

Vitamin D Status and Vitamin C and Zinc Supplementations in Patients Infected with COVID 19 in Benghazi, Libya (2021)

Souad El-mani¹, Hana El-Bakoush¹, Fawzia Bozaid¹, Reima Mansour¹, Hana Idris¹, Anwaar Bubaker², Aisha Abdsalam² & Ali Ateia Elmabsout^{1*}

¹Department of Nutrition, Faculty of Public Health, University of Benghazi, Benghazi, Libya.

²Faculty of Pharmacy, University of Benghazi, Benghazi, Libya.

Corresponding Author (Ali Ateia Elmabsout) Email: ali.elmabsout@uob.edu.ly*



DOI: <https://doi.org/10.38177/ajbsr.2026.8308>

Copyright © 2026 Souad El-mani et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Article Received: 21 June 2026

Article Accepted: 24 August 2026

Article Published: 28 August 2026

ABSTRACT

Background: Although coronavirus disease 2019 (COVID19) is asymptomatic or has mild symptoms in the majority of the population, it may lead to death by causing serious clinical syndromes. Extensive research has explored the effects of vitamin D, zinc and vitamin C on the treatment and complications of COVID19 and its potential contribution to the reduction of COVID19 incidence. The aim of the study was to investigate the vitamin D status and micronutrients supplements in patients infected with Covid19.

Methods: In this cross-section study, a total of 306 patients infected with Covid19 which consist of 171 male and 135. The data collected by web based and interview of the patients and data was analysis by using Chi-square test at $\alpha < 0.05$.

Result: The present study revealed that, 52.6% single as their marital status. Furthermore, more than 50% were have bachelor degree as type of education levels and 57.8% of patients have employee occupation. The vitamin D levels have been found in the patients during the infection were less than 10 ng/ml in around 58.2% of patients. 53.3% of patients used some vitamin supplements. Further investigation of dose of vitamin D used by the patients were found 1000 IU in around 20% of patients and 50,000 in 13.4% while the other doses of vitamin D being the least. The patients infected with COVID19 used zinc and vitamin C supplements as, 52% and 71.6% respectively. For the zinc and vitamin C tablet, the doses used found 15 mg/day) and Vitamin C was 500 mg/day. The health status of patients have been improved after used the supplementation of vitamin D, zinc and vitamin D and these improvements were reported in 68.9%, 50.7% and 70.3% respectively. According to classification of the complications, about 61.8% of patients were have serious complication and 30.4% have mild symptoms.

Conclusion: The present study revealed that potential role of vitamin D, C and Zinc in improving the symptoms of disease and also the severity of infection increased with vitamin D deficiency.

Keywords: Vitamin D; Vitamin C; Zinc; Patients; Covid19; Severity of Infection; Complications; Supplements; Respiratory Disease; Healthy.

1.0. Introduction

Although coronavirus disease 2019 (COVID-19) is asymptomatic or has mild symptoms in the majority of the population, it may lead to death by causing serious clinical syndromes such as pneumonia, acute respiratory distress syndrome (ARDS), myocarditis, microvascular thrombosis, and cytokine storm in some patients [1]. Therefore, there is a need to protect individuals from COVID-19, which is reported to have become more contagious as it has mutated, and to reduce the risk of severe disease and, consequently, the mortality rate. The COVID-19 vaccines that have been approved for emergency use have been a gleam of hope in the global struggle against COVID-19. However, the effects of vaccines on the immune system have not been clearly proven, and there have been some cases of severe COVID-19 cases, and even deaths, in patients who were fully vaccinated. As we have learned from similar viral infections, supplements such as vitamin D to support the immune system play an important role in addition to vaccination [2].

Extensive research has explored the effects of vitamin D on the treatment and complications of COVID-19 and its potential contribution to the reduction of COVID-19 incidence. Vitamin D exerts antiviral activity and inhibits viral replication by stimulating the release of cathelicidin and defensin proteins in monocytes and macrophages [2,3]. Vitamin D plays an important role in preventing respiratory system infections due to its effects such as stimulating

the chemotaxis of T-lymphocytes and clearing respiratory pathogens by inducing apoptosis and autophagy in the infected epithelium [4]. It has been reported that low T-lymphocyte levels were found in some COVID-19 patients with severe symptoms [5]. Since vitamin D supplementation increases the level of T-lymphocytes [6], this finding provides support for the hypothesis that vitamin D could be useful in the treatment of COVID-19. The severe progression of COVID-19 in some patients is one of the most important problems of the pandemic.

