 2013 إلى 2014 باستخدام عينة عشوائية متعددة المراحل في المناطق الوسطى والغربية والشرقية. تم حساب انتشار نقص فيتامين (د) والفرق بين المجموعات السكانية المختلفة. تم استخدام تحليل الانحدار اللوجستي لتحديد عوامل التنبؤ بعوامل الخطر المحتملة.

النتائج: كان انتشار نقص فيتامين (د) 49.5% في الطلاب و 44% في الموظفين. لم يكن نمط الحياة كافياً للحماية من استنفاد فيتامين (د). وكانت العادات الغذائية غير الصحية واسعة الانتشار، بعضها تجلى في مرحلة الطفولة بينما تجلى البعض الآخر في وقت لاحق في الحياة. وكان من بين عوامل الخطر لدى الطلبة الذين يعيشون في المنطقة الشرقية، من الإناث الذين تتراوح أعمارهم بين 16 و 19 سنة، والطبقة الاقتصادية المنخفضة والسمنة المفرطة وعدم استخدام مكملات أوميغا 3. وكان الموظفون الذين يعيشون في المنطقة الشرقية والإناث والطبقة المتوسطة الدخل ومستهلكو المشروبات الغازية ومن يعاني من نقص مكملات الفيتامينات أكثر عرضة للخطر.

الخاتمة: هناك حاجة لبرنامج التوعية الصحية باستخدام التوصيات القائمة على الأدلة. وينبغي اقتراح الفحص للكشف المبكر عن الحالة وتصحيحها كجزء من الاستراتيجية الصحية الوطنية. هناك حاجة لتحديد عبء نقص فيتامين (د) على الأمراض الأخرى للسيطرة عليها وتحسين المسار المرضي وخطورته.

Objectives: To measure prevalence of vitamin D deficiency in Saudi Arabia, unveil the life style, nutritional habits and status, as well as identify the potential risk factors.

Method: A school-based survey targeting Saudi school students and employees was conducted during the

period from 2013 to 2014 using multistage cluster random sample in Central, Western and Eastern regions. The prevalence of vitamin D deficiency and difference between various population subgroups were calculated. Logistic regression analysis was used to determine the predictors of potential risk factors.

Results: Prevalence of vitamin D deficiency was 49.5% in students and 44% in employees. Life style was not adequate to protect against vitamin D depletion. Unhealthy nutritional habits were widespread, some manifested in childhood while others manifested later in life. Living in the Eastern region, females, 16-19 years of age, low economic class, obese and lack of omega 3 supplements were risk factors in students. Employees living in the Eastern region, females, middle-income class, carbonated soft drink consumers, and lack of multivitamin supplements were at higher risk.

Conclusion: There is a need for a health awareness program using evidence-based recommendations. Screening for early detection and correction of the condition should be proposed to be part of the national health strategy. There is need for identifying the burden of vitamin D deficiency on other diseases to control and improve the prognosis of these conditions.

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Vitamin D deficiency health threats are evident since a century. It has been established as a potential risk for several diseases including rickets, growth retardation, muscle weakness, skeletal deformities, hypocalcemia, tetany and seizures in children,¹ as well as osteomalacia and hip fractures in adults.² Over the past decade, more vitamin D deficiency threats were identified, as it has been associated with non-musculoskeletal chronic diseases, such as cardiovascular diseases^{3,4} and diabetes mellitus.^{5,6} Nowadays, vitamin D deficiency became a global pandemic with over one billion people affected in all age groups and both genders.⁷ Furthermore, vitamin D deficiency was found to be a potential contributing cause of death in patients with cardiovascular diseases, cancers.⁸ Prevention and early diagnosis and treatment of vitamin D deficiency are identified as key tools to reduce its health burden and promote health notably in the elderly.⁹

In Saudi Arabia, few studies pointed out to vitamin D deficiency as a potential menace in the country. In Jeddah, the second largest city of the country located in the Western region, a prevalence of approximately 80% was reported in men and was related to obesity, low sun exposure, inadequate vitamin D supplementation, high waist-to-hip ratio, and older age.¹⁰ Similar prevalence was reported among school-aged girls notably those who consumed fewer dairy products and had a lower level of sun exposure.¹¹ These results were confirmed in individuals who came for routine checkups before blood donation at a hospital in the Eastern region,¹² it was equally detected in men and women and was not attributed to inadequate exposure to sunlight or inadequate intake of dairy products. Furthermore, vitamin D deficiency prevalence of 27-37% in healthy Saudi men was reported in a hospital-based survey in the Eastern region of the country.¹³

In Riyadh, the capital of the country located in the Central region, 29% of 2 mall visitors were reported to have vitamin D deficiency which was more common among females and anemic individuals.¹⁴ Furthermore, a recent study reported a prevalence of vitamin D deficiency of 90% in healthy term neonates born to healthy women which was not related to maternal levels of sun exposure or maternal consumption of foods rich in vitamin D.¹⁵ This controversy in the results may be attributed to the difference in the cut-off

points used to diagnose vitamin D deficiency, or the difference in the study design and target population. The studies had small sample sizes and were confined to a specific geographical region.¹⁰⁻¹⁵ Despite that these studies provided useful insights, yet the accuracy and generalizability of the findings are questionable.

