Original Article

Relationship between Vitamin D Deficiency, Diabetes, and Obesity

Aladeen Alloubani [a, b, *], Laila Akhu-Zaheya [c], Rama Samara [c], Ibrahim Abdulhafiz [d], Abdulmoneam Saleh [d], Albaraa Altowijri [d]

[a] Nursing Research & EBP Unit, King Hussein Cancer Center, Queen Rania Al Abdullah Street (next to Jordan University), P.O.Box 1269, Amman, 11941, Jordan
[b] Harvard Medical School, USA
[c] Jordan University of Science and Technology, Ar Ramtha 3030, Ramtha, Jordan
[d] Faculty of Medicine, University of Tabuk, Saudi Arabia

A R T I C L E   I N F O

A B S T R A C T

Aim: This study aimed to assess the prevalence of VDD in Saudi Arabia, revealing the lifestyle and nutritional habits; and assesses the association between VDD, Diabetes Mellitus, and obesity.
Methods: A descriptive, cross-sectional, and correlational design was used in this study. A convenience sampling method of 350 participants participated in the study.
Results: The results revealed that the probability of having vitamin D Deficiency was higher among females (OR = 2.06, $p > .05$); younger age-whereby with each one year decrease in age there was about 0.03 probability of having Vitamin D Deficiency (B = −0.03; $p > .05$); individuals with higher incomes (OR = 1.44, $p > .05$); smokers (OR = 0.08, $p > .05$); and a lack of exposure to the sun (OR = 8.50; $p > .05$). In addition, exercise is also a predictor of Vitamin D deficiency (OR = 3.8; $p > .05$). Moreover, less Vitamin D intake (OR 9.7; $p > .05$), less intake of Calcium (OR = 12.2, $p > .05$); In addition increase one unit in the BMI, cholesterol, LDL, HDL, and FBS increased the log odd of having liability of Vitamin D deficiency by 3.2; 1.9, 1.8, 1.0, and 2.4 ($p > .05$).
Conclusion: Vitamin D Deficiency was prevalent in both males and females across different age groups in the citizens of Saudi. Because of the connection between Vitamin D Deficiency and main chronic disease, it is necessary to emphasize the need to recognize Vitamin D Deficiency screening for risk factors. It may be reasonable for the nutritionists, nurses, and physicians, to encourage the community on approaches to enhance dietary Vitamin D or suggest supplementation.

1. Introduction

Vitamin D (D2, D3, or both) is obtained either directly by ingestion of foods naturally rich with it, or photosynthesized in the skin via sun exposure in a specific mechanism that involves liver and kidney activation of certain metabolites. Vitamin D is a key vitamin, for its role in phosphorus and calcium homeostasis [1].

Vitamin D Deficiency (VDD) is a pandemic issue which is highly prevalent in populations, irrespective of bibliographic characteristics (age, geography, and race). Yet the issue has not gained the needed diagnostic recognition [2]. VDD is responsible for some musculoskeletal diseases (such as rickets in childhood, osteomalacia in adults and osteoporosis), and many other non-musculoskeletal chronic diseases [3]. VDD is also a risk factor for cardiovascular diseases [4] and potentially predisposes glucose intolerance and Type 2 Diabetes Mellitus (DM) [5].

Recent studies revealed an association between VDD and declined cognitive abilities and dementia [6]. In addition, a meta-analysis study revealed VDD was 35% more common in obese subjects [7]. A school-based study targeting students and employees was carried utilizing multi-stage cluster, random sample in many regions in the Saudi Arabia school to estimate the Vitamin D Deficiency prevalence, lifestyle, nutritional status, and possible risk factors. The results indicate Vitamin D Deficiency prevalence was 49.5% in students, and 44% in employees [8]. Another national study covering almost the whole country reported high prevalence of VDD among Saudi Arabia children, aged between 6 and 15 years old [9]. Nevertheless, VDD is a crucial risk factor, and the available prevalence data in Saudi Arabia is scarce [10–12].

* Corresponding author. Harvard Medical School, USA.
E-mail addresses: aa.12567@khcc.jo (A. Alloubani), lailanurse@just.edu.jo (L. Akhu-Zaheya), samaraa@yahoo.com (R. Samara), iabdel-hafiz@ut.edu.sa (I. Abdulhafiz), asaleh@ut.edu.sa (A. Saleh), aaltowijri@ut.edu.sa (A. Altowijri).