Studies have pointed out an increased rate of thrombotic events and cytokine storm in severe COVID-19 patients. These events are responsible for fatal outcomes [7-9]. It is well known that vitamin D sufficiency reduces the risk of cytokine storm and regulates thrombotic pathways [10,11]. It has been reported that vitamin D sufficiency may attenuate the increased levels of inflammatory markers and cytokine storm during COVID-19 disease and that vitamin D deficiency (VDD) may be related to COVID-19 severity and mortality [12]. Consequently, the effect of VDD on COVID-19 infection and outcomes is topic that has attracted considerable interest. Most current studies about this subject have focused on the effect of VDD on COVID-19 infection, severity, and treatment, and findings on the relationship between VDD and COVID-19 mortality are limited.

Therefore, as reported in the literature [13-15], more comprehensive clinical studies are still needed. Three meta-analyses of this issue have been published, one of which is a preprint article [16-18]. In these studies, identified some problems such as inconsistent definitions of VDD (e.g., $25[\text{OH}]\text{D} < 20$ or 12 ng/mL , < 50 or 30 nmol/L), the combination of different summary statistics (e.g., odds ratio [OR], risk ratio [RR], and hazard ratio [HR]), and a tendency to perform a meta-analysis of an individual study and give the results as if they were pooled results of a meta-analysis. In the Endocrine Society's Practice Guidelines on Vitamin D, VDD is defined as a $25(\text{OH})\text{D}$ level $< 20 \text{ ng/mL}$ or 50 nmol/L) proposed by advisory bodies. The purpose of this study was to synthesize evidence on the associations of VDD with COVID-19 infection, severity, and mortality and to provide an analytical contribution to the literature on the role of vitamin D supplementation in treatment and prevention protocols for COVID-19 [19].

Some molecules and nutrients play central roles in keeping the function and integrity of the immune system, showing synergistic results in steps that are crucial for the immune response. Among these elements, zinc, and vitamin C present robust evidence of their immunomodulating activity, such that their deficit, even if superficial, can harm the metabolism and, hence, their response on the immune system [20].

1.1. Objective of the study

This study aimed to assessed vitamin D status and vitamin C and Zinc supplementations in patients infected with COVID 19.

2.0. Materials and methods

In this cross-section study, a total of 306 patients infected by Covid19 which consist of 171 male and 135. The data collected of this study started in June 2021 and ended in September 2021 in Benghazi city, Libya. Furthermore, the data collected of this study by web based and interview of the patients.

2.1. Questionnaire designed

The predesigned questionnaire was used consist of information regarding personal information, socio-demographic data. Vitamin D, Types of supplementations, symptoms and types of treatment also included. All data collected was through immediate interview with patients.

2.2. Vitamin D Status

Vitamin D status was determined by identified serum levels of vitamin D of the patients from laboratory results. The study also investigates the vitamin C and zinc supplementation.

2.3. Statistical analysis

The data were analyzed using SPSS version 26. Continuous variables were summarized using number (frequency), mean, and standard deviation while categorical variables are summarized using frequency and percentage. The proportions were compared with Karl Pearson's Chi-square test. Level of significance (α) was set at 0.05.

3.0. Results

The data collected on 306 patients shown that, the average ages of patients were 35 ± 7 years old. The most patients involved in this study were those have age groups between 35-44 years old (49.7%) followed by age groups between 18-24 years old (33%) where the other age groups presented by less than 20% (Table 1). In reading gender distribution about 56% were male and 44% female (Table 1).

Table 1. Ages and gender distribution.

		N	N %
Ages (in years)	18-24	101	33.0%
	25-34	49	16.0%
	35-44	152	49.7%
	45-55	4	1.3%
	Total	306	100.0%
Gender	male	171	55.9%
	Female	135	44.1%
	Total	306	100.0%

In regarding socio-demographic characteristics presented in table 2, more than 85% of patients were white, with about 52.6% single as their marital status. Furthermore, more than 50% were have bachelor degree as type of education levels and 57.8% of patients have employee occupation (Table 2).

