Decreasing prevalence of vitamin D deficiency in the central region of Saudi Arabia (2008-2017)

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ABSTRACT

Objective: Widespread vitamin D deficiency (serum 25-hydroxyvitamin D < 50 nmol/L) in Saudi Arabia (SA) has been documented, yet a time trend is needed to establish where the prevalence is headed. This study aims to fill this gap.

Study Design and Setting: This cross-sectional series (N = 7360) were conducted in the central region of SA from 2008 to 2017. Participants of all ages were taken from multiple cohorts that included the Biomarker Screening in Riyadh (2008–2010; N = 1460), the Osteoporosis Registry (2014–2017; N = 1225), Gestational Diabetes Mellitus cohort (2014–2017, N = 281), Vitamin D School Project (2011–2017; N = 3039) and Prediabetes cohort (2012–2017; N = 1355) master databases.

Results: Vitamin D deficiency in SA has a 10-year prevalence of 73.2%. Between 2008–2017, the prevalence of vitamin D deficiency decreased from 87.1% to 64.7% for participants aged 18–40 years (p-trend < 0.001), and from 86.2% to 45.7% in participants aged > 40 years (p-trend < 0.001). During this period, vitamin D deficiency in females decreased from 80.1% to 69.6% (p-trend < 0.001), whereas in males, it decreased from 93.2% to 49.3% (p-trend < 0.001). Serum 25(OH)D was observed to have an overall increase of 2.2 ± 0.1 nmol/L (p < 0.001) along with the seasonally adjusted annual increase of 1.3 ± 0.2 nmol/L from 2008 to 2017 (p < 0.001).

Conclusion: The decreasing trend in vitamin D deficiency in SA across all demographics suggests successful public health campaigns over time. It will be interesting to investigate further whether the general improvement in the vitamin D status at the community level also translated in lesser incidences of vitamin D-related diseases over time.

1. Introduction

Vitamin D is a secosteroid hormone essential for skeletal health since it promotes intestinal calcium absorption and stimulates strengthening of the bones [1]. A severe and persistent vitamin D deficiency can cause bone softening and skeletal deformation, i.e., rickets in infancy and childhood and osteomalacia in adults [1]. Vitamin D deficiency can also contribute to the progression of osteoporosis in the elderly. In recent years, associations between low levels of vitamin D and various chronic diseases, such as T2DM, obesity, cancer, and cardiovascular disease, have been reported in observational studies [2–6]. However, there is no evidence of a causal relation [7–10].

Vitamin D deficiency has long been recognized as a serious health issue in Saudi Arabia (SA), as reflected by the vast research interest in Saudi clinical and academic areas. Widespread prevalence of vitamin D deficiency in all groups, including elderly, women, men, pregnant

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women and their neonates, school children, and toddlers, have been documented in SA [11]. Al-Dahgri et al. [11] conducted a meta-analysis of 13 studies published from 2011 to 2016 with an overall sample size of 24,399 participants including neonates, pregnant/lactating women, adults, children and adolescents. Meta-analysis of these studies revealed a pooled prevalence of vitamin D deficiency (< 50 nmol/L) as 81.0 % (95 % CI: 68.0 %–90.0 %) [11]. Another meta-analysis study with a pooled sample of 20,787 participants, based on 16 studies published between 2008 and 2015, estimated the prevalence of vitamin D deficiency (< 50 nmol/L) in SA as 63.5 % [12]. Studies carried out before 2010 reported a wide range of prevalence from 28 % to 81 % in Saudi men, women and adolescents [13–15]. Attempts have also been made to increase awareness about vitamin D deficiency and its correctional strategies [16]. It is important to identify the on-going trends in the population’s vitamin D status, which can provide crucial information for discussions on how the population has fought back its battle against vitamin D deficiency.

Over the past decades, several studies from mostly Western nations have evaluated the trends of vitamin D status over time [17–23]. Unfortunately this vital information is missing in the Saudi population. This study is an assessment of vitamin D deficiency in the Saudi Arabian population spanning ten years conducted between 2008 and 2017. This study is the first to report vitamin D trends in the Middle East based on a nationwide representative sample collected from the central region of Saudi Arabia.

