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Case Report

Vitamin D Status Descriptive and Prescriptive Analysis Pre, Amid, Post-COVID-19: A Case Study

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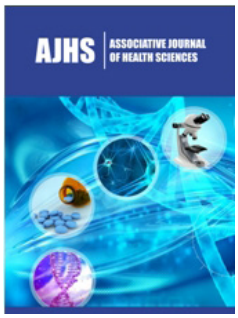
ISSN: 2690-9707



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Submission: October 07, 2024
Published: December 05, 2024

Volume 3 - Issue 5

How to cite this article: Arash Nemati* and Sahar Ghasempoor. Vitamin D Status Descriptive and Prescriptive Analysis Pre, Amid, Post-COVID-19: A Case Study. Associative J Health Sci. 3(5). AJHS. 000571. 2024.
DOI: 10.31031/AJHS.2024.03.000571

Abstract

There has been an emphasis on the role of vitamin D levels in the performance of the human immune system in combating diseases like COVID-19. This paper analyzes the vitamin D status pre-, amid, and post-COVID-19 and considers factors, such as age, gender, and sunny months. In this regard, a descriptive and prescriptive analysis is conducted in a case study using big data involving 420710 records collected from 2016 to 2023. Results showed most under-study people, particularly men, and individuals aged 4 to 35, suffer from vitamin D insufficiency. In addition, the mean vitamin D status of people settled in the under-study region lost its positive trend post-COVID-19 which began before and continued during COVID-19, implying the degrade of vitamin D among the public. Although the vitamin D status of fatal children and elders is much more pleasant than other age groups, a considerable toxic status has been seen among them. Additionally, several prescriptions are proposed to enhance the vitamin D status in the case study.

Keywords: Vitamin D status analysis; Healthcare analytics; Descriptive analysis, Prescriptive analysis; Post-COVID-19

Introduction

The positive effect of vitamin D levels on the performance of the immune system was promoted during the COVID-19 pandemic and several researchers showed an association between COVID-19 infection and vitamin D status [1-6]. Vitamin D deficiency is a popular healthcare issue worldwide [7-10]. Although the trend of vitamin D status has been studied in several countries, less attention has been paid to variations that occurred in the trend of vitamin D status pre-, amid, and post-COVID-19 [11-14]. Hence, the following questions remained unanswered in the scope of vitamin D status analysis.

What was the overall vitamin D status trend pre-, amid, and post-COVID-19?

Is there any difference between vitamin D status trends according to gender, age, month, and year pre-, amid, and post-COVID-19?

This paper answers the above-mentioned questions by proposing a data analytics approach involving several graphical and descriptive statistics measures to show the vitamin D status trend variations among different gender and age groups of the population pre-, amid, and post-COVID-19 in a case study using a big data set. Therefore, the main contribution of this paper is using a descriptive analysis framework to assess the vitamin D status trend between age and gender-based groups pre-, amid, and post-COVID-19 in a case study during various months.

In the remaining sections of the paper, the literature on vitamin D status analysis is reviewed in Section 2, and a descriptive data analytics approach is employed in a case study in Section 3 followed by Section 4 proposing the corresponding discussion. Finally, Section 5 presents the related conclusions, limitations, and recommendations.

Literature Review

This section reviews the literature on vitamin D status analysis and discusses the potential gaps to highlight the novelty aspects of this research. Azadeh et al. [15] investigated the vitamin D status among COVID-19 patients based on a three-class scale, including deficiency, insufficiency, and normal, using 150 records collected in the Sari City of Iran [15]. Nikoonejad et al. [16] studied the vitamin D status of 158 attendants from Qazvin City, Iran, using the deficiency, insufficiency, and sufficiency scale [16]. Ahmad et al. [5] categorized attendants in the vitamin D status tests collected among 19 European countries into two groups with vitamin D levels greater or less than 50. Arayıcı et al. [17] evaluated the vitamin D status of individuals from a sample by size 86772 collected before and during the COVID-19 pandemic, from 2019 to 2022, using a three-class scale involving <20, 21-30, and >30 levels of vitamin D [17].