Table 2. Socio-demographic characteristics

		N	N %
Race	White	263	85.9%
	Black	43	14.1%
	Total	306	100.0%

Marital status	Single	161	52.6%
	Married	145	47.4%
	Total	306	100.0%
Education levels	Illiterate	9	2.9%
	Primary	8	2.6%
	Secondary	80	26.1%
	Bachelor	157	51.3%
	Master	52	17.0%
	Total	306	100.0%
Occupation	Employee	177	57.8%
	Business	45	14.7%
	Students	39	12.7%
	Unemployed	42	13.7%
	Retired	3	1.0%
	Total	306	100.0%

Approximately 60% of patients were infected once with covid followed by four times 32.4%. The most sign and symptoms reported by patients were headache, loss of taste, loss of smell and cough 17.6%, 10.5%, 10.1% and 7.5% respectively (Table 3). The duration of illness have been reported by patients in which longer than 18 days presented by more than one third and about 18.3% for those whom have the duration of illness less than 3 days.

Table 3. History of COVID infection and symptoms.

		N	N %
How often have infected with corona virus	Four	99	32.4%
	Three	15	4.9%
	Tow	10	3.3%
	One	182	59.5%
	Total	306	100.0%
Signs and symptoms	Anorexia	17	5.6%
	Cough	23	7.5%
	Diarrhea	11	3.6%
	Fever	21	6.9%
	Headache	54	17.6%
	Loss of smell	31	10.1%
	Loss of taste	32	10.5%
	Sadness	10	3.3%
	Other	107	35.0%
	Total	306	100.0%

Duration of illness	Less than 3 days	56	18.3%
	3-7 days	48	15.7%
	8-11 days	33	10.8%
	12-14 days	21	6.9%
	15-18 days	33	10.8%
	Longer than 18 days	115	37.6%
	Total	306	100.0%

The vitamin D levels have been found in the patients during the infection were less than 10 ng/ml in around 58.2% of patients. 53.3% of patients used some vitamin supplements but less than 50% used Vitamin D supplements. Further investigation of dose of vitamin D used by the patients were found 1000 IU in around 20% of patients and 50,000 in 13.4% while the other doses of vitamin D being the least. In addition, the patients have good knowledge about the role of vitamin D in improve the function of immune systems (80%) (Table 4).

Table 4. Vitamin D status among patients.

		N	N %	P values
Vitamin D level once infected with Covid 19 (ng/ml)	Not Known	54	17.6%	0.000
	Above 50	42	13.7%	
	31-50	25	8.2%	
	10-30	7	2.3%	
	<10	178	58.2%	
	Total	306	100.0%	
Used any vitamins or supplements	Yes	163	53.3%	
	No	143	46.7%	
	Total	306	100.0%	
Use vitamin D	Yes	147	48%	
	No	159	52.0%	
	Total	306	100.0%	
Doses of vitamin (IU)	1000	61	19.9%	
	2000	14	4.6%	
	5000	18	5.9%	
	25000	5	1.6%	
	50000	41	13.4%	
	200000	5	1.6%	
	300000	3	1.0%	
	None	159	52 %	
	Total	306	100.0%	
Did you know that vitamin D can improve the immune system function	Yes	243	79.4%	0.000
	No	63	20.6%	
	Total	306	100.0%	

Chi-square test has been used and considered significant at $\alpha < 0.05$.

The patients infected with COVID used zinc and vitamin C supplements as, 52% and 71.6% respectively. For the Zinc and vitamin C tablet, the doses used found 15 mg/day) (17.6%) and Vitamin C was 500 mg/day. The knowledge for role of Zinc intake for improving taste was reported in less than 43% of patients and role of vitamin C in supporting immune system found in more than tow third of patients (Table 5).

Table 5. Zinc and vitamin C supplements used by patients.

