#### Impact of the COVID-19 pandemic on vitamin D status in adults

Yanzhao Chen\*1, HuiLiu1, Yang Yang1, Peng Wang1, and Guilian Kong\*1

1Demonstration Laboratory of Quality Control for *in vitro* analysis, Department of Nuclear Medicine, Henan Provincial People's Hospital, Zhengzhou University People's Hospital, The Clinical Medical College of Provincial Hospital of Zhengzhou University, Zhengzhou, Henan, 450003 China.

\* Correspondence to Guilian Kong [kongguilian666@163.com](mailto:kongguilian666@163.com) or Yanzhao Chen yanzhaochen1111@gmail.com

#### Abstract

To investigate the impact of the COVID-19 pandemic on vitamin D status among adults. A total of 1525 adults from Henan Provincial People's Hospital were included. The results revealed a significant difference in overall 25-hydroxyvitamin D (25(OH)D) levels between 2022 (18.14, 13.78, 23.68) and 2023 (19.15, 14.88, 25.01, p=0.004). Notably, males exhibited a substantial difference in 25(OH)D levels, with 18.01 (14.10, 23.53) in 2022 and 20.49 (16.11, 26.01) in 2023 (p<0.001). The prevalence of vitamin D deficiency was significantly higher in 2022 (62%) compared to 2023 (54.9%, p=0.009), with males having higher rates of deficiency (64.1% in 2022 and 47.2% in 2023). These findings were supported by an independent cohort of 168 individuals tested in both years, showing overall 25(OH)D levels of 20.73 ± 9.37 in 2022 and 22.28 ± 8.59 in 2023 (p=0.012), and vitamin D deficiency rates of 58.3% in 2022 and 47.0% in 2023 (p=0.038). In the 40-49 age group, 25(OH)D levels were significantly lower in 2022 (16.10, 12.41, 21.18) compared to 2023 (18.28, 13.91, 23.86, p=0.005), with a higher vitamin D deficiency rate in 2022 (72.8%) compared to 2023 (59.9%, p=0.02). Furthermore, in April, May, and June, 2022, 25(OH)D levels were significantly lower compared to 2023 (p<0.001, p<0.002, p<0.001, respectively), accompanied by a higher prevalence of vitamin D deficiency (p<0.001, p<0.002, p<0.001, respectively). In conclusion, our study findings indicate a substantial decline in vitamin D levels and an elevated prevalence of vitamin D deficiency among the adult population, with a particular emphasis on adult males, during the course of the COVID-19 pandemic.

#### Key words

Vitamin D, adults, COVID-19

#### Introduction

Since the emergence of the COVID-19 pandemic in Wuhan, China, in early 2020, China has implemented stringent measures to control the spread of the virus[1]. These measures entail mandatory mask usage, strict enforcement of social distancing, and stay-at-home orders when necessary. While some regions in China adopted a "zero-COVID" policy starting from August 2021, the city of Zhengzhou in Henan Province enforced rigorous lockdown measures during specific periods: January 5 to February 9, May 3 to May 17, and October 14 to December 14, 2022. These measures significantly curtailed outdoor activities, potentially leading to diminished levels of vitamin D, which is primarily synthesized in the skin through exposure to sunlight, specifically ultraviolet B radiation[2].

Vitamin D serves as a prohormone for a lipid-soluble steroid hormone. In its native form, vitamin D does not exhibit biological activity and necessitates hepatic conversion to its principal storage form, 25(OH)D[3]. Following this, it undergoes intracellular transformation within vitamin D receptor-expressing cells, culminating in the generation of the biologically active metabolite, 1,25-dihydroxyvitamin D[4]. Vitamin D plays a critical role in mediating calcium absorption and modulating bone metabolism within the human body. [5]. Moreover, vitamin D deficiency has been linked to unfavorable outcomes in COVID-19 patients, as well as increased susceptibility to bacterial and viral infections[6-8]. Vitamin D exerts influence on the expression of over 1000 genes and is implicated in various conditions, including diabetes, diverse cancer types, cardiovascular diseases, autoimmune disorders, and congenital immune disorders[6, 9-11].