2. Materials and methods

2.1. Subjects

The series of cross-sectional studies were conducted between January 2008 and December 2017 in central region of Saudi Arabia. Participants for this study were selected from multiple cohorts. The 2008–2010 database was taken from the project involving province-wide biomarker screening in Riyadh (2008–2010; N = 1460), a project of King Saud University, Ministry of Health, and the Chair for Biomarkers of Chronic Diseases (CBCD) (previously the Biomarkers Research Program, BRP), where participants were randomly recruited from their homes [24,25]. Participants from 2011 to 2017 were also taken from multiple cohorts including the Osteoporosis Registry (2014–2017; N = 1225) [26], Gestational Diabetes Mellitus cohort (2014–2017, N = 281) [27], Vitamin D School Project (2011–2017; N = 3039) [28] and Prediabetes cohort (2012–2017; N = 1355) [29] master databases. Vitamin school study was a project of King Saud University, Ministry of Education and the CBCD, where they were recruited from different schools in Riyadh. Whereas, GDM, prediabetes and Osteoporosis registry were the project of the Chair for Biomarkers of Chronic Diseases (CBCD). The younger subjects (n = 3267) were from school surveys and biomarker screening in Riyadh region. The adults (n = 2480) subjects were from multiple cohorts including biomarker screening in Riyadh region, vitamin D school project, prediabetes project, gestational diabetes mellitus project and osteoporosis registry. The elderly (n = 1613) population were from biomarker screening in Riyadh region, osteoporosis registry and prediabetes project.

2.2. Anthropometrics

Anthropometrics included body weight, and height rounded off to the nearest 0.1 kg or 0.5 cm, while hip and waist circumferences were measured using standard tape. Average diastolic and systolic blood pressure values were 2 separate measurements (in mmHg).

2.3. Assessment of circulating 25(OH)D

Blood samples collected were centrifuged and processed on the same day in CBCD at King Saud University in Riyadh, SA. Total 25(OH) D levels were calculated using COBAS e-411 with a limit of detection (LOD) and interassay coefficient of variation of 5 nmol/L and 8.0 % respectively. The assay was validated by using standardization [30,31]. Vitamin D status was categorized as 25(OH)D D ≥75 nmol/L as desirable, 50.0–74.9 nmol/L as sufficiency, 25–49.9 nmol/L as deficiency and < 25 nmol/L considered as severe deficiency [16].

2.4. Statistical analysis

Statistical Package for Social Sciences (SPSS) version 21.0 was used to conduct statistical analysis. Descriptive statistics, including means ± standard deviation (SD), were used to present continuous variables while frequencies and percentages were used to show categorical variables. Inferential statistics, including independent sample t-test and ANOVA, were used to check the mean differences. Furthermore, regression analysis was also used to quantify the relationship between time and serum 25(OH)D. A p-value <0.05 was considered statistically significant.

3. Results

3.1. Demographic characteristics

Table 1 shows the participants clinical and demographic characteristics. A total of 7360 subjects participated in this study. There were 2999 male and 4361 female participants. Mean age of the participants was 28.2 ± 15.3 years, with 25 % of them being under 14 years old or younger, while 25 % were older than 39 years. Male participants were significantly younger, with lower BMI but higher waist-hip ratio, than female participants (p < 0.001). Male participants also had significantly higher systolic blood pressure and serum 25(OH)D concentration while lower diastolic blood pressure as compared to female participants (p < 0.001).

3.2. The prevalence of vitamin D deficiency and severe deficiency in the overall population

The mean 25(OH) D concentrations, according to participant sex, are shown in Table 2. The overall mean 25(OH) D was significantly higher in males (41.6 ± 21.6) than females (39.5 ± 25.6, p < 0.001). The lowest mean 25(OH) D concentration was observed in females under 18 years (30.3 ± 16.8), while the highest was observed in females aged over 40 years (53.8 ± 29.4). Both male and female participants aged over 40 years had a significantly higher mean 25(OH) D concentration than younger participants. Blood samples gathered in summer season showed significantly higher mean serum 25(OH)D concentrations in both males and females (47.0 ± 24.4 and 50.5 ± 28.9, respectively) as compared to samples collected in the winter in both males and females (42.0 ± 20.3 and 38.4 ± 24.2, respectively, p < 0.001).