		N	N %	P values
Use zinc tablet	Yes	159	52.0%	
	No	147	48.0%	
	Total	306	100.0%	
Doses of zinc tablet (mg/day)	Do not know	197	64.4%	
	15	54	17.6%	
	25	33	10.8%	
	50	22	7.2%	
	Total	306	100.0%	
Zinc can improve the immune system	Yes	208	68.0%	
	No	98	32.0%	
	Total	306	100.0%	
zinc can improve the taste	Yes	130	42.6%	
	No	175	57.4%	0.00
	Total	305	100.0%	
Use vitamin C	Yes	219	71.6%	
	No	87	28.4%	
	Total	306	100.0%	
Dose of vitamin C (mg/day)	Do not know	167	54.6%	
	500	94	30.7%	
	1000	45	14.7%	
	Total	306	100.0%	
Vitamin C can improve the immune system	Yes	231	75.5%	0.000
	No	75	24.5%	
	Total	306	100.0%	

Chi-square test has been used and considered significant at $\alpha < 0.05$.

The health status of patients have been improved after used the supplementation of vitamin D, zinc and vitamin D and these improvements were reported in 68.9%, 50.7% and 70.3% respectively (Table 6). In the table 7 , and according to classification of the complications, about 61.8% of patients were have serious complication and 30.4% have mild symptoms (Table 7).

Table 6. Improving health status by supplementation

		N	N %
Once used vitamin D, is there any improvements	Yes	210	68.9%
	No	95	31.1%
	Total	305	100.0%
Once used vitamin C, is there any improvements	Yes	215	70.3%
	No	91	29.7%
	Total	306	100.0%
Once used zinc, is there any improvements	Yes	155	50.7%
	No	151	49.3%
	Total	306	100.0%

Table 7. Classification of the complication.

		N	N %	P values
Disease classification	Mild	93	30.4%	0.000
	Moderate	19	6.2%	
	Severe	5	1.6%	
	Serious	189	61.8%	
	Total	306	100.0%	

Chi-square test has been used and considered significant at $\alpha < 0.05$.

In the table 8, there was relationship and significant differences, low levels of vitamin D and increased the complication of COVID (P=0.003).

Table 8. Classification of complication and levels of vitamin D.

		Classification of complication							
		Mild		Moderate		Severe		Serious	
		N	N %	N	N %	N	N %	N	N %
Vitamin D level during infection	<10	18	19.4%	5	26.3%	2	40.0%	29	15.3%
	20-30	19	20.4%	5	26.3%	1	20.0%	17	9.0%
	31-50	5	5.4%	3	15.8%	1	20.0%	16	8.5%
	Above 50	3	3.2%	0	0.0%	1	20.0%	3	1.6%
	Not know	48	51.6%	6	31.6%	0	0.0%	124	65.6%
	Total	93	100.0%	19	100.0%	5	100.0%	189	100.0%

Chi-square test has been used and considered significant at $\alpha < 0.05$. Chi-square 30.2 df. 12 and P =0.003.

Vitamin D has been used as supplementation for COVID patients as shown in table 9. The two most common doses of vitamin D supplemented in high numbers of serious patients were 1000 IU (35 v 18.5%) and 50,000 IU (23 V 12.2%) respectively.

Table 9. Relation between degree of complication and dose of vitamin D.

		Classification of the complications							
		Mild		Moderate		Severe		Serious	
		N	N %	N	N %	N	N %	N	N %
Dose of vitamin D (IU)	1000	17	18.3%	6	31.6%	3	60.0%	35	18.5%
	2000	7	7.5%	0	0.0%	0	0.0%	7	3.7%
	5000	8	8.6%	2	10.5%	0	0.0%	8	4.2%
	25000	0	0.0%	2	10.5%	0	0.0%	3	1.6%
	50000	14	15.1%	3	15.8%	1	20.0%	23	12.2%
	200000	0	0.0%	2	10.5%	0	0.0%	3	1.6%
	300000	1	1.1%	0	0.0%	0	0.0%	2	1.1%
	None	46	49.5%	4	21.1%	1	20.0%	108	57.1%
	Total	93	100.0%	19	100.0%	5	100.0%	189	100.0%

Chi-square test has been used and considered significant at $\alpha < 0.05$. Chi-square 39.9 df. 21 and $P = 0.008$