Previous studies have yielded conflicting findings regarding the impact of the COVID-19 pandemic on vitamin D levels and deficiency rates. Some studies have reported no effect or even an elevation in vitamin D levels and a reduction in deficiency rates among populations[12-14]. Conversely, other studies have observed a decline in vitamin D levels and an increase in deficiency rates[15]. Currently, there is a dearth of research specifically investigating the influence of the COVID-19 pandemic on vitamin D levels in the adult population of China. Therefore, the primary objective of this study is to perform a comprehensive statistical analysis and comparative assessment of vitamin D levels among a population of healthy adults residing in Zhengzhou, Henan Province. Specifically, we aim to investigate potential variations in vitamin D levels and the prevalence of vitamin D deficiency between two distinct time periods: the COVID-19 pandemic in 2022 and the subsequent post-pandemic phase in 2023. The overarching aim is to elucidate the potential impact of the COVID-19 epidemic on vitamin D levels and the associated deficiency rates.

#### 2. Methods

##### 2.1 Study population

A cohort of 1525 individuals who underwent comprehensive health examinations at the Henan Provincial People's Hospital Examination Center between January 2022 and December 2023 was selected as the study population. The cohort consisted of 776 males and 749 females. The inclusion criteria for the study population were as follows: (1) age 18 years or older, and (2) absence of known medical conditions associated with abnormal levels of 25(OH)D, such as hyperparathyroidism or hypoparathyroidism, hyperthyroidism, severe liver or kidney diseases, post-gastrectomy status, severe infection, malignant tumors, among others. The study protocol adhered to the principles outlined in the Helsinki Declaration and received approval from the Hospital Ethics Review Committee. All procedures were conducted as part of routine clinical practice. Informed consent was waived due to the retrospective nature of the study.

##### 2.2 Data collection and 25(OH)D Measurement

Demographic information, including name, gender, age, identification number, examination date, and relevant clinical data such as underlying diseases, were obtained and extracted from the hospital's electronic system. Serum 25(OH)D levels were measured using the Elecsys® Vitamin D total kit (Roche Diagnostics) on the Roche Cobas® 8000 modular analyzer, specifically the e602 analyzer. The cutoff for defining vitamin D deficiency was based on the Clinical Application Consensus on Vitamin D and Its Analogs published by the Chinese Society of Osteoporosis and Bone Mineral Research in February 2018, which considered serum 25(OH)D levels below 20 ng/ml as indicative of deficiency.

##### 2.3 Statistical analysis

Statistical analysis was performed using SPSS 23.0 software, and data visualization was carried out using GraphPad Prism 8 software. Non-normally distributed continuous variables were described using the median with interquartile range (IQR) and analyzed using nonparametric tests. Paired t-tests were utilized for individuals who underwent 25(OH)D testing in both years, with continuous variables presented as mean ± standard deviation. Categorical variables were analyzed using chi-square tests. Statistical significance was set at a two-tailed p-value less than 0.05.

#### 3. Results

##### 3.1 Distribution Characteristics of the Study Population

A total of 1525 healthy adult participants were enrolled from the Physical Examination Center of Henan Provincial People's Hospital for this study. The demographic characteristics and distribution of the study population are summarized in Table 1. In 2022, during the period of epidemic control, there were 479 participants (287 males, 192 females). In 2023, following the complete relaxation of epidemic measures, there were 1046 participants (489 males, 557 females). Among the 1525 participants, a subset of 168 individuals (101 males, 67 females) underwent continuous 25(OH)D testing for both years (2022 and 2023). Notably, there was a statistically significant difference in gender distribution between these two years. The collected data was stratified by age groups: 18-29 years, 30-39 years, 40-49 years, 50-59 years, and ≥60 years. There was no statistically significant difference in the age distribution between the populations of 2022 and 2023. However, there was a statistically significant difference in serum 25(OH)D levels and the prevalence of vitamin D deficiency between the years 2022 and 2023.

