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Vitamin D status among adults (18–65 years old) attending primary healthcare centres in Qatar: a cross-sectional analysis of the Electronic Medical Records for the year 2017

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ABSTRACT

Objectives To investigate the prevalence of vitamin D deficiency among individuals attending primary healthcare facilities in Qatar and to assess the association between vitamin D deficiency and some medical conditions in persons aged 18–65 years old.

Setting The study was undertaken in publicly funded primary healthcare services in the State of Qatar.

Participants A total of 102 342 participants aged between 18 and 65 years old with a valid serum vitamin D test result during the year 2017.

Outcome measures Serum level <10 ng/mL (<25 nmol/L) was defined as severe vitamin D deficiency, a serum level of <20 ng/mL (<50 nmol/L) was defined as vitamin D deficiency and a serum level <30 ng/mL (<75 nmol/L) defined as vitamin D insufficiency.

Results The prevalence rate of severe vitamin D deficiency was 14.1% among study participants with no history of vitamin D replacement therapy in the previous months. The prevalence rate of vitamin D deficiency was as high as 71.4% and that of vitamin D insufficiency was up to 92.7%. None of the five chronic conditions explored in the study (diabetes, hypertension, asthma, stroke and cardiovascular disease) had an obvious association with severe vitamin D deficiency status in a bivariate analysis. However, multivariate modelling showed that (adjusting for age, gender, body mass index and nationality and each of the included chronic conditions) hypertension, cardiovascular diseases and stroke placed an individual at a higher risk of having an associated severe vitamin D deficiency status.

Conclusion Although not comprehensive and nationally representative, this study is suggestive of a higher prevalence of vitamin D deficiency among young adults, females, Qatari nationality and those with higher body mass index. Multivariate modelling showed that hypertension, cardiovascular diseases and stroke were associated with a higher risk of severe vitamin D deficiency status.

Strengths and limitations of this study

- ► An advantage of this study is that it used readily available data, which required fewer resources compared with collecting new data. The conclusions were therefore based on a very large set of data.
- ► The current cross-sectional study is not suitable to demonstrate temporality of any observed association. A longitudinal study design is needed to measure the risk of vitamin D deficiency for selected predisposing factors or determinants with confidence.
- ► Variability in the applied diagnostic criteria and laboratory cut-off values in identifying vitamin D deficiency and insufficiency across different studies may limit the ability of a fair comparison.
- ► Selection bias is an obvious limitation in this study. Physicians are expected to order serum vitamin D test for specific service users according to special criteria and indications or personal preference, since no clear guideline are available for ordering the test. Therefore, not all people had equal chances to be included in this study.

INTRODUCTION

Vitamin D is a steroid vitamin, which together with other physiological factors, controls the metabolism of calcium and phosphorus. There are different sources of vitamin D. Mainly exposure to the sun where ultraviolet B radiation promotes synthesis of vitamin D in the skin.[1] Diet also plays a role on vitamin D status.[2] The major dietary sources of vitamin D are milk, plant-based beverages, fortified fruit juices and yogurts.[3] Vitamin D deficiency can have serious consequences on health and is a widely spread micronutrient problem globally. Several risk factors are associated with low serum levels of vitamin D in adults. These include advancing age, female gender, clothing style, season, socioeconomic status, urban living, dark skin and body mass index (BMI).[4 5]

Vitamin D deficiency has been reported as a public health concern globally.[6] While high prevalence of vitamin D deficiency has been reported globally, reliance on a single cut-off value to define vitamin D deficiency or insufficiency is problematic because of the wide individual variability of the functional effects of vitamin D and interaction with calcium intakes.[6] In studies, cut-off values are often chosen when there is evidence of decreased risk for selected end-points for individuals with serum levels greater than that cut-off value. These end-points include fractures, cardiovascular diseases, colorectal cancer, diabetes, depressed mood, cognitive decline and death.[7] Some published studies demonstrated vitamin D deficiency can be diagnosed when the level of serum vitamin D is <25 nmol/L (<10 ng/mL).[8] Others defined deficiency as serum vitamin D <50 nmol/L (<20 ng/mL).[7] The desirable level for an adult is >75 nmol/L (>30 ng/mL). A U shape relation between serum vitamin D level and adverse outcome was noticed. A level of >250 nmol/L (>100 ng/mL) invites problems.[8] A level of 20–30 ng/mL of serum vitamin D is known as insufficient or suboptimal vitamin D status.[8]

Recently, vitamin D as a micronutrient and its deficiency has become more popular among the medical community as well as the public. Vitamin D deficiency in known to cause bone diseases in adults.[9 10] A study showed a positive correlation between bone mineral density values at both lumbar spine (L1–L4) and neck of femur and serum vitamin D levels, respectively.[11] Apart from the well-established effect of vitamin D deficiency on diseases associated with bone growth, there is a wide array of other risk factors and medical conditions which in literature provide conflicting evidence of being associated with vitamin D deficiency.

A systematic review showed an increase in the prevalence of vitamin D deficiency with age.[12] While a study conducted in Morocco, concluded that one of the main determinants of hypovitaminosis D was age >55 years.[13] While in a Saudi study, vitamin D deficiency was reported to be common among older men with no education and sedentary lifestyle.[11] Joergensen and colleagues found that vitamin D level was not associated with gender.[14] While a study conducted in Qatar reported that the mean overall vitamin D level was lower in females compared with males.[15] This gender inequality was also reported by another study from the United Arab Emirates (UAE).[16]

Vitamin D deficiency was found to be common among obese men with no education and sedentary lifestyle in a Saudi study.[11] This observation was reported in another study on a group of healthy, white, obese medical school personnel, which showed that BMI was inversely correlated with serum vitamin D3 concentrations.[5] Clothing which covers all parts of the body, spending time outdoors for less than 30 minutes/day and urban living have shown negative effects on the level of serum vitamin D.[13 17] Spending more than 1 hour outdoors was independently associated with higher vitamin D levels.[18]