The overall vitamin D deficiency in Saudi Arabia was 73.2 %. Fig. 1 shows vitamin D deficiency and severe deficiency, in both sexes according to age groups. Females aged under 18 years had a higher prevalence of both vitamin D deficiency and severe deficiency, with 89.7 % and 44.8 % of subjects, respectively. Females aged between 18–40 years were 72.8 % deficient and 37.8 % severely deficient. However, females above 40 years of age had a significantly lower prevalence of deficiency and severe deficiency, with 51.2 % and 19.1 %, respectively, than younger female participants. Males aged under 18 years and between 18 and 40 years also had higher prevalence of vitamin D deficiency, 76.8 % and 73.9 %, respectively, as compared to vitamin D deficiency, which was lower in older male participants affecting 61.3 %. Similarly, the severe deficiency was also found to be lower in male participants aged over 40 years affecting 15.6 %, as compared to 22.7 % and 20.8 % in subjects aged less than 18 years and 18–20 years, respectively.
3.3. Vitamin D trends

Fig. 2 shows the prevalence of vitamin D deficiency and severe deficiency between 2008 and 2017 for all participants. It showed that the overall vitamin D deficiency and severe deficiency decreased from 86.6% and 48.8% in 2008, to 59.0% and 16.7%, respectively, in 2017.

The prevalence of vitamin D deficiency and severe deficiency across 2008 and 2017, according to sex and age groups are shown in Table 2. The prevalence of vitamin D deficiency and severe deficiency between 2008 and 2017 for all participants. It showed that the overall vitamin D deficiency and severe deficiency decreased from 86.6% and 48.8% in 2008, to 59.0% and 16.7%, respectively, in 2017. The prevalence of vitamin D deficiency and severe deficiency across 2008 and 2017, according to sex and age groups are shown in Table 2. Table 4 shows the mean 25(OH) D concentrations between 2008 and 2017, according to sex and age groups. The average serum 25(OH)D in 2008 was 36.1 ± 19.9 and 24.6 ± 15.7 nmol/l in males and females respectively. In 2017, the average serum 25(OH)D increased to 45.5 ± 25.3 and 55.2 ± 30.5 nmol/l in males and females, respectively. The prevalence of vitamin D deficiency and the severe deficiency also improved in 2017 in both male and female participants, as shown in Table 3. Regression analysis also showed a significantly higher trend with an increment of 1.3 ± 0.1 nmol/l in males and 3.0 ± 0.2 nmol/l in females every year. This increasing trend in vitamin D concentration remained significant in both genders after adjusting for the season of blood collection, age, and BMI (Table 6).

The average serum 25(OH)D in 2008 for participants aged <18 years was 30.2 ± 17.7 nmol/l that increased to 38.0 ± 18.1 in 2015 but decreased to 30.9 ± 22.0 in 2016. However, the average serum 25(OH)D D in participants aged between 18–40 years increased from 27.9 ± 18.7 in 2008 to 46.5 ± 26.0 in 2017. Similarly, the average serum 25(OH)D in participants aged more than 40 years increased from 34.8 ± 21.7 in 2008 to 60.1 ± 31.8 in 2017. Regression analysis also showed a significantly higher trend with the highest increment observed in participants aged older than 40 years with 3.2 ± 0.3, followed by 1.8 ± 0.2 nmol/l in participants aged between 18–40 years, while the smallest increment of 0.9 ± 0.2 nmol/l was observed in participants aged below 18 years. This increasing trend in 25(OH)D concentration was still significant in all age groups after adjusting for the season of blood collection, age, bmi and gender (Table 6).

![Fig. 1. Deficiency and Severe Deficiency in males and females according to Age.](image-url)

### Table 1
Demographic and clinical characteristics.

| Parameters          | Overall       | Sex               | Age           |          |          |
|---------------------|---------------|-------------------|---------------|----------|----------|
|                     |               | Male              | Females       | <18 years| 18–40 years| >40 years|
| N                   | 7360          | 2999              | 4361          | 3111     | 2480     | 1767      |
| Age (Years)         |               | 26.3 ± 14.7       | 29.5 ± 15.5  | 14.2 ± 1.8 | 30.7 ± 6.5 | 50.4 ± 8.0 |
| Male                | 2999          | 2999 (40.7)       | –             | 1404 (45.1) | 1011 (40.8) | 582 (32.9) |
| Female              | 4361 (59.3)   | –                 | 4361 (59.3)  | 1707 (54.9) | 1469 (59.2) | 1185 (67.1) |
| BMI (kg/m²)         | 26.1 ± 6.6    | 25.2 ± 6.2        | 26.7 ± 6.8   | 22.3 ± 5.3 | 28.4 ± 5.9 | 30.6 ± 5.5   |
| WHR                 | 0.86 ± 0.10   | 0.89 ± 0.08       | 0.83 ± 0.09  | 0.85 ± 0.08 | 0.85 ± 0.09 | 0.88 ± 0.09  |
| Systolic BP (mmHg)  | 118.1 ± 15.7  | 120.0 ± 14.6      | 116.8 ± 16.2| 115.3 ± 14.2| 118.5 ± 14.1| 123.0 ± 19.2  |
| Diastolic BP (mmHg) | 73.9 ± 11.7   | 73.3 ± 10.9       | 74.3 ± 12.3  | 70.7 ± 11.1| 74.1 ± 10.2 | 80.2 ± 12.8   |
| 25(OH) D (nmol/l)   | 40.3 ± 24.1   | 41.6 ± 21.6       | 39.5 ± 25.6  | 34.3 ± 18.1| 39.8 ± 24.7 | 51.8 ± 28.0   |
| Vitamin D Deficiency| 5390 (73.2)   | 2183 (72.8)       | 3207 (73.5)  | 2609 (83.9)| 1816 (73.2) | 964 (54.6)   |
| Severe Deficiency   | 2165 (29.4)   | 620 (20.7)        | 1545 (35.4)  | 1083 (38.4)| 765 (30.8) | 317 (17.9)   |