4.0. Discussion

However, despite vaccination which has been carried out in many countries utilizing the vaccines approved for emergency use, it is likely that COVID-19 will pose a threat to public health for a considerable period of time. Thus, it is necessary to protect individuals from infection with the virus, which is stated to have become more contagious owing to mutation [21]. It is necessary to decrease the risk of development of severe symptoms leading to increased mortality rate. Apart from vaccination which is a preventive measure against COVID-19 infection, it has been recommended that individuals use supplements, which increase the efficiency of the immune system [22]. In light of the above-stated information, the aim of the present study was to investigate the impact of VDD on the infection and outcomes owing to its antiviral properties and provide additional evidence in literature.

In the studies, the definition of VDD varied depending on the levels of serum 25(OH)D; for example, serum 25(OH)D at the level of 23 ng/mL can be considered VDD in one study and vitamin D insufficiency in the other. Thus, summarizing results of the studies in connection with VDD irrespective of the definition of the condition in terms of the level of serum 25(OH)D can mislead the reader. The importance of making the distinction between the two definitions has been proved by the results of the present study. According to the results of the D-CIMA meta-analysis, the likelihood of infection with COVID-19 is 1.64 times higher in individuals with serum 25(OH)D level lower than 20 ng/mL or 50 nmol/L. Serum 25(OH)D level lower than 20 ng/mL or 50 nmol/L increases the likelihood of severe COVID-19 2.42 times. Nevertheless, according to the DCMMA meta-analysis, low vitamin D levels have no influence on the mortality rate among those who have been infected with COVID-19 [23,24]. There is no significant connection between VDD and severe COVID-19 in the DCMMA study [25].

As a consequence, the current relationship will be overlooked, and the impact of vitamin D in prevention will be disregarded. Hence, the results obtained in the study cannot be considered reliable. According to the meta-analysis of Munshi et al. [6], there were only 6 studies with a relatively small number of samples ($n = 376$). They claimed

that patients with poor prognosis had significantly lower levels of vitamin D serum compared to those with good prognosis with an adjusted standardized mean difference of -0.58 (95% CI, -0.83 to -0.34; $p < 0.001$). Furthermore, the authors provided a subgroup meta-analysis, where they compared the levels of vitamin D according to regions. It was revealed that a subgroup was inappropriate because it was created based on one study. The researchers of Chen et al. [7] performed a meta-analysis study involving with 377,265 samples to explore the connections between VDD and infection, hospitalization, and mortality of COVID19. They found a significant connection for COVID-19 infection (OR, 1.47; 95% CI, 1.09 to 1.97) and hospitalization (OR, 1.83; 95% CI, 1.22 to 2.74), while they did not reveal a significant connection for mortality (OR, 2.73; 95% CI, 0.27 to 27.61) [7].

According to which vitamin D supplementation has a protective effect against acute respiratory infections [26,27]. It was indicated that macrophages and dendritic cells, being antigen-presenting cells, participate in the production of vitamin D active form and macrophages and dendritic cells are affected by vitamin D.

Viral infections increase the need for such vitamins as A, B, C, and D [10]. Despite the lack of preclinical evidence of the effectiveness of this vitamin against coronavirus, ascorbic acid (vitamin C), water-soluble nutrient with antioxidant properties, is commonly used today [28,29]. In humans, preclinical trials show that vitamin C improves immunoregulation and reduces inflammation outcomes by inhibiting the production of proinflammatory cytokines, regulating reactive oxygen species, and protecting host cells [30]. Such effects, combined with low toxicity, encouraged recent researches to include high-dose intravenous vitamin C (HDIVC) into the regular treatment of patients with serious diseases like acute respiratory distress syndrome (ARDS) [31], sepsis, and cardiac surgery (59). Zinc gluconate is widely available OTC supplement, which people use for viral illnesses treatment. Zinc controls immune responses by stimulating the white blood cells and antibodies production. Previous studies confirm the findings of the current study [32-34].