Regionally, multiple studies were conducted. In 2017, a study in Qatar revealed approximately 64% of participants exhibited a VD Deficiency [13]. In another study, conducted in the United Arab Emirates to assess the association between VDD and obesity in 2014, the study results confirmed deficiency, particularly in obese populations but no direct effect on the glycemic profile, yet high relationships with body mass index, fat mass, and waist circumference [14]. A similar cross-sectional study in Kuwait was conducted to assess associations between VDD and Diabetes, revealed high associations with diabetes [15].

In Saudi Arabia, a study was conducted in 2013 covering the entire population indicated high prevalence of VDD, and a low number of the population were taking supplements. It was also indicated the need to provide supplement among populations with a high deficiency [16]. Furthermore, in a recent study of the prevalence of VDD among obese Saudi females, Vitamin D levels were at the lowest in obese participants constituting a percentage of 54.6% compared to overweight and normal weight [17].

A retrospective review conducted in 2014 in Riyad, specifically in King Abdul-Aziz Medical City, taking glycemic profile in consideration, stated the alarming association of VDD with weight and high prevalence amongst the 3475 participants [18]. According to the literature's results, it was hypothesized that Vitamin D Deficiency was prevalent in the Saudi population. However, few studies were conducted in Tabuk, which is the city of interest. A recent prevalence study conducted among female university students revealed a percentage of 80.6% attributed to rare sun exposure, insufficient intake, and urban residence [19].

However, VDD is a worldwide subject of concern. Unexpectedly this issue is present in almost all communities even those predicted to have high levels of the vitamin [20]. A cohort study conducted in South Australia reported prevalence of VDD and stated that Vitamin D level may be improved by obesity reduction [21]. A study conducted in Italy in 2014, revealed a high number of adolescents were exhibiting VD insufficiency with 82.2% having VDD [22]. Moreover, in a study conducted in 2016, by applying the Vitamin D standardization program protocols (VDSP) to preexisting population representative data in 14 European population studies (including: Ireland, Germany, UK, Norway, Iceland, and Finland), it was concluded that high prevalence of VDD that required attention [23].

2. Aim

This study aimed to measure the prevalence of VDD in Tabuk City of Saudi Arabia, revealing the lifestyle and nutritional habits; and to assess the association between VDD, Diabetes Mellitus, and obesity.

3. Methods

3.1. Design

A descriptive, cross-sectional, and correlational design were used in this study, a convenience sampling method of 350 males and females participants, aged from 18 to 60 years in Tabuk city, in the north-west coast of the Saudi Arabia [24].

The study involves interviews, questionnaires, and physical examinations. The interview comprises socioeconomic, nutritional, and health-related issues. The questionnaire was utilised to gather the demographic information from the participants such as gender, marital status, as well as rates of exposure to sunlight. Furthermore, the survey examined participants' knowledge of Vitamin D source and its association with the Diabetes Mellitus. The examination element covers of therapeutic and physiologic measures and laboratory tests.

3.2. Instruments

A questionnaire for assessment of Vitamin D deficiency risk factors was used by individual interviewers to collect a demographic data such as (gender, age, marital status and income), smoking status (smoker or a nonsmoker), Residential area (rural or urban), sun exposure frequency, and physical activities. In addition, dietary consumption of calcium and vitamin D was measured by using a 24-h Dietary Recall (24HR) At a Glance to assess foods eaten in the last 24 h, which a structured interview was conducted by a trained nurse. Moreover, the participants' sun exposure was classified into frequently, sometimes, or rarely, based on whether they were exposed to direct sunlight for a minimum of 15 min for three times per week or less [25].

3.3. Data collection procedure

Data were collected between March 15 and April 30, 2017, at the University of Tabuk's main campus and a large mall in Tabuk to guarantee the representation of the public. Slovin's equation was used to estimate the sample size by using an alpha value of 0.05, and population size was 910,030 in 2017. The sample size was 327 subjects. However, the investigators included 350 subjects to overcome any attrition over the data collection process.