Evidence of other diseases and conditions, which may deteriorate or improve according to the level of serum vitamin D through an indirect mechanism are also available. Diabetes mellitus is more likely with vitamin D deficiency, as vitamin D acts through several mechanisms on glucose metabolism. Literature showed that Vitamin D can act on insulin producing cells (β cells) in the pancreas to produce more insulin, it acts on the muscle and fat cells to improve insulin action by reducing insulin resistance as well as vitamin D indirectly improves insulin production and its action by improving the level of calcium inside the cells.[14 19–21] In a study from Spain, vitamin D concentrations correlated negatively with total cholesterol and low-density lipoproteins (LDL) cholesterol levels.[18] Colorectal cancer mortality was inversely related to serum vitamin D level, with levels 80 nmol/L or higher associated with a 72% risk reduction compared with lower than 50 nmol/L.[2] A cross-sectional study showed a positive correlation between bone mineral density values at both lumbar spine (L1–L4) and neck of femur and serum vitamin D levels, respectively.[11]

In Qatar, prevalence of vitamin D deficiency has been reported as 90%.[12 15] The current study aims to investigate the prevalence of vitamin D deficiency among adult persons attending primary healthcare facilities in Qatar. In addition, it assessed the association between vitamin D deficiency and selected medical conditions (diabetes, asthma, hypertension, cardiovascular diseases and stroke) in people aged 18–65 years old. The current study will test the hypothesis that these selected medical conditions are associated with vitamin D status to provide a much-needed snapshot of the extent of this micronutrient deficiency in the State of Qatar.

METHODS

Study design

Cross-sectional study.

Study setting

Qatar, a peninsular Arab country with a high-income economy backed by the world's third-largest natural-gas reserves, has been investing significantly on its healthcare system. This includes a publicly funded primary healthcare service delivered by the Primary Health Care Corporation (PHCC) which is the largest primary care provider publicly funded by the State of Qatar. At the time of undertaking this study, PHCC had 23 primary healthcare centres (all accredited by Accreditation Canada International) distributed across the country on three geographical regions. Every resident in Qatar with a valid residence permit is eligible to register with a PHCC health centre for a nominal annual fee and utilise its services.

Study population

A total of 102 342 Electronic Medical Records (EMR) were extracted from PHCC's EMR system for service users aged between 18 and 65 years old with a valid serum vitamin D test result during the year 2017.

Study variables

The outcome variable was vitamin D deficiency which was tested at three cut-off values. The independent (exposure) variables included age, gender, nationality, BMI and a list of selected chronic medical conditions. These included diabetes, hypertension, asthma, stroke and cardiovascular disease.

Data collection

In PHCC, individuals are tested for vitamin D serum levels if requested by a doctor. The tests are conducted in health centre laboratories. Blood drawn from an individual by a phlebotomist was processed using an Abbott ARCHETICT i1000SR IMMUNO analyzer designed to perform automated immunoassay tests, utilisingchemiluminescent microparticle assay detection technology. The results of the test were recorded by the laboratory on PHCC's EMR system. The laboratory internal quality control was conducted at the beginning of morning shift and judged by Westgard rules and Levey Jennings plot one time per day. The external quality control followed the Randox International Quality Assessment Scheme protocol. Data were extracted from the PHCC's EMR system for the defined study population. The data was extracted for a time period of 1 year starting from 1 January to 31 December 2017. A total of 421 283 adults (aged 18–65 years old) accessed primary healthcare services in 2017. Out of those active users, 102 342 individuals had a valid serum vitamin D measurement during the 1-year study period. The PHCC EMR system uses SNOMED codes (a systematically organised computer processable collection of medical terms providing codes, terms, synonyms and definitions used in clinical documentation and reporting). These codes are quality controlled and reviewed by the Health Information Management (HIM) department of PHCC. The HIM department is responsible for translating SNOMED codes into ICD-10 codes (International Classification of Disease the 10th Revision) and continuously updating the coding manual with any new code used in the organisational database at a monthly interval. The HIM department provided a full list of variables for the study population using filters requested for the purpose of the study. The codes and algorithms used for specifying the data extraction process is described in online supplementary appendix A.

Data analysis

The Statistical Package for Social Sciences (V.23) was used for data analysis. Descriptive statistics were done first. Data cleaning involved logical checks for consistency of related variables (like being treated with Vitamin D replacement and the type of formulary used for treatment being valid for those treated only) and range checks for dates to be within the specified study time.

A review of the literature suggests many cut-off values for defining vitamin D inadequacy. For the purposes of this study, severe vitamin D deficiency was defined as having a serum level of <10 ng/mL, vitamin D deficiency was defined as having a serum level of <20 ng/mL and vitamin D insufficiency was defined as having a serum level of <30 ng/mL.

As treatment with replacement therapy was expected to affect the measured concentration of serum vitamin D, the extracted data was split into two groups. The individuals treated with vitamin D replacement therapy before the date label for testing serum concentration of vitamin D were included in the treatment group while the others in the untreated group.

Age was recoded into age groups of 10 years intervals. Only the first (18–29 years) and last (50–65 years) age groups were different in class interval width. BMI in kg/m^2 was classified into five groups using the WHO classification. These groups were: acceptable (<25), overweight (25–29.9), grade 1 or low risk obesity (30–34.9), grade 2 or moderate risk obesity (35–39.9) and obesity grade 3 (morbid obesity) (40+). The season during which testing of vitamin D took place was classified into quarters of a year (the first quarter, for example, included the months of January, February and March).

Multivariate discriminant analysis was used to predict a severe vitamin D status based on age, nationality, gender, BMI and comorbid chronic conditions. The multivariate modelling helped to control the confounding effect of all the explanatory variables included in the model. No test of significance was needed since all the population with available data was analysed and no attempt is made to generalise the conclusion to an untested population.

Quality control measures

In the preparation phase of the study, an extensive review of literature was undertaken and academic experts in community medicine and other related fields were consulted. The study authors were responsible for data collection in collaboration with the HIM department. Collection of blood and its laboratory analysis followed PHCC's standard operating procedures.

Ethical consideration

The study presented minimal risk of harm to its human participants. The data collected was anonymised. None of the study participants' personal information was revealed to the research team.

Patient and public involvement

Patients' priorities, experience and preferences were not gathered nor were they involved in designing the study. PHCC's HIM department facilitated data collection. There are no plans to disseminate results to the study participants directly as they are already anonymised.

RESULTS

The study results are based on the analysis of 102 342 primary healthcare service users (adults between 18 and 65 years old) with a valid serum vitamin D test result during the year 2017 as shown in table 1.