Note: Data presented as Mean ± SD; N(%) for categorical variables; vitamin D (nmol/l) < 50 nmol/l is considered as deficient.

indicates significant differences from males; Superscript A and B indicates significant differences from <18 years and 18–40 years respectively; P < 0.05 considered significant.

### Table 2
Mean 25(OH) D concentrations in different age group and seasons according to sex.

| Age Group          | Males | P-values | Females | P-values |
|--------------------|-------|----------|---------|----------|
| <18 years          | 39.1 ± 18.4 | <0.001 | 30.3 ± 16.8 | <0.001 |
| 18–40 years        | 41.6 ± 23.2 | - | 38.6 ± 25.6 | - |
| >40 years          | 47.6 ± 24.5A | - | 53.8 ± 29.4A | - |
| Season             |        |          |         |          |
| Winter             | 42.0 ± 20.3 | <0.001 | 38.4 ± 24.2 | <0.001 |
| Summer             | 47.0 ± 24.4 | - | 50.5 ± 28.9 | - |

Note: Data presented as Mean ± SD, p < 0.05 considered significant. Super-
script A and B indicates significant difference from <18 years and 18–40 years.
4. Discussion

This study showed that despite some improvement, low levels of 25(OH)D remain a serious public health issue in SA. We observed that young adolescents less than 18 years suffer had the highest prevalence of vitamin D deficiency as compared to elderly who had the lowest, which is consistent with other studies [32–35]. Similar results have also been reported in other countries including United Kingdom, China, South Korea and Thailand [32–35]. Since ageing is associated with decreased vitamin D production in the skin, adequate sun exposure becomes extremely important for achieving optimal vitamin D status. Vitamin D deficiency in the young Saudi population may affect the overall bone health negatively due to the importance of this period in achieving peak bone mass [33].

Al-Mogbel [36] noted that females are prone to vitamin D deficiency because of the absence of outdoor activities, however both male and female participants in this study had similar vitamin D deficiency affecting 72.8 % and 73.5 % of the subjects, respectively. Despite abundance of sun light throughout the year, direct exposure is limited in SA population due to high daytime temperatures which hinder people from practicing various activities outdoors [36]. Furthermore, the use of types of clothing that prevent the exposure of the skin to sunlight and the dark skin color in most Arab communities, increases the amount of time needed to produce enough active vitamin D. In addition, the lack of public awareness of the importance of sunlight and healthy food culture in these communities, have also added to the low levels of serum 25(OH)D in SA (Table 5).

The most notable observation in this study is the increasing levels of
strated the importance of oral vitamin D supplementation in improving serum 25(OH)D concentrations. However, milk fortified with vitamin D showed mixed results with one of the four milk brands found to be as effective as an oral vitamin D tablet. In contrast, other brands were either associated with modest increases or even decreases in 25(OH)D levels. Researchers attributed this recent surge in 25(OH)D concentration, evident in western nations, to raised health awareness and increased intake and supplementations of vitamin D. In the South Korean population, recent findings from western countries have shown a normalizing trend in vitamin D status [18,20,23]. Schleicher et al. [23] also linked the improvement in serum 25(OH)D concentration between 2007 and 2010. In our study, the overall increase in mean serum 25(OH)D level increasing from 48 to 65 nmol/L [20].

Note: Data presented as mean ± SD; Slope and p-values are calculated using linear regression analysis. Slope is adjusted for season.