Table 1. Characteristics of study subjects in the year 2022 (during COVID-2019 pandemic) compared to 2023 (post COVID-2019 pandemic)

|  |  |  |  |
| --- | --- | --- | --- |
| Variables | 2022(n=479) | 2023(n=1046) | *p* Value |
| Gender, n (%) |  |  |  |
| Male | 287(59.9%) | 489(46.7%) | <0.001 |
| Female | 192(40.1%) | 557(53.3%) |  |
| Age(years) | 45(36,56) | 47(35,56) | 0.429 |
| Age(years), n (%) |  |  |  |
| 18-29 | 36(7.5%) | 103(9.8%) | 0.051 |
| 30-39 | 148(30.9%) | 273(26.1%) |  |
| 40-49 | 114(23.8%) | 212(20.3%) |  |
| 50-59 | 108(22.5%) | 272(26.0%) |  |
| ≥60 | 73(15.2%) | 186(17.8%) |  |
| 25(OH)D (ng/ml) | 18.14(13.78,23.68) | 19.15(14.88,25.01) | 0.004 |
| VD status (ng/ml), n (%) |  |  |  |
| <20 | 297(62%) | 574(54.9%) | 0.009 |
| ≥20 | 182(38%) | 472(45.1%) |  |

Abbreviations: COVID‐19, coronavirus disease 2019; 25(OH)D, 25-hydroxy vitamin D.

##### 3.2 Impact of the COVID-19 Pandemic on Vitamin D Levels in the Population

Serum levels of 25(OH)D were assessed using median and quartile values in the study participants. Statistical analysis revealed a significant difference in 25(OH)D levels between the year of during COVID-19 pandemic (2022) and the year of post COVID-19 pandemic (2023), with a p-value of 0.004. Within the same gender group, males exhibited significantly lower serum levels of 25(OH)D in 2022 compared to 2023 (p<0.001). However, no statistically significant difference was observed in 25(OH)D levels among females (p=0.908). Further analysis indicated that there was no statistically significant disparity in vitamin D levels between males and females in 2022 (p=0.774). Nonetheless, in 2023, the vitamin D levels among males exhibited a marked increase in comparison to females, with a statistically significant difference (p<0.001). as indicated in Table 2.

Among different age groups, individuals aged 40-49 years demonstrated significantly lower serum levels of 25(OH)D in 2022 compared to 2023 (p=0.005), Subsequent analysis demonstrated a statistically significant elevation in vitamin D levels among individuals aged 50-59 years and those above 60 years during both the years 2022 and 2023, in contrast to the remaining age cohorts (p<0.001). The detailed results are presented in Table 3.

Furthermore, the population was stratified by month, and a comparative analysis of serum 25(OH)D levels between the two years was conducted. The statistical analysis revealed that the levels of 25(OH)D in February, March, and April of 2022 were significantly lower compared to the corresponding period in 2023, with p-values of <0.001, 0.002, and <0.001, respectively. In contrast, the testing results in October 2022 were higher than in 2023, with a statistically significant difference (p=0.026). However, there were no statistically significant differences observed in the remaining months when comparing the results between 2022 and 2023. The detailed results are presented in Table 4.

For the subset of 168 individuals who underwent continuous 25(OH)D testing over two consecutive years, the results were reported as mean ± standard deviation. The overall testing results in 2022 (20.73 ± 9.37) were significantly lower than those in 2023 (22.28 ± 8.59), with a p-value of 0.012. Among females, the testing results in 2022 (19.37 ± 9.60) were significantly lower than those in 2023 (21.97 ± 9.46), with a p-value of 0.015. However, among males, there was no statistically significant difference in the testing results between 2022 (21.64 ± 9.15) and 2023 (22.49 ± 8.01), with a p-value of 0.253, as presented in Figure 1a.

Table 2. The 25(OH)D concentration and the rate of vitamin D deficiency in different gender groups in 2022(during COVID-2019 pandemic) compared to 2023 (post COVID-2019 pandemic)

|  |  |  |  |
| --- | --- | --- | --- |
| Variables | 2022(n=479) | 2023(n=1046) | *p* Value |
| Total M(P25-P75) | 18.14(13.78,23.68) | 19.15(14.88,25.01) | 0.004 |
| Male M(P25-P75) | 18.01(14.10,23.53) | 20.49(16.11,26.01) | <0.001 |
| Female M(P25-P75) | 18.28(13.27,24.39) | 17.69(13.72,23.43) | 0.908 |
| *p* Value | 0.774 | <0.001 |  |
| VD status  <20 (ng/ml), n (%) |  |  |  |
| Total | 297(62%) | 574(54.9%) | 0.009 |
| Male | 184(64.1%) | 231(47.2%) | <0.001 |
| Female | 113(58.9%) | 343(61.6%) | 0.505 |
| *p* Value | 0.245 | <0.001 |  |

*Note*: The concentration unit of 25(OH)D was ng/ml.