Table 1 Frequency distribution of the total study sample with an available recorded value for serum vitamin D during the year 2017

	N	%
Age group in years		
18–29	23348	22.8
30–39	30889	30.2
40–49	24736	24.2
50–65	23369	22.8
Total	102342	100.0
Gender		
Female	67393	65.9
Male	34946	34.1
Total	102339	100.0
Nationality		
Other nationalities	72314	70.7
Qatari	30028	29.3
Total	102342	100.0
Vitamin D therapy before the last serum vitamin D test		
No	70818	68.9
Yes	31903	31.1
Total	102721	100.0
BMI measurement		
Acceptable (<25)	18108	23.2
Overweight (25–29.9)	26523	34.0
Grade 1 or low risk obesity (30–34.9)	19549	25.1
Grade 2 or moderate risk obesity (35–39.9)	9008	11.6
Grade 3 obesity (morbid obesity) (40+)	4779	6.1
Total	77967	100.0

BMI, body mass index.

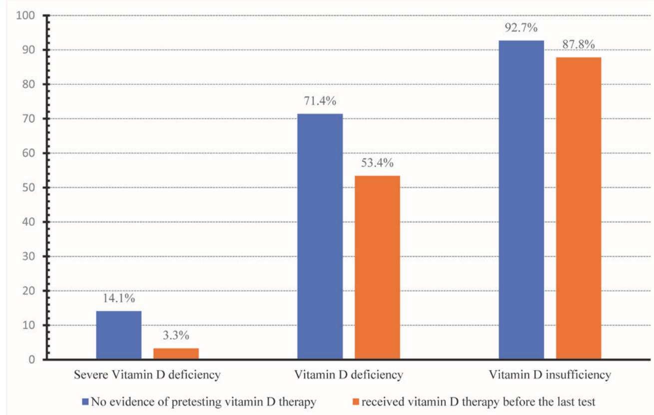

Figure 1 Among study participants with no evidence of prior vitamin D replacement therapy, the prevalence rate of the severe form of vitamin D deficiency (serum level <10 ng/mL) was 14.1% and this rate declined to 3.3% among treated individuals. on the other side, the prevalence rate of vitamin D deficiency (serum level <20 ng/mL) was 71.4% among non-treated study participants compared with 53.4% among treated ones. A third cut-off value for defining vitamin D insufficiency is set at <30 ng/mL, at this level the prevalence rate was as high as 92.7% among the non-treated group reduced slightly to 87.8% among the treated group.

Figure 1 demonstrates the prevalence rate of vitamin D insufficiency, deficiency and severe deficiency among treated and untreated study participants.

As shown in table 2, the relation between sociodemographic factors and vitamin D status is relatively affected by the cut-off values of vitamin D. Table 2 also shows there is no obvious or consistent seasonal variations in prevalence rate of vitamin D deficiency at any of the three tested cut-off values.

Table 2 shows age had a strong association with vitamin D deficiency status. In addition, age is known to be associated with BMI and other risk factors studied. Therefore, age qualifies as a strong confounder for any association between explanatory variables tested and the deficiency status. Undertaking a stratified analysis, adjusting for age as a confounder offers a solution to adjust for this undesired confounding effect.

After adjusting for age group, the association between gender, nationality, season, BMI and selected chronic health conditions with the prevalence of severe vitamin D deficiency among individuals with no evidence of vitamin D therapy is shown in table 3.

Multivariate discriminant analysis was used to predict a severe vitamin D status based on age, nationality, gender, BMI and comorbid chronic conditions. As shown in table 4, age, gender and nationality were among the top three factors that predicts a severe form of vitamin D deficiency. An older age is associated with a decreased risk of having a severe deficiency status, like the effect of being a male. Whereas Qatari nationality is associated with a higher probability of having severe vitamin D deficiency. Although a higher BMI would be more predictive of severe deficiency, it was at the bottom of the list of predictor variables. Among the chronic conditions included in the model, hypertension, cardiovascular diseases and stroke increased the risk of having an associated severe vitamin D deficiency status. While, diabetes and asthma were associated with a lower probability of having the outcome.

In addition, a model (formula) was provided to predict the risk of having an associated severe vitamin D deficiency based on all the variables discussed previously. The formula can calculate the discriminant score 'D'. If D is less than −0.245 then the individual is considered at risk of having severe vitamin D deficiency. The more extreme the calculated D on the negative side the higher is the probability for the individual to have this severe form of vitamin D deficiency.

DISCUSSION

This study explored the status of serum vitamin D among individuals accessing PHCC healthcare centres in Qatar.

Table 2 The prevalence of selected outcomes based on different serum vitamin D cut-off values for study participants with no evidence of vitamin D therapy before testing stratified by sociodemographic variables

	Total	Severe vitamin D deficiency		Vitamin D deficiency		Vitamin D insufficiency	
	N	N	%	N	%	N	%
Age group in years							
18–29	17 862	4712	26.4	14 610	81.8	17 036	95.4
30–39	22 788	2951	12.9	16 565	72.7	21 276	93.4
40–49	16 808	1536	9.1	11 482	68.3	15 522	92.3
50–65	13 234	775	5.9	7847	59.3	11 711	88.5
Gender							
Female	44 773	7459	16.7	32 649	72.9	41 328	92.3
Male	25 916	2514	9.7	17 852	68.9	24 214	93.4
Nationality							
Other nationalities	51 158	6277	12.3	36 344	71	47 905	93.6
Qatari	19 534	3697	18.9	14 160	72.5	17 640	90.3
Season (year quarter) of testing for serum vitamin D							
First quarter	14 691	2085	14.2	10 697	72.8	13 753	93.6
Second quarter	15 127	1807	11.9	10 682	70.6	14 092	93.2
Third quarter	18 447	2860	15.5	13 545	73.4	17 183	93.1
Fourth quarter	22 427	3222	14.4	15 580	69.5	20 517	91.5
BMI (kg/m^2) measurement in latest visit							
Acceptable (<25)	13 079	2191	16.8	9224	70.5	11 997	91.7
Overweight (25–29.9)	17 606	2257	12.8	12 307	69.9	16 205	92.0
Grade 1 or low risk obesity (30–34.9)	11 987	1642	13.7	8676	72.4	11 134	92.9
Grade 2 or moderate risk obesity (35–39.9)	5313	825	15.5	4042	76.1	4967	93.5
Grade 3 obesity (morbid obesity) (40+)	2756	488	17.7	2169	78.7	2585	93.8

BMI, body mass index.