Nevertheless, the potential risk of vitamin D deficiency in Saudi Arabia cannot be neglected. There is a need for identifying the magnitude of the condition in the population. Thus, the objectives of this study were to measure the prevalence of vitamin D deficiency in the country, unveil the related life style and nutritional habits and status, as well as identify the potential risk factors. The study targeted a large sample from different regions in the country and considered all population subgroups to provide more accurate estimates. The addition of children to the study is an asset to estimate the prevalence of vitamin D deficiency early in life. The results of this study will help in alerting the health system to vitamin D threat.

Methods. A school-based cross-sectional study was conducted in 3 regions of Saudi Arabia between January 2013 and December 2014. As the study aimed to assess the vitamin D deficiency threat in the country, a sample of the population was required, thus school-based survey was found to be a relevant approach to reach all age groups. Saudi school students in all levels were targeted to detect the burden of such condition early in life. Saudi school employees were a second target as they can provide an estimate of the vitamin D deficiency later in life. Furthermore, studying the status of school employees may throw light on the needs to build potent community awareness programs to promote health and halt the vitamin D deficiency threat in the Kingdom.

Sample size. The following formula was used to determine the sample size of the target population. Minimum required sample size = $D [Z_{1-\alpha}^2 \times p \times (1-p)] / d^2$ Where:

D= design effect of 2 was used to account for increased variance due to the cluster sampling technique

$Z_{1-\alpha}$ = the z-score corresponding to the desired confidence level of the estimate. A 95% confidence level (95%CI) was chosen, corresponding to $Z_{1-\alpha} = 1.96$.

p = the expected vitamin D prevalence. It was decided to test the hypothesis that vitamin D deficiency prevalence in adults is 80% according to prior data from Saudi Arabia for adults.¹⁰ However, there is no accurate prevalence of vitamin D deficiency in children, thus a prevalence of 50% was considered for school students. d = degree of precision 5% was chosen.

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The application of the above formula yields a sample size of 768 children and 492 adults in each region to participate in the study. It was expected that up to 20% of the sampled students themselves, or their parents/guardians, as well as approximately 10% of sampled employees may refuse to participate in the survey. In order to deal with this problem, the sample was inflated by 20% for students and 10% for employees. Thus, a minimum of 922 students and 541 employees from each region was considered with a total of 2,766 students and 1,623 employees to allow for assessing the prevalence of vitamin D deficiency in each region. However, we were able to recruit 4,035 students and 2,104 employees from the Central, Western, and Eastern regions of Saudi Arabia (Table 1).

Sampling technique. A multi-stage sampling technique was used to select participants. The sample was drawn from Central, Western, and Eastern geographical regions of Saudi Arabia. Owing to the limited resources, the southern and northern regions were not included in the study. A sampling frame was prepared for each region including all cities with a population greater than 500,000 inhabitants according to the last population census in 2006. Then, from each city, a number of schools were randomly selected. This number was proportional to the population living in the city. In each school, one class from each educational level (primary, intermediate and secondary schools) was randomly selected, and all students in the class were included in the study. Furthermore, all school employees of the selected schools, including teachers, administrators and other workers, were included in the study.

Individuals with renal, liver or gastrointestinal disease and those receiving any form of drug treatment that could possibly affect bone metabolism (for example, calcitonin, corticosteroids, anticonvulsants, or thyroid hormones) were excluded from the study.

Data collection. A standardized and pre-tested questionnaire was used to collect data about background characteristics including age, gender, skin color, school level for students and type of work for employees. As it

is difficult to measure the economic level using income, the type of residence was chosen as a measure of the economic status. Participants were classified into low income (those living in primitive houses), intermediate income (those living in apartments), and high income (those living in villas). Participants were also asked about their life style (exposure to sun, physical activity, and smoking habits), as well as their nutritional habits (intake of multivitamins, intake of omega 3, type of milk products consumed, and carbonated soft drink consumption).

The nutritional status was assessed by direct measurement. Body weight to the nearest 0.1kg was measured using a standard beam balance, and body height to the nearest 1mm was measured using a Harpenden stadiometer (Holtain, Crosswell, UK). Body mass index (BMI) was calculated as the weight (kilograms) divided by height squared (square meters). Body mass index was further classified into normal weight (<25 kg/m²), overweight (>25-30 kg/m²), and obesity (>30 kg/m²).

To assess vitamin D serum level, 5 ml of blood was collected from each individual as clotted sample and was kept on ice until centrifugation on the same day. Serum was kept in aliquots at -20°C until analysis. Serum levels of 25-hydroxyvitamin D were measured using chemiluminescent immunoassay (Liaison 25 OH Vitamin D Total Assay; DiaSorin, Stillwater, MN, USA). This analysis method measures the total vitamin D in the range of 10-375 nmol/L. The sensitivity of the assay is <10 nmol/l and the intra- and inter-assay coefficients of variation were 5% for the intra-assay and 10.4% for the inter-assay. We adopted the Institute of Medicine cutoff points for vitamin D levels^{16,17} classifying serum levels into sufficient (50-125 nmol/L), insufficient (25-50 nmol/L), deficient (<25 nmol/L), and toxic (>250 nmol/l).