Abbreviations: COVID‐19, coronavirus disease 2019; 25(OH)D, 25-hydroxy vitamin D.

Table 3. The 25(OH)D concentration and the rate of vitamin D deficiency in different age groups in 2022(during COVID-2019 pandemic) compared to 2023 (post COVID-2019 pandemic)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Age (years) | 2022 | | 2023 | | *p* | 2022 | 2023 | *p* |
| n | M (P25, P75) | n | M (P25, P75) | 25(OH)D<20 ng/ml, n (%) | |
| 18-29 | 36 | 16.09(13.43,21.41) | 103 | 15.08(12.81,21.26) | 0.706 | 26(72.2%) | 75(72.8%) | 0.945 |
| 30-39 | 148 | 17.10(12.87,20.49) | 273 | 17.59(13.84,22.12) | 0.059 | 110(74.3%) | 179(65.6%) | 0.064 |
| 40-49 | 114 | 16.10(12.41,21.18) | 212 | 18.28(13.91,23.86) | 0.005 | 83(72.8%) | 127(59.9%) | 0.020 |
| 50-59 | 108 | 20.14(15.31,27.13) | 272 | 21.63(16.34,27.76) | 0.322 | 52(48.1%) | 121(44.5%) | 0.518 |
| >60 | 73 | 24.20(17.16,33.70) | 186 | 21.47(17.18,29.88) | 0.200 | 26(35.6%) | 72(38.7%) | 0.644 |
| *p* |  | <0.001 |  | <0.001 |  | <0.001 | <0.001 |  |

Abbreviations: COVID‐19, coronavirus disease 2019; 25(OH)D, 25-hydroxy vitamin D.

##### 3.3 Impact of the COVID-19 Pandemic on the Prevalence of Vitamin D Deficiency in the Population

In the year during COVID-19 pandemic in 2022, a total of 297 individuals (62% of the total population) had serum 25(OH)D levels below 20 ng/ml. In 2023, the number of individuals with vitamin D deficiency increased to 574, representing 54.9% of the total population. Statistical analysis revealed a significant difference in the prevalence of vitamin D deficiency between 2022 and 2023 (p = 0.009). When stratifying by gender, the prevalence of vitamin D deficiency among males was 64.1% in 2022, which was higher than the 47.2% in 2023, with a statistically significant difference (p < 0.001). However, no statistically significant difference was observed in the prevalence of vitamin D deficiency among females (p = 0.505). Further analysis demonstrated that there was no statistically significant difference in the prevalence of vitamin D deficiency between males and females in 2022 (p=0.245). However, in 2023, the prevalence of vitamin D deficiency among males was significantly lower in comparison to females, with a statistically significant difference (p<0.001). The results are presented in Table 2.

When comparing by age group, the prevalence of vitamin D deficiency in the 40-49 age group in 2022 was 72.8%, higher than the 59.9% in 2023, with statistically significant differences (p = 0.020). No statistically significant difference was observed in the prevalence of vitamin D deficiency in other age groups. Further analysis revealed a significantly lower prevalence of vitamin D deficiency among individuals aged 50-59 years and those above 60 years in both 2022 and 2023, as compared to other age groups. This difference was statistically significant (p<0.001). The results are presented in Table 3.

When comparing by month, the prevalence of vitamin D deficiency in February, March, and April of 2022 was 96.4%, 73.7%, and 80.3%, respectively, higher than the corresponding periods in 2023, which were 62.0%, 50.5%, and 53.8%, respectively, with statistically significant differences (p < 0.001, 0.015, and < 0.001, respectively). No statistically significant difference was observed in the prevalence of vitamin D deficiency in other months. The results are presented in Table 4.

Among the 168 individuals who underwent 25(OH)D tests in both years, the prevalence of vitamin D deficiency in 2022 was 58.3%, higher than the 47.0% in 2023, with a statistically significant difference (p = 0.038). Among males, the prevalence of deficiency in 2022 was 54.5%, higher than the 40.6% in 2023, with a statistically significant difference (p = 0.049). No statistically significant difference was observed in the prevalence of vitamin D deficiency among females， as presented in Figure 1b.