Benameur et al. [18] used a data set collected from September 2019 to February 2022 to analyze the vitamin D status according to three classes deficiency, insufficiency, and sufficiency [18]. Also, they proposed a gender-based tabular representation of vitamin D status. Cavarzere et al. [19] presented the annual trend of deficiency, insufficiency, and sufficiency of vitamin D status of children and adolescents before and during the COVID-19 pandemic using a data set collected from January 2019 to February 2021 in Italy, focusing on annual [19]. Hikmet et al. [20] used low and normal levels to investigate the vitamin D status of patients suffering prolonged COVID-19 symptoms using the data collected from February to November 2021 in Denmark [20]. Mosca et al. [11] allocated the vitamin D attendants to four classes, including severe deficiency, deficiency, insufficiency, and sufficiency, using a 2182-size data set collected from Italian children with chronic diseases during 2019-2021. They illustrated the share of four age groups of children and a gender-based vitamin D status representation.

Antonucci et al. [12] employed three classes, including deficiency, insufficiency, and sufficiency to study the vitamin D status among Italian children and adolescents, comparing the pre- and amid-pandemic. Chen [13] studied the annual trend of vitamin D deficiency in several age groups of attendants from Henan Province, China, during and after the COVID-19 pandemic using the data set collected in 2022 and 2023. Durden et al. [14] employed a five-level scale, including <25, 25-50, 50-75, 75-100, and >100, to examine the vitamin D status during the COVID-19 pandemic using data collected from patients treated at the Charleston Area Medical Center (CAMC) in the United States.

According to Table 1 [5,11-20], none of the previous works compared the vitamin D status pre-, amid, and post-COVID-19. In addition, this is the first time that the vitamin D status of the public living in a region is investigated based on a wide range of criteria, such as gender, age, month, and year, simultaneously, particularly using a big data set involving 420710 records.

Table 1: The research gap on vitamin D status analysis post-COVID-19.

	Age-Based Analysis	Gender-Based Analysis	Monthly Trend	Annual Analysis	Pre, Amid, and post-COVID-19 Comparison	Sample Size	Data Set	Case Study
Azadeh et al. [15]		✓				150	2019	Iran-Mazandaran
Nikoonejad et al. [16]		✓				158	2021	Iran-Qazvin
Ahmad et al. [5]				✓		-	2020-2023	19 countries
Arayıcı et al. [17]	✓	✓		✓		86772	2021-2019	Turkey
Benameur et al. [18]	✓	✓				7234	2021-2019	Saudi Arabia
Cavarzere et al. [19]	✓			✓		491	2021-2019	Italy
Hikmet et al. [20]	✓	✓				442	2021	Denmark
Mosca et al. [11]	✓	✓				2182	2019-2021	Italy
Antonucci et al. [12]			✓	✓		2317	2018-2021	Italy
Chen and Kong [13]	✓		✓	✓		1525	2022-2023	China-Henan
Durden et al. [14]		✓		✓		35556	2019-2021	USA-Charleston
This Paper	✓	✓	✓	✓	✓	420710	2016-2023	Iran-Babol City

Case Study

Babol City is a major city in the Mazandaran province located in the northern green band of Iran in the southern coastal area of the Caspian Sea. The climate in this city is cloudy and rainy during autumn and winter, from October to the next March, and almost sunny during spring and summer, from April to September. Babol Razi Pathobiology and Genetic Lab is the biggest healthcare laboratory between several cases in Babol City.

Data set

A data set by size of 421692 records involving several fields, including age, sexuality, vitamin D level value, and date of test, from 2016 to 2023 is collected. There were several anomaly cases which are corrected by deletion or substitution, as illustrated in Table 2.

According to Table 2, 902 anomaly cases are omitted and 1099 vague cases are substituted, resulting in a clean data set involving 420710 records.