Table 4
25(OH)D (nmol/l) concentration from 2008-2017 according to Sex and Age.

| Year | Overall | Sex | Age | | |
|------|---------|-----|-----|-----|-------|
|      |         | Females | Males | ≤ 18 Years | 19–40 Years | > 40 Years |
| 2008 | 30.4 ± 18.8 | 24.6 ± 15.7 | 36.1 ± 19.9 | 30.2 ± 17.7 | 27.9 ± 18.7 | 34.8 ± 21.7 |
| 2009 | 31.7 ± 19.7 | 25.7 ± 15.4 | 36.2 ± 21.4 | 31.4 ± 18.0 | 29.9 ± 21.3 | 35.5 ± 22.6 |
| 2010 | 31.6 ± 18.4 | 25.9 ± 14.4 | 36.9 ± 20.1 | 32.1 ± 18.9 | 28.9 ± 17.9 | 33.0 ± 16.8 |
| 2011 | 37.1 ± 22.2 | 35.8 ± 24.1 | 39.9 ± 17.5 | 33.7 ± 16.7 | 41.1 ± 28.3 | 42.4 ± 24.7 |
| 2012 | 38.3 ± 21.7 | 34.5 ± 21.7 | 44.3 ± 20.5 | 34.2 ± 16.6 | 38.4 ± 24.8 | 46.8 ± 24.6 |
| 2013 | 42.2 ± 24.6 | 44.8 ± 28.6 | 40.0 ± 20.4 | 37.3 ± 18.3 | 36.4 ± 22.4 | 54.2 ± 29.2 |
| 2014 | 41.1 ± 24.1 | 41.9 ± 25.6 | 36.7 ± 19.5 | 34.1 ± 19.1 | 42.6 ± 25.6 | 58.2 ± 28.6 |
| 2015 | 43.9 ± 22.3 | 43.5 ± 24.3 | 44.3 ± 19.2 | 38.0 ± 18.1 | 42.8 ± 21.0 | 56.3 ± 25.8 |
| 2016 | 47.5 ± 27.0 | 45.7 ± 27.4 | 50.6 ± 26.0 | 30.9 ± 22.0 | 42.2 ± 25.0 | 58.2 ± 27.7 |
| 2017 | 50.6 ± 28.5 | 55.2 ± 30.5 | 45.5 ± 25.3 | – | 46.5 ± 26.0 | 60.1 ± 31.8 |
| Slope | 2.2 ± 0.1 | 3.0 ± 0.2 | 1.3 ± 0.1 | 0.9 ± 0.2 | 1.8 ± 0.2 | 3.2 ± 0.3 |
| P-value | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Slope | 1.3 ± 0.2 | 1.6 ± 0.3 | 0.8 ± 0.3 | 0.8 ± 0.3 | 1.1 ± 0.3 | 2.5 ± 0.4 |
| P-value | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| SD for age | 27.0 | 31.2 | 45.7 | 26.0 | 30.9 | 45.5 |
| SD for sex | 24.8 | 41.9 | 24.6 | 44.8 | 22.2 | 35.8 |

Table 5
Age and Sex distribution according to Year.

| Year | Age | Male | Female | | |
|------|-----|------|--------|-----|-------|
| 2008 | 26.0 ± 16.1 | 243 (50.6) | 237 (49.4) | | |
| 2009 | 25.3 ± 15.7 | 237 (57.0) | 179 (43.0) | | |
| 2010 | 24.8 ± 15.8 | 290 (52.0) | 270 (48.0) | | |
| 2011 | 23.5 ± 12.4 | 235 (33.2) | 473 (66.8) | | |
| 2012 | 26.7 ± 15.7 | 394 (37.6) | 654 (62.4) | | |
| 2013 | 28.7 ± 15.0 | 572 (56.1) | 447 (43.9) | | |
| 2014 | 25.3 ± 14.6 | 737 (42.7) | 990 (57.3) | | |
| 2015 | 27.6 ± 16.2 | 389 (41.3) | 552 (58.7) | | |
| 2016 | 36.9 ± 12.1 | 312 (36.0) | 555 (64.0) | | |
| 2017 | 35.5 ± 11.3 | 260 (47.6) | 286 (52.4) | | |

Note: Data presented as Mean ± SD for age while N(%) for sex.
years. This improvement can be attributed to raised health awareness and increased vitamin D supplementation among adults. Lack of increase in adolescent may be the result of lack of sun exposure, vitamin D supplements and vitamin D fortified products. There is a need to encourage and promote positive behavior change among everyone, particularly adolescents.

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Author contributions

NMA, NA, YA, MA, SS and MSA designed the study. MGAA and MNKK performed sample and data analysis. SDH wrote the manuscript. All authors reviewed the manuscript.

Declaration of Competing Interest

All authors declare no competing interest.

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