A staff nurse measured the height and weight for all of the participants. A wall-mounted stadiometer was utilised to calculate their height to the closest 0.5 cm, and their weight was documented to the closest 0.1 kg. After that, body mass index (BMI) was measured for all participants from the collected data (height [m2]/weight [kg]) [26]. In addition, a medical lab technologist collected three ml of blood tests from the participants, and the blood tests were taken to the lab at the Faculty of Medicine to assess serum 25 (OH)D, fasting blood sugar (FBS), lipid profile (Cholesterol, High-density lipoprotein (HDL) and Low-Density Lipoprotein (LDL) and bone profile such as calcium, magnesium, and phosphorous).

A total cholesterol level was classified as normal if it was less than 200 mg/dL. LDL level less than 100 mg/dl and HDL level <40 mg/dL were considered as normal and measured in serum [27]. FBS was conducted in the morning, before the participants consumed their breakfast. Diabetes is diagnosed at FBS of more than or equal to 126 mg/dl [28].

3.4. Ethical consideration

The ethical approval to conduct this study was obtained from the Institutional Review Board at the University of Tabuk. The aims of the study were described for all the participants. Participants were ensured there would be no consequence if they decided to withdraw from the study at any time. Confidentiality and anonymity of the data and the participants' answers were ensured. Informed consent was obtained. For more confidentiality, each questionnaire was assigned with an identification code number. Moreover, the collected data for this study was kept in a locked file cabinet.

4. Results

The study groups were assorted into 14 variables to allow sufficient descriptions of the findings. According to Table 1, the participants' gender, marital status, residential area, smoking, sunlight exposure, BMI, vitamin D intake, calcium intake, lipid profile and fasting blood sugar were investigated. The dependent variables were Vitamin D Deficiency and Vitamin D Sufficiency.

Logistic regression was conducted to assess the predictors of Vitamin Deficiency. Eleven predictors were entered into the

Table 1
Socio-demographic and lifestyle frequency and percentages connected with vitamin D sufficiency and deficiency.

Variables	Vitamin D Sufficiency (n = 89)	Vitamin D Deficiency (n = 261)
Gender		
Male	50 (33.33%)	100 (66.66%)
Female	39 (19.5%)	161 (80.5%)
Marital status		
Single	43 (26.1%)	122 (73.9%)
Married	46 (24.9%)	139 (75.1%)
Residential area		
Urban	79 (25.8%)	227 (74.2%)
Rural	10 (22.7%)	34 (77.3%)
Income		
< 6000 SR	38 (32.7%)	78 (67.3%)
6000–12000 SR	37 (22.4%)	128 (77.6%)
> 12000 SR	14 (20.3%)	55 (79.7%)
Smoking		
Smoker	32 (13.3%)	208 (86.7%)
Non-smoker	57 (51.8%)	53 (48.2%)
Sun exposure		
Frequently	62 (67.4%)	30 (32.6%)
Sometimes	23 (17%)	122 (83%)
Rarely	4 (3.2%)	119 (96.8%)
BMI		
<24.9	74 (74%)	26 (26%)
25–29.9	15 (10%)	136 (90%)
> 30	0 (0%)	99 (100%)
Exercise		
Frequently	67 (74.4%)	23 (25.6%)
Sometimes	19 (12.1%)	138 (87.9%)
Rarely	3 (2.9%)	100 (97.1%)
Vitamin D intake		
> DRI	73 (62.9%)	43 (37.1%)
< DRI	16 (6.8%)	218 (93.2%)
Calcium intake		
> DRI	71 (59.7%)	48 (40.3%)
< DRI	18 (7.8%)	213 (92.2%)
Cholesterol Level		
Normal	71 (58.7%)	50 (41.3%)
Hypercholesterolemia	18 (7.9%%)	211 (92.1%)
LDL		
Normal	68 (47.6%)	75 (52.4%)
Abnormal	21 (9.3%)	204 (90.7%)
HDL		
Normal	64 (52.5%)	58 (47.5%)
Abnormal	25 (11%)	203 (89%)
FBS		
Normal	69 (53.1%)	61 (46.9%)
Hyperglycemia	20 (9.1%)	200 (90.9%)

Abbreviations: BMI: Body mass index; DRI: Dietary Reference Intake; a 600 I U/d according to DRI for vitamin D. b 1000 mg/d according to DRI for calcium; LDL: Low-density lipoprotein; HDL: High-density lipoprotein; FBS: Fasting Blood Sugar.

regression. The results revealed that the probability of having Vitamin D Deficiency was more prevalent among females (OR = 2.06, $p > .05$); younger age-whereby with each one year decrease in age there was about 0.03 probability of having Vitamin D Deficiency (B = −0.03; $p > .05$); more income individuals (OR = 1.44, $p > .05$); being smoker (OR = 0.08, $p > .05$); and not being exposed to the sun (OR = 8.50; $p > .05$). In addition, exercise is also a predictor of Vitamin D Deficiency (OR = 3.8; $p > .05$) (Table 2).