Table 2: Anomaly cases and the corresponding pre-processing corrective actions.

Anomaly Case of Vitamin D Value	Anomaly Count	Corrective Action
"-"	881	Delete
"2"	21	Delete
< 4	713	Substituted with 5
> 100	1	Substituted with 105
> 110	350	Substituted with 115
> 125	1	Substituted with 130
> 150	34	Substituted with 155

Descriptive analysis

Figure 1 illustrates the annual and overall age demography of vitamin D test attendants in six age classes, including 0-1, 1-4, 4-14, 14-35, 35-70, and greater than 70 years based on cleaned data set records.

According to Figure 1, about a quarter and half of the attendants are from age groups 14-35 and 35-70, respectively. Also, vitamin D tests have increased post-COVID-19 at least in this laboratory probably due to the promotion of vitamin D's significant role on the body's immune system. Table 3 shows the sexual demography per age class per year, highlighting noticeable differences between the share of female and male attendants in the adult age groups, the individuals greater than 14 years old.

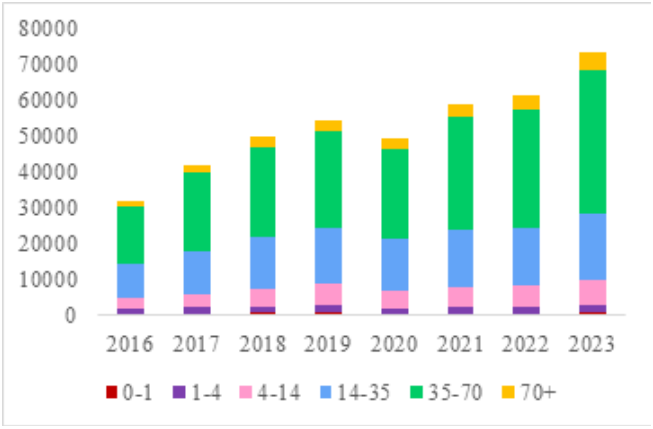

Figure 1: The age demography of vitamin D test attendants.

Table 3: The share of genders in each age group (%).

	All		0-1		1-4		4-14		14-35		35-70		>70	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
2016	29.83	70.17	50.39	49.61	47.01	52.99	47.99	52.01	22.4	77.6	28.05	71.95	39.68	60.32
2017	31.91	68.09	54.42	45.58	49.71	50.29	46.33	53.67	24.04	75.96	31.34	68.66	41.12	58.88
2018	33.71	66.29	54.42	47.79	51.86	48.14	46.82	53.18	26.1	73.9	32.67	67.33	43.92	56.08
2019	34.86	65.14	52.21	49.36	50.3	49.7	46.53	53.47	27.52	72.48	34.08	65.92	42.46	57.54
2020	35.05	64.95	50.64	50.12	49.15	50.85	46.64	54.36	27.64	72.36	34.88	65.12	46.24	53.76
2021	35.78	64.22	49.88	49.43	52.15	47.85	47.17	52.83	27.69	72.31	35.61	64.39	45.2	54.8
2022	37.28	62.72	50.78	49.22	51.85	48.15	48.51	51.49	28.8	71.2	37.12	62.88	46.13	53.87
2023	38.33	61.67	52.4	47.6	52.78	47.22	49.55	50.45	30.47	69.53	38.14	61.86	45.26	54.74
Total	35.16	64.84	51.47	48.53	50.82	49.18	47.47	52.53	27.23	72.77	34.72	62.28	44.31	55.69

Table 3 depicts that most vitamin D test attendants are females, particularly in the age groups 14-35 and 35-70. However, the share of males has been increasing recently. Overall, the share of females is twice the proportion of males. Figure 2 depicts the scatter of daily mean vitamin D levels between attendants, highlighting the vitamin D deficiency for most attendants based on the threshold of 30 for sufficiency.