Data analysis. To describe the study population and vitamin D serum level, we used frequencies and proportions for the qualitative variables, as well as means and standard deviations (SD) for the quantitative variables. Significant differences in proportions of vitamin D deficiency in various population subgroups were assessed using Chi-square test. Logistic regression analysis was used to calculate the adjusted odds ratio (OR) to detect the potential risk factors in students and employees. The dependent variable was vitamin D deficiency (0=no, 1=yes). The independent variables were background characteristics, life style, and nutritional habits and status. A *p*-value of <0.05 was defined as the level of significance. We used Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL, USA), version 21 for data analysis.

Table 1 - Calculated and achieved sample size of Saudi school students and employees.

Regions	Students		Employees	
	Calculated	Achieved	Calculated	Achieved
Central Region	922	1,416	541	556
Western Region	922	1,334	541	796
Eastern Region	922	1,285	541	752
Total	2,766	4,035	1,623	2,104

Ethical considerations. This study was approved by the Institutional Review Board, King Abdullah International Medical Research Center and the Ethical Committee of King Abdulaziz Medical City in the Western Region. The study was anonymous and conducted in a private place. All collected data were kept confidential. Participants were informed on the risks and benefits and their right not to provide information, or to withdraw from the study at any time without any sort of penalty. An informed consent was obtained from school employees and parents/guardians of students. An informed consent was obtained from all students.

Results. As shown in Table 2, 4,035 Saudi school students were enrolled in the study with almost equal proportion of males (50.4%) and females (49.6%). Their ages ranged from 6-19 years of age (mean=14.7, SD= 2.7). Mostly (62.2%) had light brown skin color, approximately one-third had white skin color and very few (5.6%) had dark brown, or black skin color. Approximately one-third were from the primary school, and the rest were equally distributed between the intermediate and secondary school. Furthermore, approximately 50% were of high economic level, 40.4% were of intermediate economic level, and 9.2% were of low economic level.

As for the Saudi school employees, 2,104 were recruited from the 3 geographic regions with 50.9% males and 49.1% females. Their ages ranged from 20-62 years of age (mean=38.1, SD= 7.6). Mostly (66.7%) had light brown skin color, 27.6% had white skin color and 5.7% had dark brown, or black skin color. Furthermore, 81.4% were teachers and 18.6% were other school staff. Approximately 45.1% were of high economic class, 47.3% were of intermediate economic level and only 7.6% were of low economic level (Table 2).

Table 3 shows the vitamin D level, life style, nutritional habits, and status among Saudi school students and employees. Given the sensitivity of reporting smoking habits notable in students and females, the credibility of such information is questionable and thus was not considered in further analysis.

Table 4 summarized the vitamin D deficiency among the various population subgroups. School students living in the Eastern region had the highest proportion of vitamin D deficiency than from the Central region and the Western region. The proportion of vitamin D deficiency in female students was significantly more than double the prevalence in male students (69.2% in female students versus 30.1% in male students). A significant positive relationship between age and vitamin D deficiency was observed with the highest

Table 2 - Background characteristics of Saudi school students and employees.

Characteristics	Students (n=4,035)	Employees (n=2,104)	
	n (%)	n (%)	
Gender			
Male	2,034 (50.4)	1,071	(50.9)
Female	2,001 (49.6)	1,033	(49.1)
Age			
6-9 years	180 (4.5)	-	-
10-14 years	1,754 (43.5)	-	-
15-19 years	2,101 (52.1)	-	-
20-29 years	-	297	(14.1)
30-39 years	-	813	(38.6)
40+ years	-	994	(47.2)
Skin colour			
White	1,262 (32.2)	556	(27.6)
Light brown	2,443 (62.2)	1,342	(66.7)
Dark brown	204 (5.2)	105	(5.2)
Black	16 (0.4)	10	(0.5)
School level			
Primary	862 (21.4)	-	-
Intermediate	1,594 (39.5)	-	-
Secondary	1,579 (39.1)	-	-
Occupation			
Teachers	-	1,712	(81.4)
Other staff	-	392	(18.6)
Economic level			
Low	364 (9.2)	157	(7.6)
Intermediate	1,605 (40.4)	981	(47.3)
High	2,002 (50.4)	934	(45.1)

proportion in 15-19 years age group. Low income students had significantly higher prevalence of vitamin D deficiency than the intermediate and the high economic level students. Daily exposure to sun for at least 20 minutes, being physically active, intake of full fat milk products, not drinking carbonated soft drink and taking multivitamin supplements appeared to significantly decrease the risk of vitamin D deficiency in students. Vitamin D deficiency was significantly higher with the increase in BMI, where the obese had prevalence of 60.2% as compared to 54.2% in the overweight and 47.4% in the normal weight students. However, there was no significant difference in the prevalence of vitamin D deficiency in school students by skin color and taking omega 3 supplements,

In school employees (Table 4), the proportion of vitamin D deficiency was significantly higher among participants living in the Eastern region as compared to the Central region and being least in the Western region. The proportion of vitamin D deficiency in females was

Table 3 - Vitamin D level, life style, nutritional habits and status among Saudi school students and employees.