Using strict criteria for defining severe vitamin D deficiency (serum level <10 ng/mL), the prevalence rate was 14.1%. This rate is increased to 71.4% for the commonly defined deficiency status (serum level <20 ng/mL). Using laxer criteria for defining vitamin D insufficiency would raise the prevalence rate to as high as 92.7%. Although the current study analysed all the population, selection bias is expected to confound the interpretation of findings as vitamin D serum testing was only done on a quarter of eligible population. No guideline or protocol was used to identify the eligible population.

The high prevalence of vitamin D deficiency observed in the current study is comparable to that found in various subpopulations of the Middle Eastern as well as to that found in previous studies performed in Qatar. A systematic review of evidence in Qatar reported the weighted-average prevalence of vitamin D insufficiency of 90.4%.[12] Another systematic review found that severe vitamin D deficiency (<10 ng/mL) was most common in South Asia and the Middle East.[22] The prevalence of vitamin D deficiency in UAE was 85.4%.[16] In another study from Saudi Arabia conducted on adult males aged 20–74 years old, 87.8% had vitamin D level <20 ng/mL.[11] Similar reports of high prevalence of vitamin D deficiency and insufficiency status were also reported for Jordanian and Moroccan women.[13 17]

Globally, vitamin D insufficiency is prevalent in all regions of the world.[22] In the USA, the overall prevalence rate of vitamin D deficiency (≤20 ng/mL) was 41.6% among adults, with the higher rates in blacks (82.1%) and Hispanics (69.2%).[23] The prevalence of vitamin D insufficiency in Qatar is comparable to that in nearby countries (Gulf and Middle East and North Africa 'MENA' countries), while it was much higher than that in USA. A guideline for treating vitamin D deficiency is available in PHCC for paediatric age group, however, one for adults is yet to be developed. This might explain the high prevalence of vitamin D insufficiency in PHCC population, which is like the less privileged population sectors of the USA. Other factors may also contribute in explaining differences between populations like skin pigmentation, type of clothing and amount of physical activity.[24]

Table 3 The prevalence of severe vitamin D deficiency (<10 ng/mL) among study participants with no evidence of vitamin D replacement therapy before testing by selected explanatory variables after adjusting for age group

	Total	Severe vitamin D deficiency (<10 ng/mL)	
	N	N	%
Gender			
18–29 years of age			
Female	13 712	3900	28.4
Male	4150	812	19.6
30–39 years of age			
Female	15 121	2190	14.5
Male	7666	761	9.9
40–49 years of age			
Female	9528	999	10.5
Male	7278	536	7.4
50–65 years of age			
Female	6412	370	5.8
Male	6822	405	5.9
Nationality			
18–29 years of age			
Other nationalities	10 884	2563	23.5
Qatari	6978	2149	30.8
30–39 years of age			
Other nationalities	18 082	2164	12.0
Qatari	4706	787	16.7
40–49 years of age			
Other nationalities	12 815	1032	8.1
Qatari	3993	504	12.6
50–65 years of age			
Other nationalities	9377	518	5.5
Qatari	3857	257	6.7
Season (year quarter)			
18–29 years of age			
First quarter	3683	967	26.3
Second quarter	3730	910	24.4
Third quarter	5062	1393	27.5
Fourth quarter	5387	1442	26.8
30–39 years of age			
First quarter	4903	643	13.1
Second quarter	5126	536	10.5
Third quarter	5810	816	14.0
Fourth quarter	6949	956	13.8
40–49 years of age			
First quarter	3430	312	9.1
Second quarter	3551	243	6.8
Third quarter	4257	442	10.4

Continued

Table 3 Continued

	Total	Severe vitamin D deficiency (<10 ng/mL)	
	N	N	%
Fourth quarter	5570	539	9.7
50–65 years of age			
First quarter	2675	163	6.1
Second quarter	2720	118	4.3
Third quarter	3318	209	6.3
Fourth quarter	4521	285	6.3
BMI measurement in latest visit			
18–29 years of age			
Acceptable (<25)	5850	1558	26.6
Overweight (25–29.9)	3912	982	25.1
Grade 1 or low risk obesity (30–34.9)	2193	587	26.8
Grade 2 or moderate risk obesity (35–39.9)	1016	316	31.1
Obesity grade 3 (morbid obesity) (40+)	525	178	33.9
30–39 years of age			
Acceptable (<25)	3826	443	11.6
Overweight (25–29.9)	6003	776	12.9
Grade 1 or low risk obesity (30–34.9)	3904	557	14.3
Grade 2 or moderate risk obesity (35–39.9)	1651	280	17.0
Obesity grade 3 (morbid obesity) (40+)	785	162	20.6
40–49 years of age			
Acceptable (<25)	1946	137	7.0
Overweight (25–29.9)	4239	346	8.2
Grade 1 or low risk obesity (30–34.9)	3191	340	10.7
Grade 2 or moderate risk obesity (35–39.9)	1339	141	10.5
Obesity grade 3 (morbid obesity) (40+)	742	97	13.1
50–65 years of age			
Acceptable (<25)	1457	53	3.6
Overweight (25–29.9)	3452	153	4.4
Grade 1 or low risk obesity (30–34.9)	2699	158	5.9
Grade 2 or moderate risk obesity (35–39.9)	1307	88	6.7
Obesity grade 3 (morbid obesity) (40+)	704	51	7.2
Positive risk factor			
18–29 years of age			
None of the listed chronic diseases	14 738	3922	26.6

Continued

Table 3 Continued

	Total	Severe vitamin D deficiency (<10 ng/mL)	
	N	N	%
Diabetes	1716	431	25.1
Hypertension	575	133	23.1
Asthma	1109	301	27.1
Stroke	7	2	28.6
Cardiovascular disease	47	7	14.9
Any of the listed chronic diseases	3124	790	25.3
30–39 years of age			
None of the listed chronic diseases	16 333	2161	13.2
Diabetes	4093	535	13.1
Hypertension	2135	217	10.2
Asthma	1286	171	13.3
Stroke	18	2	11.1
Cardiovascular disease	101	12	11.9
Any of the listed chronic diseases	6455	790	12.2
40–49 years of age			
None of the listed chronic diseases	9166	905	9.9
Diabetes	4608	390	8.5
Hypertension	4243	320	7.5
Asthma	1241	108	8.7
Stroke	43	5	11.6
Cardiovascular disease	238	14	5.9
Any of the listed chronic diseases	7642	631	8.3
50–65 years of age			
None of the listed chronic diseases	3814	272	7.1
Diabetes	6603	344	5.2
Hypertension	6903	349	5.1
Asthma	1441	61	4.2
Stroke	88	7	8.0
Cardiovascular disease	713	38	5.3
Any of the listed chronic diseases	9420	503	5.3

BMI, body mass index.