Table 4. The 25(OH)D serum concentration and the rate of vitamin D deficiency in each month of the year 2022 (during COVID-2019 pandemic) and 2023 (post COVID-2019 pandemic).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 2022 | | 2023 | | *p* | 2022 | 2023 | *p* |
| n | M (P25, P75) | n | M (P25, P75) | 25(OH)D<20 ng/ml, n (%) | |
| Jan | 13 | 15.06(12.23,18.66） | 57 | 15.73(12.69,21.49) | 0.345 | 10(76.9%) | 42(73.7%) | 0.809 |
| Feb | 56 | 12.23(10.46,14.81） | 50 | 17.24(13.70,23.84) | <0.001 | 54(96.4%) | 31(62.0%) | <0.001 |
| Mar | 38 | 16.54(11.97,21.90） | 93 | 19.86(16.40,25.28) | 0.002 | 28(73.7%) | 47(50.5%) | 0.015 |
| Apr | 76 | 15.91(12.53,19.49） | 130 | 20.16(15.45,25.46) | <0.001 | 61(80.3%) | 70(53.8%) | <0.001 |
| May | 63 | 18.40(13.96,21.93） | 123 | 19.02(15.02,23.85) | 0.297 | 41(65.1%) | 68(55.3%) | 0.199 |
| June | 50 | 23.58(17.29,29.91） | 98 | 20.16(16.64,27.92) | 0.090 | 18(36.0%) | 48(49.0%) | 0.133 |
| July | 46 | 22.42(16.72,26.60） | 81 | 22.55(18.14,29.36) | 0.237 | 18(39.1%) | 26(32.1%) | 0.423 |
| Aug | 42 | 22.09(17.56,31.75） | 52 | 23.89(17.62,30.26) | 0.957 | 16(38.1%) | 22(42.3%) | 0.679 |
| Sep | 55 | 19.45(14.47,23.70） | 65 | 22.27(16.33,26.86) | 0.196 | 30(54.5%) | 25(38.5%) | 0.078 |
| Oct | 27 | 19.89(15.35,30.50） | 100 | 17.01(13.88,21.64) | 0.026 | 14(51.9%) | 66(66.0%) | 0.177 |
| Nov | 8 | 17.58(13.38,23.30） | 97 | 16.40(13.21,21.77) | 0.704 | 5(62.5%) | 68(70.1%) | 0.653 |
| Dec | 5 | 35.07(13.87,41.58） | 100 | 16.33(12.42,21.16) | 0.078 | 2(40.0%) | 67(67.0%) | 0.215 |
| *p* |  | <0.001 |  | <0.001 |  | <0.001 | <0.001 |  |

*Note*: The concentration unit of 25(OH)D was ng/ml.

Abbreviations: COVID‐19, coronavirus disease 2019; 25(OH)D, 25-hydroxy vitamin D.

##### 4.Discussion

Following the onset of the COVID-19 pandemic, China implemented stringent control strategies aimed at effectively mitigating disease transmission. These measures, however, imposed significant restrictions on individuals' mobility, with some even being confined to their residences during the peak of the outbreak. Throughout 2022, the city of Zhengzhou experienced a total of 107 days characterized by rigorous control measures, resulting in a marked reduction in outdoor activities among the populace. It was not until December 14, 2022, that these stringent control policies were abruptly lifted, leading to a rapid propagation of the virus. By January 6, 2023, the Health Commission of Henan Province reported an infection rate of 89% for COVID-19 across the province, with urban areas exhibiting a rate of 89.1% and rural areas at 88.9%. Subsequently, the daily lives of individuals returned to a state of normalcy prior to the pandemic. The principal source of vitamin D synthesis in the human body stems from direct cutaneous exposure to sunlight, particularly ultraviolet B radiation[2]. Consequently, the protracted duration of containment measures in Zhengzhou, Henan during 2022 is anticipated to exert an influence on the population's vitamin D levels and the prevalence of vitamin D insufficiency.