Variables	Students	Employees
<i>Vitamin D level</i>	Total= 4,000	Total= 2,075
Sufficient	183 (4.6)	226 (10.9)
Insufficient	1,838 (46.0)	937 (45.2)
Deficient	1,979 (49.5)	912 (44.0)
<i>Daily sun exposure</i>	Total= 3,896	Total= 2,055
At least 20 minutes	2,733 (70.1)	1,111 (54.1)
<i>Physical activity</i>	Total= 1,023	Total= 2,065
Yes	1,523 (50.6)	559 (27.1)
<i>Cigarettes</i>	Total= 3,008	Total= 2,063
Yes	66 (2.2)	247 (12.0)
<i>Water pipe/shisha</i>	Total=1,018	Total= 2,036
Yes	78 (2.6)	103 (5.1)
<i>Milk products</i>	Total= 2,769	Total=1,874
Skimmed	135 (4.9)	100 (5.3)
Low fat	815 (29.4)	774 (41.3)
Full fat	1,819 (65.7)	1,000 (53.4)
<i>Drinks</i>	Total= 2,931	Total=2,042
Carbonated soft drink	2,339 (79.8)	1,367 (66.9)
<i>Multivitamins</i>	Total=3,842	Total=2,013
Yes	1,796 (46.7)	906 (45.0)
<i>Omega 3</i>	Total= 2,966	Total=1,980
Yes	199 (6.7)	155 (7.8)
<i>Body mass index</i>	Total= 3,982	Total= 2,078
Normal	2,950 (74.1)	453 (21.8)
Overweight	606 (15.2)	752 (36.2)
Obese	426 (10.7)	873 (42.0)

significantly higher the prevalence in males. Those of 30 years and over had significantly higher prevalence of vitamin D deficiency than younger age group. Daily exposure to sun for at least 20 minutes, being physically active, not drinking carbonated soft drink and taking multivitamin supplements had lower risk of vitamin D deficiency. Vitamin D deficiency was significantly higher with the increase in BMI, where the obese had a vitamin D deficiency as compared to the overweight and the normal weight. Unlike school students, those with dark skin color and those not taking omega 3 supplements appeared to be at higher risk of vitamin D deficiency. Moreover, there was no significant difference in the prevalence of vitamin D deficiency by the type of milk products consumed among school employees

By controlling for the effect of other variables, the results of the logistic regression analysis in students (Table 5) have shown that those living in the Eastern region were approximately 3 times more at risk to suffer from vitamin D deficiency than the other regions.

Female students are 4 folds more at risk to develop vitamin D deficiency than males. The risk of vitamin D deficiency increased with age, those in the 15-19 age group were 5 times more at risk than the younger age groups. Furthermore, low economic class students were at double risk of acquiring vitamin D deficiency than the well-off. In addition, the obese were at higher risk of acquiring vitamin D deficiency than the non-obese and those taking omega 3 supplements were at higher risk than those taking such supplements. However, the skin color, exposure to sun, physical activity, type of milk products, carbonated soft drink consumption and intake of omega 3 supplements did not significantly affect vitamin D deficiency.

For school employees, the results of the logistic regression analysis (Table 5) have shown that still those living in the Eastern region were 3 times more at risk to suffer from vitamin D deficiency than the other regions. Female employees are at around double risk to develop vitamin D deficiency than males. Furthermore, intermediate economic level employees were at more risk of acquiring vitamin D deficiency than the other levels. Unlike school students, employees who drank carbonated soft drink were at more risk of acquiring vitamin D deficiency than those who did not take carbonated soft drink. Those who did not take multivitamin supplements were at 1.5 more risk to develop vitamin D deficiency than those who reported multivitamin intake. However, the age, skin color, exposure to sun, physical activity, type of milk products, intake of omega 3 supplements and BMI did not increase the risk.

Discussion. Our results have shown that vitamin D deficiency is a health threat in Saudi Arabia with approximately half of Saudi school students and 44% of Saudi school employees affected in the Central, Western and Eastern regions, in addition, to other similar proportions suffering from vitamin D insufficiency in both target groups. The prevalence of vitamin D deficiency and insufficiency in our study confirm previous studies conducted in the country.¹⁰⁻¹²

The vitamin D threat appears to start early in life as approximately one-third of children between 6-9 years old had vitamin D deficiency and the problem increases with the increase in age as previously reported.¹⁸ In our study, only 10.9% of 20-62 year-old school employees had sufficient vitamin D levels and this proportion was reduced to 4.6% in 6-19 year-old school students. This is an indication that in case of in action to address the vitamin D deficiency threat, there is a potential exacerbation of this condition in the growing

Table 4 - Prevalence of vitamin D deficiency among Saudi school students and employees by background characteristics, life style and nutritional habits and status.