The current study showed a negative relation between the age of participants and the prevalence rate of vitamin D deficiency. The risk of deficiency status is declining with advancing age. Evidence supporting this finding was published in a study among UAE adults showing a positive trend for serum vitamin D level with advancing age.[16] Other studies supported the association between lower serum vitamin D concentration and younger age.[17 25 26] The explanation for this observation is the use of vitamin D supplementation for elderly people, especially women, who are getting used to taking multivitamin tablets. In addition, clothing habit/lifestyle modification among younger people could provide further explanations.

Table 4 Discriminant analysis with selected explanatory variables to predict study participants with severe vitamin D deficiency differentiating them from those with serum levels of 10+

	Variables ordered by absolute size of correlation (pooled within-groups correlations between discriminating variables and standardised canonical discriminant functions) within function	Risk of having severe Vitamin D deficiency
Age in year	1	Decrease
Hypertension	2	Increase
Male versus Female Gender	3	Decrease
Qatari Nationality versus Others	4	Increase
Diabetes	5	Decrease
Cardiovascular disease	6	Increase
Asthma	7	Decrease
Stroke	8	Increase
BMI measurement	9	Increase

BMI, body mass index.

	Unstandardised coefficients
Gender (male coded as one and females as zero)	0.310
Age in year	0.081
BMI measurement in latest visit	–0.026
Nationality (Qatari coded as one and others as zero)	–0.531
Diabetes (coded as one when present and zero if absent)	0.022
Hypertension (coded as one when present and zero if absent)	–0.006
Asthma (coded as one when present and zero if absent)	0.154
Stroke (coded as one when present and zero if absent)	–0.345
Cardiovascular disease (coded as one when present and zero if absent)	–0.188
(Constant)	–2.296

D=–2.296+[0.31x(Gender)]+[0.081x(Age in year)]+[–0.026x(BMI Measurement in latest visit)]+[–0.531x (Nationality)]+[0.022x(Diabetes)]+[–0.006x(Hypertension)] [0.154x(Asthma)]+[–0.345x(Stroke)]+[–0.188×(Cardiovascular disease)].
Discriminant score (D)=–0.245. If D<–0.245 then the individual is expected to have severe vitamin D deficiency.

Younger people prefer living in apartments and have less outdoor physical activity whereas older people prefer living in houses and have more outdoor physical activity when they were younger and also now.[25] Still many studies reported evidence for an opposite age association with vitamin D status. These studies reached to a conclusion that older age acts as a predictor for lower vitamin D level.[11 13 22 27 28] Possible explanation for this include shortage in effective programme of prevention and treatment may results in vitamin D deficiency to be common among elderly.[29] A decreases in synthesis of vitamin D3 in the skin under influence of UV light with ageing due to insufficient sunlight exposure, and a decreased functional capacity of the skin.[30] Ageing is usually associated with a decrease in food intake, which may cause concurrent vitamin D deficiency.[31]

In the current study, the severe form of vitamin D deficiency was more prevalent among females (almost double that of males). This gap would almost disappear when we compare both genders according to the insufficiency status. This finding agrees with a study from UAE reporting an almost similar mean serum vitamin D level for both genders.[16] In a Jordanian study conducted on study participants aged >18 years, the prevalence of low vitamin D status (<30 ng/mL) was 37.3% in females compared with only 5.1% in males. Dress style for females in Arabic culture was independently related to low vitamin D status; women wearing 'Hijab' (adjusted OR=1.7, p=0.004) or 'Niqab' (adjusted OR=1.5, p=0.061) were at a higher risk for low vitamin D status than were western-dressed women.[27] Other studies highlighted the higher risk of females for a deficiency status.[22 25 32]

In the current study, Qatari nationality (local population) had the highest rate of severe deficiency (18.9%) compared with other nationalities (12.3%). The UAE study showed a statistically significant lower mean vitamin D level (19.1 ng/mL) among the local population compared with expatriates (20.07 ng/mL).[16] The type of dress covering the whole body (in females as well as males) may explain such a difference.

Our study reports highest prevalence of severe vitamin D deficiency among obese individuals. In addition, a positive trend for severe vitamin D deficiency was observed with increasing BMI. Many studies supported the fact that low serum vitamin D levels are significantly more common among obese people with BMI >30.[11 23 32 33] Obesity-associated low vitamin D levels is possible due to the decreased bioavailability of vitamin D from cutaneous and dietary sources among obese people.[5]

Current study demonstrated that severe deficiency was less common among adults sampled during spring (second quarter), compared with other seasons. It seems that having good weather during this time of the year in Qatar may allow sun exposure which stimulate production of vitamin D in the body. Saudi Arabia showed that hypovitaminosis D was more common during spring and summer.[11] Another study from Morocco showed that vitamin D insufficiency was very common in healthy adult Moroccan women during summer.[13] In Europe, surprisingly vitamin D concentrations were higher in the Northern European and Scandinavian countries compared with Southern Europe. This could be partly explained by avoidance of sunlight exposure and inability to perform daily activities in Southern Europe compared with the Northern.[31]

None of the five chronic conditions explored in the current study (diabetes, hypertension, asthma, stroke and cardiovascular disease) had an obvious association with severe vitamin D deficiency status in bivariate analysis. The multivariate modelling, however showed that (adjusting for age, gender, BMI and nationality and each of the included chronic conditions) hypertension, cardiovascular diseases and stroke increased the risk of having an associated severe vitamin D deficiency status. Whereas, diabetes and asthma were associated with a lower probability of having an associated deficiency status. There is an abundance of literature discussing the association between these chronic conditions and vitamin D status. Some suggested that vitamin D plays an important role in a broad range of organ functions, including cardiovascular health and thus a deficiency status would be associated with a significant increase in the prevalence of vascular disease, coronary artery disease, myocardial infarction, heart failure and stroke.[34] This plausible explanation for a beneficial role of vitamin D in preventing or ameliorating the above listed conditions was consistently challenged by another group of literature failing to document a link between these conditions and vitamin D.