Moreover, less Vitamin D intake (OR 9.7; $p > .05$), less intake of Calcium (OR = 12.2, $p > .05$); In addition, an increase of one unit in the BMI, cholesterol, LDL, HDL, and FBS increased the log odd of having liability of vitamin D deficiency by 3.2; 1.9, 1.8, 1.0, and 2.4 ($p > .05$). Furthermore, increase in BMI would increase the probability of Vitamin D Deficiency (OR = 25.0; $p > .05$). Being smokers, having more income.

5. Discussion

The finding of this cross-sectional study is alarming. Our results revealed the majority of the participants in the current study suffering from Vitamin D Deficiency. Moreover, looking to the demographic characteristics, the results showed the number of female participants suffering from Vitamin D Deficiency was more than male. The results were inconsistent with previous studies [29–31]. Conversely, the result was consistent with previous studies [32–34] adding that in Saudi Arabia usually women are wearing a cover on their face (Khemar), where their faces are not exposed to the sun; this also was reflected in our results, whereby there were Vitamin D Deficiency among participants who were not exposed to the sun. This is consistent with other studies, Married participants, being smoker, high BM and less exercise were more liable to have vitamin D deficiency [35,36]. This study is consistent with other studies. Looking to Calcium and Vitamin D dietary intake, less Dietary Reference Intake participants were more in term of Vitamin D deficiency. Participants with lower HDL, higher cholesterol level, LDL, and FBS, were more in term of vitamin D deficiency [37].

Other studies proposed a connection between the onset of Diabetes Type II, a metabolic syndrome result and vitamin D

Table 2
Binary logistic regression analysis of the variables associated with Vitamin D deficiency.

	B	S.E.	Wald	P value	O.R.	95% C.I. For O.R.	
						Lower	Upper
Gender (M = 0; F = 1)	.725	.249	8.491	.004	2.064	1.268	3.361
Marital Status (Single = 0; Married = 1)	.063	.246	.066	.798	1.065	.658	1.724
Residential Area (Urban = 0; Rural = 1)	.168	.383	.193	.660	1.183	.559	2.505
Age	-.029	.012	6.072	.014	.972	.950	.994
Income (Less than 6000 = 0; More than 6000 = 1)	.364	.177	4.237	.040	1.439	1.018	2.036
Smoking (Smoker 0; Non Smoker 1)	−1.945	.269	52.178	>.001	.143	.084	.242
Sun Exposure (Exposed = 0; Not exposed = 1)	2.139	.452	22.378	>.001	8.487	3.499	20.586
BMI	3.217	.709	20.563	>.001	24.959	6.213	100.261
Exercise	1.328	.583	5.197	.023	3.775	1.205	11.827
Vitamin D Intake (More than DRI = 0; Less than DRI = 1)	2.269	.713	10.136	.001	9.671	2.392	39.096
Calcium Intake (More than DRI = 0; Less than DRI = 1)	2.499	.751	11.076	.001	12.171	2.794	53.024
Cholesterol	1.893	.756	6.271	.012	6.638	1.509	29.204
LDL	1.768	.393	20.195	>.001	5.859	2.710	12.669
HDL	.966	.387	6.231	.013	2.628	1.231	5.613
FBS	2.426	.293	68.516	>.001	11.311	6.369	20.090

Abbreviations: partial logistic regression coefficients (B), standard errors of the partial slope coefficients (S.E.), Wald test, significance level (P), odds ratio (OR) and confidence interval (CI).

deficiency [38,39]. However, Vitamin D has significant impacts on the action of insulin and may have influence on many pathways, which may be of significance in the growth of Diabetes Type II [40].

Also, there is a strong association with Obesity and Diabetes, which confirms and stands as an accumulating evidence alongside the locally conducted studies in gulf region. Additionally, the findings of the local epidemiologic results on Vitamin D Deficiency, including the current study, are undeniably persistent, regardless of the methods used to quantify 25(OH) D, strengthening the suggestion that Vitamin D Deficiency is an epidemic issue in Saudi Arabia.