Variables	Vitamin D deficiency			
	Students		Employees	
	n	(%)	n (%)	P-value
Region				0.000
Central	1,410	(46.6)	552 (38.0)	
Western	1,326	(45.3)	784 (31.5)	
Eastern	1,264	(57.0)	739 (61.6)	
Gender				0.000
Male	2,015	(30.1)	1,050 (32.7)	
Female	1,985	(69.2)	1,025 (55.5)	
Age (years)				0.000
6-9	174	(31.0)	-	
10-14	1,741	(43.5)	-	
15-19	2,085	(56.0)	-	
20-29	-	-	293 (31.4)	
30-39	-	-	806 (47.6)	
≥40	-	-	869 (45.0)	
Skin color				0.442
White	1,253	(48.4)	547 (39.1)	
Light brown	2,418	(50.5)	1,327 (44.8)	
Dark brown	203	(47.8)	104 (51.0)	
Black	16	(62.5)	10 (60.0)	
Economic level				0.042
Low	360	(55.3)	154 (29.9)	
Intermediate	1,585	(48.0)	969 (47.6)	
High	1,991	(49.9)	920 (42.8)	
Daily sun exposure (minutes)				0.000
>20	2,710	(47.6)	1,094 (37.8)	
<20	1,152	(54.3)	932 (51.9)	
Physical activity				0.000
Yes	1,510	(40.5)	549 (36.2)	
No	1,484	(57.9)	1,487 (47.1)	
Milk products				0.038
Skimmed	133	(49.6)	100 (43.0)	
Low fat	809	(53.2)	761 (44.3)	
Full fat	1,810	(47.7)	988 (43.7)	
Carbonated soft drink				0.001
Yes	2,324	(51.0)	1,347 (46.6)	
No	592	(43.4)	667 (40.3)	
Vitamins				0.000
Yes	1,782	(46.4)	894 (37.0)	
No	2,032	(52.2)	1,093 (49.9)	
Omega 3				0.133
Yes	197	(44.2)	154 (35.1)	
No	2,750	(49.7)	1,799 (45.0)	
Body mass index				0.000
Normal	2,926	(47.4)	443 (35.4)	
Overweight	601	(54.2)	745 (41.7)	
Obese	420	(60.2)	861 (49.9)	

generations. Inequalities in vitamin D deficiency were encountered between regions, gender, skin color, and economic class. Our study has confirmed the existence of within-country regional variations in vitamin D levels.^{19,20} Vitamin D deficiency was found to be more pronounced in the Eastern region of the country, where the prevalence reached up to 61.6% being around 3 folds higher than in the Central and Western regions. Previously, the studies failed to attribute the detected higher prevalence of vitamin D deficiency in the Eastern region to inadequate sun exposure or sub-optimal intake of dairy products.¹² One possible reason for the high rates of vitamin D deficiency in the Eastern region was postulated to be attributed to the high level of air pollution in this region,²¹ as air pollution reduces skin exposure to ultraviolet rays.

Our results have also confirmed the gender differences in vitamin D deficiency.²² Despite that some studies in the region did not find an association between clothing habits and vitamin D deficiency,^{23,24} others postulated that the conservative culture and concealed clothing style of females in the region were potential causes of low rates of sun exposure and high rates of vitamin D deficiency.^{13,25,26} Approximately two-thirds of students and employees had light brown skin color, approximately a third had white skin color, and very few had either dark brown or black skin color. Vitamin D deficiency was more pronounced among students with light brown complexion and employees with dark brown or black skin color. However, contrary to previous studies,^{25,27} the adjusted OR did not show significant impact of skin color on vitamin D deficiency. As it is difficult to assess the economic status using income categories, as the type of residence was used as an estimate for the economic class. Our results have shown that half of students and 45% of employees are of high economic level while less than 10% can be considered of low economic class. Vitamin D deficiency was more pronounced among low economic level students than the well-off. Our study has confirmed the results of previous work referring to the relation between type of housing and vitamin D deficiency.²⁸ Low economic class students living in primitive houses were at around double the risk to have vitamin D deficiency than their better off peers. While in employees, vitamin D deficiency was more in the intermediate economic class than in the other 2 economic class categories.

Our results have shown that the potential causes of vitamin D deficiency in Saudi Arabia may be attributed to improper life style, unhealthy nutritional habits, as well as overweight and obesity. Despite that 70% of school students and 54% of school employees reported

daily exposure to sun for at least 20 minutes, vitamin D deficiency was diagnosed in 47.6% of students and 37.8% of employees and the adjusted OR failed to show significant differences in vitamin D deficiency by daily sun exposure for at least 20 minutes. Furthermore, only half of the students and around one third of employees reported being physically active. Despite that vitamin D deficiency was less in those who were physically active than in those who were not, yet the adjusted OR did not show significant differences in vitamin D deficiency by physical activity in both target groups. These results confirm previous studies^{18,22} that there may be potential decrease in the risk of vitamin D deficiency by sun exposure and physical activity, yet the life style of Saudi school students and employees is not sufficient to protect them against vitamin D deficiency. This finding might be attributed to the fact that the sunny hot weather in Saudi Arabia, almost all over the year, as well as the clothing style and conservative culture may limit sun exposure and physical activity.