Evidence in favour of a possible link between cardiovascular problems and low vitamin D status has been reported in studies. The prevalence of vitamin D insufficiency (<30 ng/mL) was higher in participants with selected cardiovascular disease risk factors, including obesity, hypertension, diabetes mellitus, hypertriglyceridaemia and hypercholesterolaemia.[32 35] The results of a study from India found a significant correlation between the prevalence of vitamin D deficiency and acute coronary syndrome in comparison to healthy controls. In accordance to that study, vitamin D deficiency was associated with a statistically significant increase in the prevalence of peripheral vascular disease.[36] A study conducted on 239 patients with coronary artery disease revealed very high prevalence (up to 96%) of abnormally low vitamin D levels.[37] Severe vitamin D deficiency (<10 ng/mL) was shown to be independently associated with in-hospital cardiovascular mortality in 206 patients with acute coronary syndromes.[38] Severe vitamin D deficiency has been suggested to be strongly associated with sudden cardiac death, cardiovascular events and mortality and borderline associated with stroke and fatal infection.[39] In a cohort study conducted in USA, vitamin D deficiency was associated with an increased risk of all stroke cases (haemorrhagic and ischaemic).[40] Other studies failed to document a link between cardiovascular disease and vitamin D. In the study by Park and Lee, serum vitamin D levels did not differ significantly between the cardiovascular disease and non-cardiovascular disease groups.[41] Similarly, the analysis carried in high-risk patients with stable coronary heart disease does not support a prognostic value of baseline-vitamin D levels for secondary cardiovascular event incidence or all-cause mortality.[42]

Several studies assessed the association between serum levels of vitamin D and select cardiovascular disease risk factors in adults. Vitamin D level was significantly lower in hypertensives cases.[23 32 35] In addition, vitamin D deficiency was associated with a significant increases in the prevalence of hypertension.[34 36] Accumulating evidence derived from a systematic review favours the hypothesis that vitamin D deficiency contributes to arterial hypertension.[43] Two cohort studies monitored vitamin D levels for 4–8 years, these studies showed that the relative risk (adjusted by multivariate modelling) for incident hypertension for individuals with vitamin D deficiency (<15 ng/mL) was increased by six times in males and two times in females compared with those with a plasma level ≥30 ng/mL.[44] Increasing vitamin D level in the blood has been directly or indirectly shown to reduce blood pressure in several studies.[45 46] Other studies failed to document a beneficial effect for vitamin D supplementation. A large prospective study by Forman *et al* in 2005 found no association between vitamin D intake from diet or as supplements and the risk of incident hypertension.[47] In addition, several clinical trials using supplementation of vitamin D did not show any significant decrease in blood pressure.[48–50]

Conflicting research evidence exits about the possible relation between vitamin D and diabetes mellitus. Some literature supported a positive association and suggested that hypovitaminosis D may be a significant risk factor for glucose intolerance in some, but not all, populations. Individuals with vitamin D deficiency status (<20 ng/mL) had a greater prevalence of components of metabolic syndromes including type 2 diabetes than did those with acceptable vitamin D status.[51] Type 2 diabetes patients had a higher incidence of hypovitaminosis D in different studies.[23 32 52] In addition, vitamin D deficiency was associated with a significant increase in prevalence and likelihood of developing of diabetes.[34–36] Two studies indicated that prolonged treatment of osteomalacia with vitamin D increases insulin secretion and improves glucose tolerance.[53 54] Other literature failed to show a positive association or even showed an inverse association. Data from the Third National Health and Nutrition Examination Survey showed an inverse association between vitamin D status and diabetes in non-Hispanic white and Mexican American people, but not in non-Hispanic black people. An explanation for the lack of association could be the existence of a variable threshold effect among different ethnic groups.[28] In another study conducted on 1071 randomly selected white English individuals aged 40–65 years, serum vitamin D levels were not related to glucose status.[55]

Many studies were published about a possible role for vitamin D in childhood asthma. In adults, such an association was also subject to conflicting evidence. Among supporters for a possible positive association between asthma and low vitamin D is a study among African American showing that vitamin D deficiency was significantly greater among cases than controls (86% vs 19%).[56] Conversely, another study showed that vitamin D deficiency was more frequent among healthy control compared with asthmatic cases.[57] In addition, two studies demonstrated that vitamin D supplementation increases the risk of allergic asthma.[58 59]

The current study is subject to well-known sources of bias, which needs to be addressed as limitations. The study used an analytical cross-sectional design, therefore any reported associations between selected explanatory variables and vitamin D status or absence of such explored associations should not be interpreted in the sense of risk or predictors. Since temporality as a criterion of causality cannot be verified in a cross-sectional design. One is unable to decide whether vitamin D deficiency status resulted in a specific disease status or that status was the precipitating factor for the deficiency status. Only age, gender and to some extent nationality are expected to be incriminated as risk factors, since these are fixed criteria. In addition, difference in the applied diagnostic criteria and laboratory cut-off values in identifying vitamin D deficiency and insufficiency across different studies may limit the ability of a fair comparison between studies. Selection bias is always a limitation in observational designs. Although the whole population satisfying the inclusion criteria was analysed in the current study, they still represent a selected group of approximately one fourth of the total population seeking primary healthcare services during the 1-year study period. This part of the population who had their vitamin D serum tested was not a randomly selected subgroup, since the physicians requesting this biochemical test would have used some special criteria and indications to order the test, which is not standardised to follow a clinical guideline. Therefore, not all people had equal chances to be included in this study and the results cannot be generalised to every adult seeking health services in primary care setting. Based on the preceding argument the researcher is inclined to expect the reported results for vitamin D deficiency to represent a slight overestimate of the real situation.