Putting the results of our study side by side with the one conducted in Australia, we witness consistency in the results [21], mainly due to the aging population in Australia, obesity and physical inactivity (sedentary lifestyle) whereas VDD in Saudi Arabia is a result of dark skin tone, full covering clothing which in turn decrease sun exposure.

The results of the study conducted in Italy regarding VDD in healthy adolescents [22] also showed high levels of VDD, although Italian altitudes are considered sufficient for natural Vitamin D production. Causes for the widespread deficiency in Italy include sedentary lifestyle of adolescents and indoor activities such as video games and TV, which leads to lack of sun exposure, accompanied by lack of Vitamin D and calcium intake from its food sources or supplements.

Regional results are in harmony with our study's results. In Qatar, UAE and Kuwait [13—15] this is related to socioeconomic and demographic characteristics including population age structure, ethnicity (similar skin tone), educational levels and religious affiliations (dress code), Moreover, similar climates, and sedentary life styles accompanied by lack of Vitamin D intake are the key factors.

6. Conclusion

Vitamin D deficiency was prevalent in both males and females amongst diverse age groups in the Saudi citizens. Because of the connection among Vitamin D Deficiency and main chronic diseases, it necessitates to emphasize the need to recognize Vitamin D Deficiency screening for risk factors. It may be reasonable for the nutritionist, nurses, and physicians to encourage the community on approaches to enhance dietary vitamin D or suggest supplementation.

Although the Saudi population gains adequate sunshine which should facilitate Vitamin D synthesis, this study recognized a

considerable prevalence level of Vitamin D Deficiency in its sample of healthy adult male and female participants. Moreover, it found the following risk factors for Vitamin D Deficiency (limited sun exposure, inadequate dietary Vitamin D, high cholesterol level and diabetes). Accordingly, it is necessary at the public level to evaluate the Vitamin D level so that properly targeted plans directing at vitamin D supplementation and fortification can be placed.

Author contributions

All authors interpreted the results, revised the manuscript, and approved the final version of the manuscript.

Conflicts of interest

We hereby certify that this material, which we now submit for your Journal is entirely our own work and there is "No conflict of interest has been declared by author(s).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.dsx.2019.02.021.

Disclosures

We hereby certify that this material, which we now submit for your Journal is entirely our own work and there is "No conflict of interest has been declared by author(s).

References

[1] Veldurthy V, Wei R, Oz L, Dhawan P, Jeon YH, Christakos S. Vitamin D, calcium homeostasis and aging. Bone Res 2016;4:16041. https://doi.org/10.1038/

boneres.2016.41.

[2] G R, Gupta A, G R, Gupta A. Vitamin D deficiency in India: prevalence, causalities and interventions. Nutrients 2014;6(2):729–75. https://doi.org/10.3390/nu6020729.

[3] Wintermeyer E, Ihle C, Ehnert S, et al. Crucial role of vitamin D in the musculoskeletal system. Nutrients 2016;8(6):319. https://doi.org/10.3390/nu8060319.

[4] Kienreich K, Tomaschitz A, Verheyen N, et al. Vitamin D and cardiovascular disease. Nutrients 2013;5(8):3005–21. https://doi.org/10.3390/nu5083005.

[5] Griz LHM, Bandeira F, Gabbay MAL, et al. Vitamin D and diabetes mellitus: an update 2013. Arq Bras Endocrinol Metabol 2014;58(1):1–8. https://doi.org/10.1590/0004-2730000002535.

[6] Schlögl M, Holick MF. Vitamin D and neurocognitive function. Clin Interv Aging 2014;9:559–68. https://doi.org/10.2147/CIA.S51785.

[7] Pereira-Santos M, Costa PRF, Assis AMO, Santos CAST, Santos DB. Obesity and vitamin D deficiency: a systematic review and meta-analysis. Obes Rev 2015;16(4):341–9. https://doi.org/10.1111/obr.12239.

[8] Kaddam IM, Al-Shaikh AM, Abaalkhail BA, et al. Prevalence of vitamin D deficiency and its associated factors in three regions of Saudi Arabia. Saudi Med J 2017;38(4):381–90. https://doi.org/10.15537/smj.2017.4.18753.