Approximately 34% of students and 47% of employees consume low fat or skimmed milk products. Full fat milk products decreased the risk of vitamin D deficiency only in childhood; however, the adjusted OR did not show significant difference in vitamin D deficiency by the type of milk neither in students nor in employees. This confirms the call for full fat milk products fortified with vitamin D in childhood^{25,27} to prevent vitamin D depletion early in life as their use later on after the condition is established will not help in restoring vitamin D serum level. Approximately 80% of students and 67% of employees consumed carbonated soft drink. The proportion of vitamin D deficiency was higher among those who consumed carbonated soft drink than in those who did not. However, the adjusted odd ratios has shown the negative impact of carbonated soft drink consumption on vitamin D deficiency in employees and not in students. This is an indication to the potential cumulative negative impact of carbonated soft drink on vitamin D serum level, which manifests later in life. Approximately half of students and employees did not take multivitamins. Our results have shown that multivitamin intake has reduced the risk of vitamin D deficiency both in students and employees, yet the results were only significant for employees. This is an indication of the cumulative negative effect of lack of multivitamins, which manifests later in life. Thus, multivitamin intake in childhood may help in preserving vitamin D serum level. Furthermore, only 6.7% of school students and 7.8% of school employees reported taking Omega 3 supplements regularly. Omega 3 intake reduced the risk of vitamin D deficiency in students, yet

its impact in protecting against vitamin D deficiency was not apparent in employees. This highlights the need for omega 3 supplement in childhood to protect against vitamin D depletion and their addition cannot remedy the established condition later in life.

Approximately 26% of students and 80% of employees were either overweight or obese. As previously reported,²⁹⁻³² vitamin D deficiency increased significantly with the increase in BMI in both students and employees with 60% of obese students and half of obese employees suffering from vitamin D deficiency. However, the impact of overweight and obesity on vitamin D deficiency appeared only in students where the obese were at double risk to suffer from vitamin D deficiency. Though the adjusted OR increased with increase in BMI, yet results did not reach statistical significance in employees. This postulates that if the condition is established, weight loss will not help in correcting the vitamin D deficiency later in life.

Study limitations. Although our study used an objective, valid and reliable measure for BMI and serum vitamin D level, the data on life style and nutritional habits potentially associated with these levels were self-reported. Moreover, we were not able to control for several factors, which may impact vitamin D serum level, among them are the smoking habits and the full nutritional habits pattern. Despite that the negative relation between smoking and vitamin D levels has been detected in several studies,³³⁻³⁶ the credibility of this information was questionable given the sensitivity of reporting such practice notably in school students and females. There is a need for more in-depth research to understand the nutritional pattern and full life style practices in the country that may affect vitamin D serum level. In addition, we included 3 regions in Saudi Arabia, but the Northern and Southern regions were not represented in this study, thus an overall national prevalence of vitamin D deficiency may vary. Lastly, our target population was obtained from a school setting, which might limit the generalizability of our results.

In conclusion, vitamin D deficiency and insufficiency are highly prevalent in the Central, Western, and Eastern regions of Saudi Arabia. The condition starts in childhood and thus action early in life is needed. Females, Eastern region residents, and those in the low economic class need special attention. Inadequate life style and insufficient nutritional habits are prevailing and are potential factors affecting the vitamin D serum level. Some of them need to be controlled early in life to avoid their cumulative negative effect on vitamin D serum level later on. Thus, we recommend a potent health awareness program to promote the lifestyle and improve the nutritional habits. The planning for such

Table 5 - Factors associated with vitamin D deficiency in Saudi school students and employees, results of logistic regression analysis.