CONCLUSION

Although not comprehensive and nationally representative, this study is suggestive of a higher prevalence of vitamin D deficiency among young adults, females, Qatari nationality and those with higher BMI. No clear association was observed using bivariate analysis for any of the five chronic conditions explored in the current study with severe deficiency status. Multivariate modelling showed that hypertension, cardiovascular diseases and stroke increased the risk of having an associated severe vitamin D deficiency status.

Recommendations

The high prevalence of vitamin D deficiency was based on a cut-off value of <20 ng/mL among adult population of PHC service users. Further evidence is required to justify the use of such a cut-off value or defining a new cut-off value that is more suitable for Qatar. In addition, an intervention study is needed to study the effectiveness of different treatment protocols in PHCC population.

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REFERENCES

1. Hollis BW. Circulating 25-hydroxyvitamin D levels indicative of vitamin D sufficiency: implications for establishing a new effective dietary intake recommendation for vitamin D. *J Nutr* 2005;135:317–22.
2. Freedman DM, Looker AC, Chang S-C, *et al*. Prospective study of serum vitamin D and cancer mortality in the United States. *J Natl Cancer Inst* 2007;99:1594–602.
3. Canadian nutrient file. Ottawa (on): health Canada, 1997. Available: www.hcsc.c.ca/fn-an/nutrition/fiche-nutri-data/index_e.html [Accessed 1 Dec 2018].
4. Bassil D, Rahme M, Hoteit M, *et al*. Hypovitaminosis D in the middle East and North Africa. *Dermatoendocrinol* 2013;5:274–98.
5. Wortsman J, Matsuoka LY, Chen TC, *et al*. Decreased bioavailability of vitamin D in obesity. *Am J Clin Nutr* 2000;72:690–3.
6. D BL T. Vitamin D insufficiency. *Mayo Clin Proc* 2011;86:50–60.
7. LeBlanc ES, Zakher B, Daeges M, *et al*. Screening for vitamin D deficiency: a systematic review for the U.S. preventive services Task force. *Ann Intern Med* 2015;162:109.
8. Hanley DA, Cranney A, Jones G, *et al*. Guidelines Committee of the scientific Advisory Council of osteoporosis Canada. vitamin D in adult health and disease: a review and guideline statement from osteoporosis Canada (summary). *Can Med Assoc J* 2010;182:1315–9.
9. William Reed Business Media Ltd. Midday sun is good for vitamin D levels, say scientists. Available: https://www.nutraingredients.com/Article/2005/05/27/Midday-sun-is-good-for-vitamin-D-levels-say-scientists [Accessed 28 Nov 2018].
10. Holick MF. Sunlight and vitamin D for bone health and prevention of autoimmune diseases, cancers, and cardiovascular disease. *Am J Clin Nutr* 2004;80:1678S–88.
11. Ardawi M-SM, Sibiany AM, Bakhsh TM, *et al*. High prevalence of vitamin D deficiency among healthy Saudi Arabian men: relationship to bone mineral density, parathyroid hormone, bone turnover markers, and lifestyle factors. *Osteoporos Int* 2012;23:675–86.
12. Badawi A, Arora P, Sadoun E, *et al*. Prevalence of vitamin D insufficiency in Qatar: a systematic review. *J Public health Res* 2012;1:36.
13. Allali F, El Aichaoui S, Khazani H, *et al*. High prevalence of hypovitaminosis D in Morocco: relationship to lifestyle, physical performance, bone markers, and bone mineral density. *Semin Arthritis Rheum* 2009;38:444–51.
14. Joergensen C, Hovind P, Schmedes A, *et al*. Vitamin D levels, microvascular complications, and mortality in type 1 diabetes. *Diabetes Care* 2011;34:1081–5.
15. Mahdy SM, Al-Emadi SA, Khanjar IA, *et al*. Vitamin D status in health care professionals in Qatar. *Saudi Med J* 2010;31:74–7.
16. Yammine K, Al Adham H. The status of serum vitamin D in the population of the United Arab Emirates. *East Mediterr Health J* 2016;22:682–6.
17. Nichols EK, Khatib IMD, Aburto NJ, *et al*. Vitamin D status and determinants of deficiency among non-pregnant Jordanian women of reproductive age. *Eur J Clin Nutr* 2012;66:751–6.
18. Cutillas-Marco E, Prosper AF, Grant WB, *et al*. Vitamin D status and hypercholesterolemia in Spanish general population. *Dermatoendocrinol* 2013;5:358–62.
19. Wolf M, Shah A, Gutierrez O, *et al*. Vitamin D levels and early mortality among incident hemodialysis patients. *Kidney Int* 2007;72:1004–13.
20. Pittas AG, Dawson-Hughes B, Li T, *et al*. Vitamin D and calcium intake in relation to type 2 diabetes in women. *Diabetes Care* 2006;29:650–6.
21. Brijesh M, Saurav P. Prevalence of vitamin D deficiency in type-2 diabetes mellitus patients and its correlation with glycemic control. *Int J Bioassays* 2014;3:3313–7.
22. Mithal A, Wahl DA, Bonjour J-P, *et al*. Global vitamin D status and determinants of hypovitaminosis D. *Osteoporosis International* 2009;20:1807–20.
23. Forrest KYZ, Stuhldreher WL. Prevalence and correlates of vitamin D deficiency in US adults. *Nutr Res* 2011;31:48–54.
24. Matsuoka LY, Wortsman J, Hollis BW. Use of topical sunscreen for the evaluation of regional synthesis of vitamin D3. *J Am Acad Dermatol* 1990;22:772–5.
25. Hovsepian S, Amini M, Aminorroaya A, *et al*. Prevalence of vitamin D deficiency among adult population of Isfahan City, Iran. *J Heal Popul Nutr* 2011;29.
26. Kaykhaei MA, Hashemi M, Narouie B, *et al*. High prevalence of vitamin D deficiency in Zahedan, Southeast Iran. *Ann Nutr Metab* 2011;58:37–41.
27. Batieha A, Khader Y, Jaddou H, *et al*. Vitamin D status in Jordan: dress style and gender discrepancies. *Ann Nutr Metab* 2011;58:10–18.
28. Scragg R, Sowers M, Bell C. Third National health and nutrition examination survey. serum 25-hydroxyvitamin D, diabetes, and ethnicity in the third National health and nutrition examination survey. *Diabetes Care* 2004;27:2813–8.
29. Goldray D, Mizrahi-Sasson E, Merdler C, *et al*. Vitamin D deficiency in elderly patients in a general Hospital. *J Am Geriatr Soc* 1989;37:589–92.
30. Lips P. Vitamin D deficiency and secondary hyperparathyroidism in the elderly: consequences for bone loss and fractures and therapeutic implications. *Endocr Rev* 2001;22:477–501.
31. van der Wielen RPJ, de Groot LCPGM, van Staveren WA, *et al*. Serum vitamin D concentrations among elderly people in Europe. *The Lancet* 1995;346:207–10.
32. Martins D, Wolf M, Pan D, *et al*. Prevalence of cardiovascular risk factors and the serum levels of 25-hydroxyvitamin D in the United States: data from the third National health and nutrition examination survey. *Arch Intern Med* 2007;167:1159–65.
33. Baradaran A, Behradmanesh S, Nasri H. Association of body mass index and serum vitamin D level in healthy Iranian adolescents. *Endokrynol Pol* 2012;63:29–33.
34. Anderson JL, May HT, Horne BD, *et al*. Relation of vitamin D deficiency to cardiovascular risk factors, disease status, and incident events in a general healthcare population. *Am J Cardiol* 2010;106:963–8.
35. Vacek JL, Vanga SR, Good M, *et al*. Vitamin D deficiency and supplementation and relation to cardiovascular health. *Am J Cardiol* 2012;109:359–63.
36. Bhougalv BN, Kundal V, Behl K, *et al*. Prevalence of vitamin D deficiency in critically ill patients of cerebrovascular accidents. *JK Sci* 2017;18:211–5.
37. Lee JH, Gadi R, Spertus JA, *et al*. Prevalence of vitamin D deficiency in patients with acute myocardial infarction. *Am J Cardiol* 2011;107:1636–8.
38. Correia LCL, Sodré F, Garcia G, *et al*. Relation of severe deficiency of vitamin D to cardiovascular mortality during acute coronary syndromes. *Am J Cardiol* 2013;111:324–7.
39. Drechsler C, Pilz S, Obermayer-Pietsch B, *et al*. Vitamin D deficiency is associated with sudden cardiac death, combined cardiovascular events, and mortality in haemodialysis patients. *Eur Heart J* 2010;31:2253–61.