Vitamin D plays a crucial role in the absorption of calcium which exerts pivotal roles in diverse physiological processes encompassing cellular signaling, hemostasis, myocyte contractility, and neural modulation[16]. Moreover, investigations have elucidated the ability of vitamin D to facilitate phosphorus absorption, thereby directly influencing the calcium-phosphorus balance and skeletal metabolism in the human system[17]. Epidemiological evidence has firmly established associations linking vitamin D deficiency with an array of chronic ailments, including autoimmune disorders such as multiple sclerosis, type 1 diabetes, and rheumatoid arthritis, as well as cardiovascular disease, type 2 diabetes, neurocognitive impairments, and infectious diseases, notably including COVID-19[18-21].

Henan Province is situated in the central-eastern region of China, primarily characterized by expansive plains and encompassing an area of 16.7 square kilometers. Its geographic center is located at coordinates 33.5°N and 113.3°E. The province is predominantly situated within the warm temperate zone, with the southern area undergoing a transition from subtropical to warm temperate, demonstrating a continental monsoon climate. On average, the annual temperature in the province ranges from 12°C to 16°C, while the duration of sunlight varies depending on the specific date.

In this study, we observed a substantial decline in the number of individuals seeking medical examinations at our institution due to the COVID-19 pandemic, particularly during January and October to December of 2022, which exhibited a significant decrease compared to the corresponding periods in 2023. Concurrently, the pandemic of COVID-19 resulted in a decline in the overall serum 25(OH)D levels and an increase in the overall prevalence of vitamin D deficiency within the adult population. When stratifying by gender, we found that the impact of the COVID-19 pandemic was more pronounced among males than females. Specifically, in males, the serum 25(OH)D levels in 2023 were significantly higher than those in 2022, and the prevalence of vitamin D deficiency in 2023 was significantly lower than that in 2022. However, no significant differences in serum 25(OH)D levels and deficiency rates were observed between the two years among females. When comparing genders within the same year, the serum vitamin D levels in females were slightly higher than those in males in 2022, and the prevalence of vitamin D deficiency was lower than that in males, albeit these differences did not reach statistical significance. This phenomenon may be attributable to the fact that vitamin D is a fat-soluble vitamin stored in adipose tissue, and the disparity in body fat composition between genders may play a contributory role[22]. In 2023, this pattern was reversed, with significantly higher serum vitamin D levels and significantly lower deficiency rates observed among males compared to females. This intriguing finding may be elucidated by the impact of the COVID-19 pandemic, as even though both males and females experienced reduced outdoor activity, females tend to adhere more diligently to sunscreen usage. Research has demonstrated that sunscreen with SPF30 can diminish vitamin D synthesis by 95%[23]. Consequently, the impact of the COVID-19 pandemic appears to have a greater effect on males than females. This phenomenon was further corroborated by the analysis of vitamin D levels in 168 individuals examined in both 2022 and 2023. The mean serum 25(OH)D levels in 2023 were higher than those in 2022, both in the overall population and when comparing the same gender. Furthermore, the prevalence of vitamin D deficiency in 2023 was lower than that in 2022. Although disparities in 25(OH)D levels were noted among females between the two years, no significant differences in vitamin D deficiency rates were observed. In contrast, no disparities in 25(OH)D levels were observed among males between the two years, but a significant difference in vitamin D deficiency rates was evident. In the comparison of different age groups, it was observed that the vitamin D levels in the 40-49 age group were significantly lower in 2022 compared to 2023. Additionally, the prevalence of vitamin D deficiency in this age group was significantly higher in 2022 than in 2023. Moreover, irrespective of the year (2022 or 2023), there was a gradual increase in vitamin D levels and a decrease in deficiency rates with advancing age. These findings are consistent with previous research conducted in various regions of China and other countries globally[24, 25]. The observed pattern can potentially be attributed to increased outdoor activity among older individuals after retirement, considering that the retirement age in China is 60 for males and 50 or 55 for females. Regarding the monthly comparison, it was noted that vitamin D levels in February, March, and April of 2022 were significantly lower than the corresponding months in 2023. Similarly, the deficiency rates of vitamin D in 2022 were higher compared to 2023 during the same months. These outcomes align with previous investigations in children conducted at Henan Children's Hospital[15]. Furthermore, this study revealed that vitamin D levels were highest during the summer months (June, July, August, and September) in both 2022 and 2023, followed by a gradual decline, reaching the lowest levels during the winter season. Overall, vitamin D levels during the summer and autumn seasons were significantly higher compared to the winter and spring seasons. These findings are consistent with prior studies conducted in other regions of China and other countries[25-27]. The observed trends can be attributed to longer daylight hours, elevated ultraviolet radiation levels during the summer, as well as favorable weather conditions and increased outdoor activity time during the autumn season, all of which contribute to higher vitamin D levels.