Variables	Students			Employees		
	Odds ratio	95% CI	P-value	Odds ratio	95% CI	P-value
<i>Region</i>			0.000			0.000
Central	1.00	Reference		1.00	Reference	
Western	0.94	0.79-1.13		0.88	0.67-1.17	
Eastern	2.54	1.81-3.56		2.52	1.91-3.31	
<i>Gender</i>			0.000			0.000
Male	1.00	Reference		1.00	Reference	
Female	3.87	3.20-4.68		2.31	1.79-2.97	
<i>Age</i>			0.000			0.114
6-9 years	1.00	Reference		-	-	
10-14 years	3.39	1.05-10.97		-	-	
15-19 years	4.86	1.50-15.70		-	-	
20-29 years	-	-		1.00	Reference	
30-39 years	-	-		1.42	0.99-2.02	
40+ years	-	-		1.21	0.83-1.75	
<i>Economic level</i>			0.005			0.018
Low	1.67	1.19-2.36		0.88	0.55-1.42	
Intermediate	0.93	0.77-1.12		1.36	1.06-1.73	
High	1.00	Reference		1.00	Reference	
<i>Skin color</i>			0.464			0.165
White	1.0	Reference		1.00	Reference	
Light brown	1.11	0.93-1.34		1.23	0.96-1.58	
Dark brown/black	1.18	0.80-1.74		1.43	0.88-2.31	
<i>Daily sun exposure</i>			0.846			0.530
20+ minutes	1.00	Reference		1.00	Reference	
< 20 minutes	0.98	0.80-1.20		1.08	0.85-1.38	
<i>Physical activity</i>			0.084			0.700
Yes	1.00	Reference		1.00	Reference	
No	1.18	0.98-1.42		1.05	0.81-1.36	
<i>Milk products</i>			0.787			0.650
Skimmed	1.10	0.74-1.65		0.94	0.57-1.54	
Low fat	1.06	0.87-1.28		0.90	0.71-1.13	
Full fat	1.00	Reference		1.00	Reference	
<i>Carbonated soft drink</i>			0.199			0.018
Yes	1.15	0.93-1.42		1.32	1.05-1.67	
No	1.00	Reference		1.00	Reference	
<i>Vitamin supplements</i>			0.722			0.000
Yes	1.00	Reference		1.00	Reference	
No	1.03	0.87-1.23		1.55	1.24-1.93	
<i>Omega 3 supplements</i>			0.014			0.156
Yes	1.00	Reference		1.00	Reference	
No	1.53	1.09-2.16		1.34	0.89-2.00	
<i>Body mass index</i>			0.001			0.122
Normal	1.00	Reference		1.00	Reference	
Overweight	1.24	0.99-1.57		1.05	0.77-1.43	
Obese	1.59	1.22-2.08		1.30	0.96-1.77	

program needs further research to describe the current lifestyle and nutritional habits to stress on the correct knowledge and avoid misconceptions. Furthermore, we propose adding vitamin D screening to the national health strategy of the country. There is a need for setting a screening schedule to cover all age groups for early detection and treatment of cases. Lastly, there is a need for further research to detect the burden of vitamin D deficiency on other health conditions in attempt to reduce vitamin D threat and help improve the prognosis of such conditions.