[9] Al Shaikh AM, Abaalkhail B, Soliman A, et al. Prevalence of vitamin D deficiency and calcium homeostasis in Saudi children. J Clin Res Pediatr Endocrinol 2016;8(4):461–7. https://doi.org/10.4274/jcrpe.3301.

[10] Nasreddine LM, Kassis AN, Ayoub JJ, Naja FA, Hwalla NC. Nutritional status and dietary intakes of children amid the nutrition transition: the case of the Eastern Mediterranean Region. Nutr Res 2018;57:12–27. https://doi.org/10.1016/J.NUTRES.2018.04.016.

[11] Altowijri A, Alloubani A, Abdulhafiz I, Saleh A. Impact of nutritional and environmental factors on vitamin D deficiency. Asian Pac J Cancer Prev 2018;19(9):2569–74. https://doi.org/10.22034/APJCP.2018.19.9.2569.

[12] Al-Faris NA. High prevalence of vitamin D deficiency among pregnant Saudi women. Nutrients 2016;8(2):77. https://doi.org/10.3390/nu8020077.

[13] Al-Dabhani K, Tsilidis KK, Murphy N, et al. Prevalence of vitamin D deficiency and association with metabolic syndrome in a Qatari population. Nutr Diabetes 2017;7(4). https://doi.org/10.1038/nutd.2017.14. e263-e263.

[14] Sadiya A, Ahmed SM, Skaria S, Abusnana S. Vitamin D status and its relationship with metabolic markers in persons with obesity and type 2 diabetes in the UAE: a cross-sectional study. J Diabetes Res 2014;2014:869307. https://doi.org/10.1155/2014/869307.

[15] Zhang FF, Al Hooti S, Al Zenki S, et al. Vitamin D deficiency is associated with high prevalence of diabetes in Kuwaiti adults: results from a national survey. BMC Public Health 2016;16(1):100. https://doi.org/10.1186/s12889-016-2758-x.

[16] Tuffaha M, El Bcheraoui C, Daoud F, et al. Deficiencies under plenty of sun: vitamin D status among adults in the kingdom of Saudi Arabia, 2013. N Am J Med Sci 2015;7(10):467–75. https://doi.org/10.4103/1947-2714.168675.

[17] Abdelkarem HM, El-Sherif MA, Gomaa SB. Vitamin D status and insulin resistance among young obese Saudi females. Saudi Med J 2016;37(5):561–6. https://doi.org/10.15537/smj.2016.5.13581.

[18] Alfawaz H, Tamim H, Alharbi S, Aljaser S, Tamimi W. Vitamin D status among patients visiting a tertiary care center in Riyadh, Saudi Arabia: a retrospective review of 3475 cases. BMC Public Health 2014;14(1):159. https://doi.org/10.1186/1471-2458-14-159.

[19] Alzaheb RA, Al-Amer O. Prevalence and predictors of hypovitaminosis D among female university students in Tabuk, Saudi Arabia. Clin Med Insights Women's Health 2017;10. https://doi.org/10.1177/1179562X17702391. 1179562X1770239.

[20] Palacios C, Gonzalez L. Is vitamin D deficiency a major global public health problem? J Steroid Biochem Mol Biol 2014;144:138–45. https://doi.org/10.1016/J.JSBMB.2013.11.003.

[21] Gill TK, Hill CL, Shanahan EM, et al. Vitamin D levels in an Australian population. BMC Public Health 2014;14(1):1001. https://doi.org/10.1186/1471-2458-14-1001.

[22] Vierucci F, Del Pistoia M, Fanos M, Erba P, Saggese G. Prevalence of hypovitaminosis D and predictors of vitamin D status in Italian healthy adolescents. Ital J Pediatr 2014;40(1):54. https://doi.org/10.1186/1824-7288-40-54.

[23] Cashman KD, Dowling KG, Škrabáková Z, et al. Vitamin D deficiency in Europe: pandemic? Am J Clin Nutr 2016;103(4):1033–44. https://doi.org/10.3945/ajcn.115.120873.

[24] Labour Force Survey. Saudi Arabia: population aged 15 and above by nationality (Saudi/non-Saudi), activity status and administrative region (governorate) of residence. Saudi Arabia; 2014.