This study represents the inaugural comparison of adult vitamin D levels and deficiency rates during and post the COVID-19 pandemic in Henan Province of China. Nonetheless, several limitations warrant consideration. Firstly, the study cohort primarily emanated from Henan Province, a plain region in China, thereby potentially engendering variances when juxtaposed with diverse locales. Secondly, the implementation of stringent containment measures compelled individuals to adhere to home confinement, consequently yielding a constrained sample size during this period. Notably, the study lacked comprehensive documentation pertaining to individual-specific outdoor activity duration, dietary habits, and vitamin D supplementation regimens, thereby potentially introducing inherent biases in the derived findings.

In conclusion, this study established that the COVID-19 pandemic exerts a demonstrable impact on diminishing vitamin D levels and elevating the prevalence of vitamin D deficiency in the adult population, with a particularly notable effect observed in males. These findings highlight the critical significance of sufficient outdoor activities in facilitating adequate vitamin D supplementation within the human organism.

##### Author contributions

The manuscript composition was undertaken by Yanzhao Chen and Guilian Kong. Yanzhao Chen, Hui Liu, Yang Yang, and Peng Wang were responsible for the collection and screening of research materials. The study design and manuscript revision were carried out by Yanzhao Chen and Guilian Kong.

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##### Conflict of interest

The authors declare no conflict of interest.

##### Data availability statement

The data that underlies the conclusions drawn in this study are available upon request from the corresponding author. However, due to the presence of sensitive participant information, these data cannot be publicly disclosed.

##### Ethics statement

The study protocol adhered to the principles outlined in the Helsinki Declaration and received approval from the Hospital Ethics Review Committee. All procedures were conducted as part of routine clinical practice. Informed consent was waived due to the retrospective nature of the study.

##### Reference

1. Liu J, Liu S: The management of coronavirus disease 2019 (COVID-19). *J Med Virol* 2020, 92(9):1484-1490.

2. Holick MF, MacLaughlin JA, Clark MB, Holick SA, Potts JT, Jr., Anderson RR, Blank IH, Parrish JA, Elias P: Photosynthesis of previtamin D3 in human skin and the physiologic consequences. *Science* 1980, 210(4466):203-205.

3. Bikle DD: Vitamin D metabolism, mechanism of action, and clinical applications. *Chem Biol* 2014, 21(3):319-329.

4. Holick MF, Schnoes HK, DeLuca HF, Suda T, Cousins RJ: Isolation and identification of 1,25-dihydroxycholecalciferol. A metabolite of vitamin D active in intestine. *Biochemistry* 1971, 10(14):2799-2804.

5. Bouillon R, Van Cromphaut S, Carmeliet G: Intestinal calcium absorption: Molecular vitamin D mediated mechanisms. *J Cell Biochem* 2003, 88(2):332-339.

6. Bae JH, Choe HJ, Holick MF, Lim S: Association of vitamin D status with COVID-19 and its severity : Vitamin D and COVID-19: a narrative review. *Rev Endocr Metab Disord* 2022, 23(3):579-599.

7. Grant WB, Lahore H, McDonnell SL, Baggerly CA, French CB, Aliano JL, Bhattoa HP: Evidence that Vitamin D Supplementation Could Reduce Risk of Influenza and COVID-19 Infections and Deaths. *Nutrients* 2020, 12(4).

8. Greulich T, Regner W, Branscheidt M, Herr C, Koczulla AR, Vogelmeier CF, Bals R: Altered blood levels of vitamin D, cathelicidin and parathyroid hormone in patients with sepsis-a pilot study. *Anaesth Intensive Care* 2017, 45(1):36-45.

9. Holick MF: Vitamin D deficiency. *N Engl J Med* 2007, 357(3):266-281.

10. Garland CF, Garland FC, Gorham ED, Lipkin M, Newmark H, Mohr SB, Holick MF: The role of vitamin D in cancer prevention. *Am J Public Health* 2006, 96(2):252-261.