40. Judd SE, Morgan CJ, Panwar B, *et al*. Vitamin D deficiency is associated with stroke in black and white participants of the REGARDS study. *Stroke* 2014;11:93–102.
41. Park S, Lee B-K. Vitamin D deficiency is an independent risk factor for cardiovascular disease in Koreans aged ≥ 50 years: results from the Korean National health and nutrition examination survey. *Nutr Res Pract* 2012;6:162–8.
42. Grandi NC, Breitling LP, Vossen CY, *et al*. Serum vitamin D and risk of secondary cardiovascular disease events in patients with stable coronary heart disease. *Am Heart J* 2010;159:1044–51.
43. Pilz S, Tomaschitz A, Ritz E, *et al*. Vitamin D status and arterial hypertension: a systematic review. *Nat Rev Cardiol* 2009;6:621–30.
44. Forman JP, Giovannucci E, Holmes MD, *et al*. Plasma 25-hydroxyvitamin D levels and risk of incident hypertension. *Hypertension* 2007;49:1063–9.
45. Krause R, Bühring M, Hopfenmüller W, *et al*. Ultraviolet B and blood pressure. *Lancet* 1998;352:709–10.
46. Pfeifer M, Begerow B, Minne HW, *et al*. Effects of a short-term vitamin D(3) and calcium supplementation on blood pressure and parathyroid hormone levels in elderly women. *J Clin Endocrinol Metab* 2001;86:1633–7.
47. Forman JP, Bischoff-Ferrari HA, Willett WC, *et al*. Vitamin D intake and risk of incident hypertension: results from three large prospective cohort studies. *Hypertens* 2005;46:676–82.
48. Margolis KL, Ray RM, Van Horn L, *et al*. Effect of calcium and vitamin D supplementation on blood pressure: The women's health initiative randomized trial. *Hypertension* 2008;52:847–55.
49. Orwoll ES, Oviatt S. Relationship of mineral metabolism and long-term calcium and cholecalciferol supplementation to blood pressure in normotensive men. *Am J Clin Nutr* 1990;52:717–21.
50. Scragg R, Khaw KT, Murphy S. Effect of winter oral vitamin D3 supplementation on cardiovascular risk factors in elderly adults. *Eur J Clin Nutr* 1995;49:640–6.
51. Chiu KC, Chu A, Go VLW, *et al*. Hypovitaminosis D is associated with insulin resistance and beta cell dysfunction. *Am J Clin Nutr* 2004;79:820–5.
52. Takiishi T, Gysemans C, Bouillon R, *et al*. Vitamin D and diabetes. *Rheum Dis Clin North Am* 2012;38:179–206.
53. Boucher BJ. Inadequate vitamin D status: does it contribute to the disorders comprising syndrome 'X'? *Br J Nutr* 1998;79:315–27.
54. Zittermann A. Vitamin D in preventive medicine: are we ignoring the evidence? *Br J Nutr* 2003;89:552–72.
55. Wareham NJ, Byrne CD, Carr C, *et al*. Glucose intolerance is associated with altered calcium homeostasis: a possible link between increased serum calcium concentration and cardiovascular disease mortality. *Metabolism* 1997;46:1171–7.
56. Freishtat RJ, Iqbal SF, Pillai DK, *et al*. High prevalence of vitamin D deficiency among inner-city African American youth with asthma in Washington, DC. *J Pediatr* 2010;156:948–52.
57. Goleva E, Searing DA, Jackson LP, *et al*. Steroid requirements and immune associations with vitamin D are stronger in children than adults with asthma. *J Allergy Clin Immunol* 2012;129:1243–51.
58. Wjst M. The vitamin D slant on allergy. *Pediatr Allergy Immunol* 2006;17:477–83.
59. Hyppönen E, Sovio U, Wjst M, *et al*. Infant vitamin D supplementation and allergic conditions in adulthood: Northern Finland birth cohort 1966. *Ann N Y Acad Sci* 2004;1037:84–95.