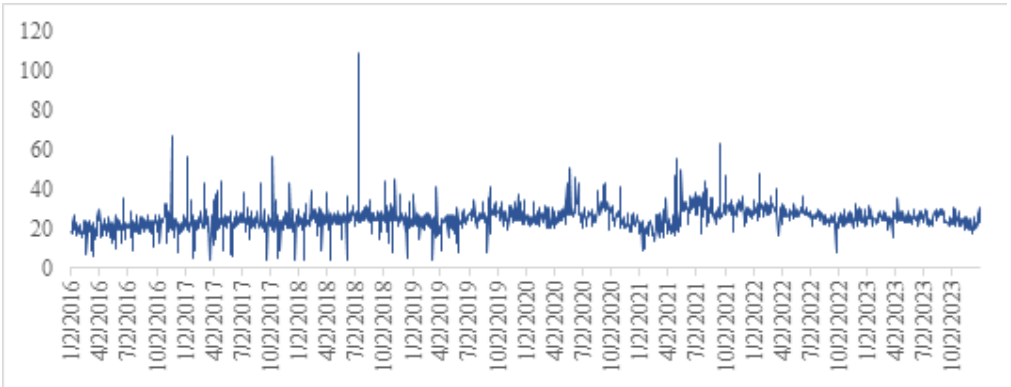

Figure 2: The frequency of vitamin D levels.

Table 4 presents the descriptive statistics of clean data set based on the vitamin D level value, verifying the high degree deficiency for under-study attendants.

According to Table 4, the mean equal to 25.3 shows an average of vitamin D level even lower than the traditional critical level of 30, and the third quantile equal to 32 implies that almost three quarters of attendants suffer from vitamin D deficiency. The worse thing is that the vitamin D level of about one quarter of attendants is less than 15, according to the first quantile, Q_1. Table 5 proposes more details of vitamin D status based on a 7-class range of vitamin D status.

Table 4: The descriptive statistics of vitamin D level.

	Mean	SE Mean	StDev	Minimum	Q_1	Median	Q_3	Maximum	IQR
All	25.3	0.022	14.48	1	15	23	32	155	17
Female	26.08	0.029	15.17	1	16	24	34	155	18
Male	23.85	0.033	12.97	1	15	22	30	155	15
0-1	31.98	0.222	14.28	4	23	30	38	155	15
4-Jan	22.75	0.109	13.24	2	14	21	28	155	14
14-Apr	21.7	0.066	13.34	2	13	19	28	155	15
14-35	21.7	0.037	12.75	1	12	20	28	155	16
35-70	27	0.03	14.45	2	17	25	34	155	17
>70	33.22	0.112	17.95	2	22	30	41	155	19

Table 5 shows about 71% of attendants suffer from vitamin D insufficiency, implying the need for vitamin D significance promotion in the public. Figure 3 illustrates the annual trend of vitamin D status among all attendants, verifying the worsening trend post-COVID-19 compared to Amid-COVID-19.

Table 5: The descriptive statistics of vitamin D status.

Diagnosis (Vitamin D status)	Deficient	Low	Insufficient	Sufficient	The best	High	Toxic
Vitamin D level	0-10	20-Oct	20-30	30-40	40-80	80-100	>100
%	13.1	28	30	17	11.3	0.4	0.2
Cumulative %	13.1	41.1	71.1	88.1	99.4	99.8	100

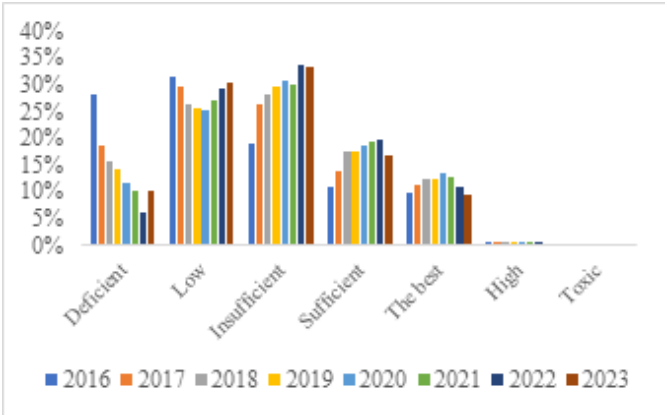

Figure 3: The annual trend of vitamin D status pre, amid, and post-COVID-19.