11. Shirvani A, Kalajian TA, Song A, Holick MF: Disassociation of Vitamin D's Calcemic Activity and Non-calcemic Genomic Activity and Individual Responsiveness: A Randomized Controlled Double-Blind Clinical Trial. *Sci Rep* 2019, 9(1):17685.

12. Kwon JY, Kang SG: Changes in Vitamin D Status in Korean Adults during the COVID-19 Pandemic. *Nutrients* 2022, 14(22).

13. Lippi G, Ferrari A, Targher G: Is COVID-19 lockdown associated with vitamin D deficiency? *Eur J Public Health* 2021, 31(2):278-279.

14. Meoli M, Muggli F, Lava SAG, Bianchetti MG, Agostoni C, Kocher C, Buhrer TW, Ciliberti L, Simonetti GD, Milani GP: Vitamin D Status in Adolescents during COVID-19 Pandemic: A Cross-Sectional Comparative Study. *Nutrients* 2021, 13(5).

15. Li T, Li X, Chen N, Yang J, Yang J, Bi L: Influence of the COVID-19 pandemic on the vitamin D status of children: A cross-sectional study. *J Med Virol* 2023, 95(1):e28438.

16. Holick MF: Sunlight and vitamin D for bone health and prevention of autoimmune diseases, cancers, and cardiovascular disease. *Am J Clin Nutr* 2004, 80(6 Suppl):1678S-1688S.

17. Bell TD, Demay MB, Burnett-Bowie SA: The biology and pathology of vitamin D control in bone. *J Cell Biochem* 2010, 111(1):7-13.

18. Martineau AR, Jolliffe DA, Hooper RL, Greenberg L, Aloia JF, Bergman P, Dubnov-Raz G, Esposito S, Ganmaa D, Ginde AA *et al*: Vitamin D supplementation to prevent acute respiratory tract infections: systematic review and meta-analysis of individual participant data. *BMJ* 2017, 356:i6583.

19. Pereira M, Dantas Damascena A, Galvao Azevedo LM, de Almeida Oliveira T, da Mota Santana J: Vitamin D deficiency aggravates COVID-19: systematic review and meta-analysis. *Crit Rev Food Sci Nutr* 2022, 62(5):1308-1316.

20. Hewison M: Vitamin D and innate and adaptive immunity. *Vitam Horm* 2011, 86:23-62.

21. Holick MF: The One-Hundred-Year Anniversary of the Discovery of the Sunshine Vitamin D(3): Historical, Personal Experience and Evidence-Based Perspectives. *Nutrients* 2023, 15(3).

22. Lagunova Z, Porojnicu AC, Lindberg F, Hexeberg S, Moan J: The dependency of vitamin D status on body mass index, gender, age and season. *Anticancer Res* 2009, 29(9):3713-3720.

23. Matsuoka LY, Ide L, Wortsman J, MacLaughlin JA, Holick MF: Sunscreens suppress cutaneous vitamin D3 synthesis. *J Clin Endocrinol Metab* 1987, 64(6):1165-1168.

24. Griffin TP, Wall D, Blake L, D GG, Robinson S, Bell M, Mulkerrin EC, O'Shea PM: Higher risk of vitamin D insufficiency/deficiency for rural than urban dwellers. *J Steroid Biochem Mol Biol* 2020, 197:105547.

25. GaoGao C: Serum vitamin D levels in Shanghai adults: effects of gender, age and season. *Chi J Osteoporos* 2022, 28:5.

26. Niculescu DA, Capatina CAM, Dusceac R, Caragheorgheopol A, Ghemigian A, Poiana C: Seasonal variation of serum vitamin D levels in Romania. *Arch Osteoporos* 2017, 12(1):113.

27. Yao Y, Fu S, Li N, Hu F, Zhang H, Zhu Q, Luan F, Zhang F, Zhao Y, He Y: Sex, Residence and Fish Intake Predict Vitamin D Status in Chinese Centenarians. *J Nutr Health Aging* 2019, 23(2):165-171.

Figure 1. The 25(OH)D was tested in 168 participants (male,101 and female,67) both of the year 2022 and 2023. Error bars indicated mean ± SD, \**P* < 0.05.