References

- Holick MF. Resurrection of vitamin D deficiency and rickets. *J Clin Invest* 2006; 116: 2062-2072.
- Lai JK, Lucas RM, Clements MS, Roddam AW, Banks E. Hip fracture risk in relation to vitamin D supplementation and serum 25-hydroxyvitamin D levels: asystematic review and meta-analysis of randomised controlled trials and observational studies. *BMC Public Health* 2010; 10: 331.
- Reid IR, Bolland MJ. Role of vitamin D deficiency in cardiovascular disease. *Heart* 2012; 98: 609-614.
- Ford JA, MacLennan GS, Avenell A, Bolland M, Grey A, Witham M; RECORD Trial Group. Cardiovascular disease and vitamin D supplementation: trial analysis, systematic review, and meta-analysis. *Am J Clin Nutr* 2014; 100: 746-755.
- Mitri J, Muraru MD, Pittas AG. Vitamin D and type 2 diabetes: a systematic review. *Eur J Clin Nutr* 2011; 65: 1005-1015.
- Mitri J, Pittas AG. Vitamin D and diabetes. *Endocrinol Metab Clin North Am* 2014; 43: 205-232.
- Holick MF, Chen TC. Vitamin D deficiency: a worldwide problem with health consequences. *Am J Clin Nutr* 2008; 87: 1080S-6S.
- Chowdhury R, Kunutsor S, Vitezova A, Oliver-Williams C, Chowdhury S, Kiefte-de-Jong JC, et al. Vitamin D and risk of cause specific death: systematic review and meta-analysis of observational cohort and randomised intervention studies. *BMJ* 2014; 348: g1903.
- Bjelakovic G, Glud LL, Nikolova D, Whitfield K, Wettterslev J, Simonetti RG, et al. Vitamin D supplementation for prevention of mortality in adults. *Cochrane Database Syst Rev* 2014; 1: CD007470.
- Ardawi MS, Qari MH, Rouzi AA, Maimani AA, Raddadi RM. Vitamin D status in relation to obesity, bone mineral density, bone turnover markers and vitamin D receptor genotypes in healthy Saudi pre- and postmenopausal women. *Osteoporos Int* 2011; 22: 463-475.
- Siddiqui AM, Kamfar HZ. Prevalence of vitamin D deficiency rickets in adolescent school girls in Western region, Saudi Arabia. *Saudi Med J* 2007; 28: 441-444.
- Elsammak MY, Al-Wossaibi AA, Al-Howeish A, Alsaeed J. High prevalence of vitamin D deficiency in the sunny Eastern region of Saudi Arabia: a hospital-based study. *East Mediterr Health J* 2011; 17: 317-322.
- Sadat-Ali M, AlElq A, Al-Turki H, Al-Mulhim F, Al-Ali A. Vitamin D levels in healthy men in Eastern Saudi Arabia. *Ann Saudi Med* 2009; 29: 378-382.
- Alsuwadia AO, Farag YM, Al Sayyari AA, Mousa DH, Alhejaili FF, Al-Harbi AS, et al. Prevalence of vitamin D deficiency in Saudi adults. *Saudi Med J* 2013; 34: 814-818.
- AlFaleh KM, Al-Manie AM, Al-Mahmoud HF, Al-Razqan HM, Al-Mutlaq AB, Al-Rumaih SA, et al. Prevalence of vitamin D deficiency in Saudi newborns at a tertiary care center. *Saudi Med J* 2014; 35: 178-182.
- Ross AC, Taylor CL, Yaktine AL, Del Valle HB, editors. Dietary reference intakes for calcium and vitamin D. Washington (DC): National Academies Press (US); 2011.
- Rosen CJ, Abrams SA, Aloia JF, Brannon PM, Clinton SK, Durazo-Arvizu RA, et al. IOM committee members respond to Endocrine Society vitamin D guideline. *J Clin Endocrinol Metab* 2012; 97: 1146-1152.
- Al-Othman A, Al-Musharaf S, Al-Daghri NM, Krishnaswamy S, Yusuf DS, Alkharfy KM, et al. Effect of physical activity and sun exposure on vitamin D status of Saudi children and adolescents. *BMC Pediatr* 2012; 12: 92.
- Kim SH, Ban GY, Park HS, Kim SC, Ye YM. Regional differences in vitamin D levels and incidence of food-induced anaphylaxis in South Korea. *Ann Allergy Asthma Immunol* 2016; 116: 237.e1-243.e1.
- Kelly D, Theodoratou E, Farrington S, Fraser R, Campbell H, Dunlop MG, et al. The contributions of adjusted ambient UVB at the place of residence and other determinants to serum 25-hydroxyvitamin D concentrations. *Br J Dermatol* 2016; 174: 1068-1078.
- Prentice A. Vitamin D deficiency: a global perspective. *Nutr Rev* 2008; 66: S153-S164.
- Elshafie DE, Al-Khashan HI, Mishriky AM. Comparison of vitamin D deficiency in Saudi married couples. *Eur J Clin Nutr* 2012; 66: 742-745.
- Sedrani SH, Elidrissy AW, El Arabi KM. Sunlight and vitamin D status in normal Saudi subjects. *Am J Clin Nutr* 1983; 38: 129-132.
- Hashemipour S, Larijani B, Adibi H, Javadi E, Sedaghat M, Pajouhi M, et al. Vitamin D deficiency and causative factors in the population of Tehran. *BMC Public Health* 2004; 4: 38.
- Fields J, Trivedi NJ, Horton E, Mechanick JI. Vitamin D in the Persian Gulf: integrative physiology and socioeconomic factors. *Curr Osteoporos Rep* 2011; 9: 243-250.
- Bassil D, Rahme M, Hoteit M, Fuleihan Gel H. Hypovitaminosis D in the Middle East and North Africa: Prevalence, risk factors and impact on outcomes. *Dermatoendocrinol* 2013; 5: 274-298.
- Mithal A, Wahl DA, Bonjour JP, Burckhardt P, Dawson-Hughes B, Eisman JA, et al. Global vitamin D status and determinants of hypovitaminosis D. *Osteoporos Int* 2009; 20: 1807-1820.
- Khan AH, Iqbal R, Naureen G, Dar FJ, Ahmed FN. Prevalence of vitamin D deficiency and its correlates: results of a community-based study conducted in Karachi, Pakistan. *Arch Osteoporos* 2012; 7: 275-282.

29. González-Molero I, Rojo-Martínez G, Morcillo S, Gutierrez C, Rubio E, Pérez-Valero V, et al. Hypovitaminosis D and incidence of obesity: a prospective study. *Eur J Clin Nutr* 2013; 67: 680-682.
30. Vanlint. Vitamin D and obesity. *Nutrients* 2013; 5: 949-956.
31. Gallagher JC, Yalamanchili V, Smith LM. The effect of vitamin D supplementation on serum 25(OH)D in thin and obese women. *J Steroid Biochem Mol Biol* 2013; 136: 195-200.
32. Cipriani C, Pepe J, Piemonte S, Colangelo L, Cilli M, Minisola S. Vitamin d and its relationship with obesity and muscle. *Int J Endocrinol* 2014; 2014: 841248.
33. Brot C, Jorgensen NR, Sorensen OH. The influence of smoking on vitamin D status and calcium metabolism. *Eur J Clin Nutr* 1999; 53: 920-926.
34. Supervía A, Nogués X, Enjuanes A, Vila J, Mellibovsky L, Serrano S, et al. Effect of smoking and smoking cessation on bone mass, bone remodeling, vitamin D, PTH and sex hormones. *J Musculoskelet Neuronal Interact* 2006; 6: 234-241.
35. Cutillas-Marco E, Fuertes-Prosper A, Grant WB, Morales-Suárez-Varela M. Vitamin D deficiency in South Europe: effect of smoking and aging. *Photodermatol Photoimmunol Photomed* 2012; 28: 159-161.
36. Kassi EN, Stavropoulos S, Kokkoris P, Galanos A, Moutsatsou P, Dimas C, et al. Smoking is a significant determinant of low serum vitamin D in young and middle-aged healthy males. *Hormones (Athens)* 2015; 14: 245-250.

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