According to Figure 3, the vitamin D status followed a positive increasing trend before the end of the COVID-19 pandemic. However, people forget the significance of vitamin D for having an effective immune system post-COVID-19 because the share of insufficient and low vitamin D has been ascending and the proportion of sufficient and the best classes has been descending since 2022, post-COVID-19. Figure 4 compares the vitamin D status of men and women.

Figure 4 shows a much higher share of low and insufficient vitamin D status among men than women. Instead, women experienced a higher share of high and toxic vitamin D status. Overall, a lower dispersion could be seen among women's vitamin D status and their situation is much better than men in terms of vitamin D probably due to consuming more vitamin D complement. Figure 5 illustrates the best situation of vitamin D status for 0-1, 35-70, and +70 age groups, and the worst condition has been experienced by 1-4, 4-14, and 14-35 groups.

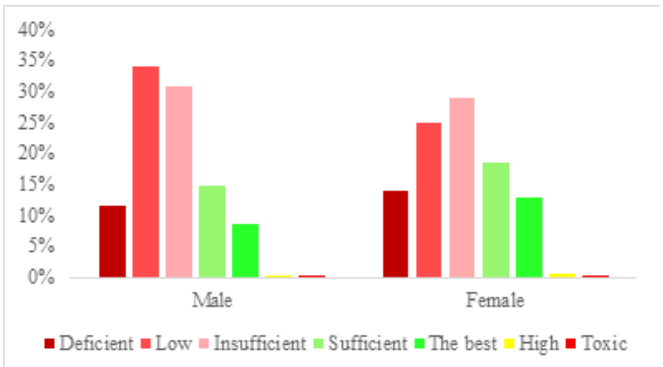

Figure 4: The gender-based vitamin D status analysis.

According to Figure 5, there is a high toxic share in the 0-1, 35-70, and +70 age groups, representing a kind of anomaly in

vitamin D complement consumption. Figure 6 illustrates the overall monthly trend of each vitamin D status share to investigate the corresponding violation during sunny months.

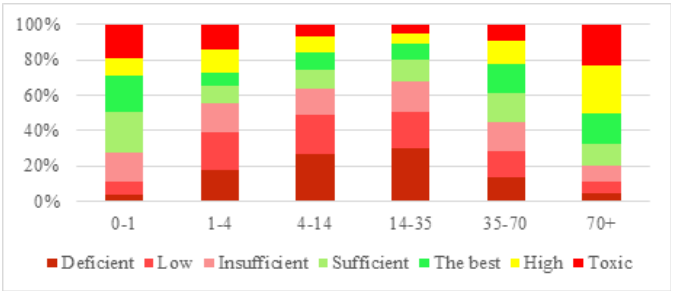

Figure 5: The age group-based vitamin D status.

Figure 6 shows a significant decrease in the deficiency and an increase in the low and insufficient vitamin D statuses during sunny months, including April, May, June, July, September, and October, because of natural vitamin D absorption.

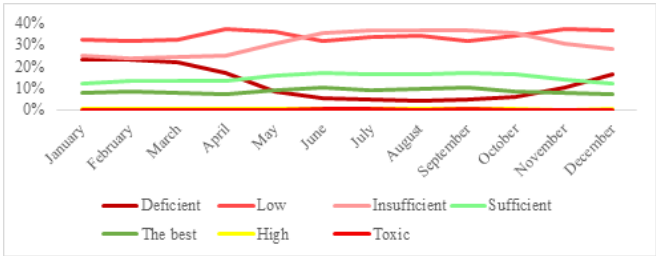

Figure 6: The monthly trend of vitamin D status.