[25] Al-Faris N, Al-Faris AN. High prevalence of vitamin D deficiency among pregnant Saudi women. Nutrients 2016;8(2):77. https://doi.org/10.3390/nu8020077.

[26] Centers for Disease Control and Prevention. Body mass index (BMI) | healthy weight. 2018. . Published, https://www.cdc.gov/healthyweight/assessing/bmi/ . [Accessed 13 December 2018].

[27] National Institutes of Health. Cholesterol levels: what you need to know. Natl Libr Med 2012;7(2):6–7. https://medlineplus.gov/magazine/issues/summer12/articles/summer12pg6-7.html.

[28] American Diabetes Association. Diagnosing diabetes and learning about prediabetes. Am Diabetes Assoc 2017. http://www.diabetes.org/are-you-at-risk/prediabetes/?loc=superfooter. [Accessed 13 December 2018].

[29] Al-Horani H, Abu Dayyih W, Mallah E, et al. Nationality, gender, age, and body mass index influences on vitamin D concentration among elderly patients and young Iraqi and Jordanian in Jordan. Biochem Res Int 2016;2016:1–8. https://doi.org/10.1155/2016/8920503.

[30] Sharifi N, Amani R, Hajiani E, Cheraghian B. Women may respond different from men to vitamin D supplementation regarding cardiometabolic biomarkers. Exp Biol Med 2016;241(8):830–8. https://doi.org/10.1177/1535370216629009.

[31] 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 Heal J 2011;17(4):317–22. http://applications.emro.who.int/emhj/V17/04/17_4_2011_0317_0322.pdf. [Accessed 13 December 2018].

[32] Alharbi AA, Alharbi MA, Aljafen AS, et al. Gender-specific differences in the awareness and intake of Vitamin D among adult population in Qassim Region. J Family Community Med 2018;25(3):148–54. https://doi.org/10.4103/jfcm.JFCM_164_17.

[33] Hovsepian S, Amini M, Aminorroaya A, Amini P, Iraj B. Prevalence of vitamin D deficiency among adult population of isfahan city, Iran. J health popul nutr 2011;29(2):149–55. http://www.ncbi.nlm.nih.gov/pubmed/21608424. [Accessed 10 February 2018].

[34] Johnson LK, Hofsø D, Aasheim ET, et al. Impact of gender on vitamin D deficiency in morbidly obese patients: a cross-sectional study. Eur J Clin Nutr 2012;66(1):83–90. https://doi.org/10.1038/ejcn.2011.140.

[35] Macdonald HM, Mavroeidi A, Barr RJ, Black AJ, Fraser WD, Reid DM. Vitamin D status in postmenopausal women living at higher latitudes in the UK in relation to bone health, overweight, sunlight exposure and dietary vitamin D. Bone 2008;42(5):996–1003. https://doi.org/10.1016/J.BONE.2008.01.011.

[36] Botella-Carretero JI, Alvarez-Blasco F, Villafruela JJ, Balsa JA, Vázquez C, Escobar-Morreale HF. Vitamin D deficiency is associated with the metabolic syndrome in morbid obesity. Clin Nutr 2007;26(5):573–80. https://doi.org/10.1016/J.CLNU.2007.05.009.

[37] Forrest KYZ, Stuhldreher WL. Prevalence and correlates of vitamin D deficiency in US adults. Nutr Res 2011;31(1):48–54. https://doi.org/10.1016/J.NUTRES.2010.12.001.

[38] Chiu KC, Chu A, Go VLW, Saad MF. Hypovitaminosis D is associated with insulin resistance and β cell dysfunction. Am J Clin Nutr 2004;79(5):820–5. https://doi.org/10.1093/ajcn/79.5.820.

[39] Targher G, Zenari L, Bertolini L, Falezza G, Muggeo M, Zoppini G. Plasma total homocysteine levels are associated with von Willebrand factor, soluble intercellular adhesion molecule-1, and soluble tumor necrosis factor-alpha receptors in young type 1 diabetic patients without clinical evidence of macrovascular complications. Diabetes Care 2001;24(8):1496–7. https://doi.org/10.2337/diacare.28.5.1228.

[40] Ozfirat Z, Chowdhury TA. Vitamin D deficiency and type 2 diabetes. Postgrad Med 2010;86(1011):18–25. https://doi.org/10.1136/pgmj.2009.078626.