Discussion and Prescriptive Analysis

Table 4 shows the mean of the Babol citizens' vitamin D level is just 25.3, less than 30 as a popular threshold, and even the vitamin D level of half of them is less than 23, implying the improper condition of public vitamin D level in this city. Furthermore, the overall mean vitamin D level among women is more than men, and the mean of four age groups involving 1-4, 4-14, 14-35, and 35-70 is less than the conventional threshold equal to 30. Even three-quarters of Babol citizens from each age group 1-4, 4-14, and 14-35 have a vitamin D level less than 28. On the other hand, Table 5 illustrates the majority of Babol citizens, about three quarters, suffer from vitamin D insufficiency. Hence, enhancing the citizens' awareness about the significance of vitamin D as a key factor to empower the immune system and encourage them to get more vitamin D directly by food and complements or indirectly from the sun should be taken into account by the city healthcare authorities.

Figure 3 depicts that the vitamin D status experienced a continuous positive trend during periods before and during COVID-19, up to 2021. However, this positive trend has been broken and substituted by a negative trend after COVID-19, since 2022. This alarm reminds the city's healthcare decision-maker to take some actions to put a change point on this undesirable trend to guarantee public health in the future. Hence, providing a time-based plan like a 5- or 10-year roadmap to reach reasonable vitamin D status is highly recommended. Figure 4 illustrates the worse situation of vitamin D status between males rather than women despite the more limitations for women to absorb vitamin D naturally because of dressing restrictions, the Islamic hijab. The main reason probably is taking more vitamin D complements by women than men due to a public sense that women care their health more than men in this city. Although the vitamin D status among both men and women is not reasonable, it seems that men need more warns and recommendations about their health as well as vitamin D levels. Figure 5 shows the worst vitamin D status in two age groups, including 4-14 and 14-35, probably due to the feeling of no need to receive vitamin D complements between young individuals. Also, three age groups, including 0-1, 1-4, and >70, have experienced the most high and toxic vitamin D status probably due to following bad complement consumption habits over the specialists' prescription. As a result, there is an emergency need to promote the significance of vitamin D levels among young people and inform elders to follow reasonable vitamin D consumption rates. Figure 6 depicts a noticeable impact of sunshine on the vitamin D status of people during sunny months in Babol City, particularly the decrease in deficiency and a small increase in sufficiency status. Accordingly, providing facilities for sun baths during sunny months and promoting using rich foods with vitamin D or vitamin D complements during cold and cloudy months are reasonable remedies to mitigate vitamin D insufficiency.

Conclusion, Limitation and Recommendation

A vitamin D level and status data analysis is conducted to investigate the corresponding trend pre-, amid, and post-COVID-19 in a case study based on big data collected from 2016 to 2023. Results showed a positive trend of vitamin D status among Babol citizens before and during COVID-19. However, this trend has gotten an adverse slope after COVID-19 since 2022, meaning that people are forgetting the importance of vitamin D as a key factor affecting the performance of human immunization. In addition, the vitamin D status is insufficient and worse among the majority of the public, particularly among men and individuals aged from 4 to 35. Also, a considerable proportion of vitamin D overdoses occur between fatal and elders probably because of not following the proper personalized prescription. Finally, the average vitamin D status gets better during sunny months, implying the significant impact of naturally direct vitamin D absorption.

The results of this research are restricted to the people settled in a city with its specific healthcare, food habits, and weather conditions. Hence, conducting the same research in other areas in Iran or other countries and comparing the results is recommended. The future works can focus on seasonal violation of vitamin D status and level, conducting predictive analysis on vitamin D level, and proposing several classifications using machine learning and deep learning algorithms based on vitamin D level and other personal specifications, such as food habits, weight, job, hygiene, chronic diseases, and family health history.

Conflict of Interest

The authors have no relevant financial or non-financial interests to disclose.

Declaration of generative AI and AI-assisted technologies in the writing process

None.

Data and Code Availability Statement

The Authors would submit the related data set and codes whenever a request is received.

Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors.

Compliance with Ethical Standards

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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