5.0. Conclusion

The vitamin D levels have been found in the patients during the infection were less than 10 ng/ml in more than half of patients. Further investigation of dose of vitamin D used by the patients were found 1000 IU. The patients infected with COVID used zinc and vitamin C supplements. The health status of patients have been improved after used the supplementation of vitamin D, zinc and vitamin D and these improvements and according to classification of the complications, more than half of patients were have severe complication. Low levels of vitamin D and increased the complication of COVID. This study recommended that Vitamin D, C and zinc supplement may boost the immune system and reduced the severity of disease.

5.1. Future perspective

The findings of this study highlight a significant correlation between severe Vitamin D deficiency (<10 ng/ml) and increased COVID-19 complications, alongside the beneficial role of micronutrient supplementation (Vitamin D, Vitamin C, and Zinc) in alleviating symptoms. However, given the cross-sectional nature of this research, future investigations must address several critical dimensions to translate these observational findings into definitive clinical and public health strategies.

Declarations

Source of Funding

This study did not receive any grant from funding agencies in the public or not-for-profit sectors.

Conflict of Interest

The authors declare that they have no conflict of interest.

Consent for Publication

The authors declare that they consented to the publication of this study.

Ethical Approval

The study was approved by the regional ethics committee and conducted according to the guidelines from the Pharmacy committees.

Informed Consent

All participants provided written informed consent before commencement.

Acknowledgement

The authors would like to thank all participants in this study.

References

- [1] Mohammad, S., Mishra, A., & Ashraf, M.Z. (2019). Emerging role of vitamin D and its associated molecules in pathways related to pathogenesis of thrombosis. *Biomolecules*, 9(11): 649. <https://doi.org/10.3390/biom9110649>.
- [2] Weir, E.K., Thenappan, T., Bhargava, M., & Chen, Y. (2020). Does vitamin D deficiency increase the severity of COVID-19? *Clinical Medicine*, 20(4): e107–e108. <https://doi.org/10.7861/clinmed.2020-0301>.
- [3] Zemb, P., Bergman, P., Camargo, C.A., Jr., Cavalier, E., Cormier, C., Courbebaisse, M., et al. (2020). Vitamin D deficiency and the COVID-19 pandemic. *Journal of Global Antimicrobial Resistance*, 22: 133–134. <https://doi.org/10.1016/j.jgar.2020.05.006>.
- [4] Grant, W.B., Lahore, H., McDonnell, S.L., Baggerly, C.A., French, C.B., Aliano, J.L., & Bhattoa, H.P. (2020). Evidence that vitamin D supplementation could reduce risk of influenza and COVID-19 infections and deaths. *Nutrients*, 12(4): 988. <https://doi.org/10.3390/nu12040988>.
- [5] Pereira, M., Damascena, A.D., Azevedo, L.M.G., Oliveira, T.A., & Santana, J.M. (2022). Vitamin D deficiency aggravates COVID-19: Systematic review and meta-analysis. *Critical Reviews in Food Science and Nutrition*, 62(5): 1308–1316. <https://doi.org/10.1080/10408398.2020.1841090>.
- [6] Munshi, R., Hussein, M.H., Toraih, E.A., Elshazli, R.M., Jardak, C., Sultana, N., et al. (2021). Vitamin D insufficiency as a potential culprit in critical COVID-19 patients. *Journal of Medical Virology*, 93(2): 733–740. <https://doi.org/10.1002/jmv.26360>.

- [7] Chen, J., Xie, L., Yuan, P., Ma, J., Yu, P., Zheng, C., et al. (2020). Low serum vitamin D level and COVID-19 infection and outcomes, a multivariate meta-analysis. *MedRxiv [Preprint]*. <https://doi.org/10.1101/2020.10.24.20218974>.
- [8] Holick, M.F., Binkley, N.C., Bischoff-Ferrari, H.A., Gordon, C.M., Hanley, D.A., Heaney, R.P., et al. (2011). Evaluation, treatment, and prevention of vitamin D deficiency: An Endocrine Society clinical practice guideline. *Journal of Clinical Endocrinology & Metabolism*, 96(7): 1911–1930. <https://doi.org/10.1210/jc.2011-0385>.
- [9] Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., & The PRISMA Group (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Medicine*, 6(7): e1000097. <https://doi.org/10.1371/journal.pmed.1000097>.
- [10] D'Avolio, A., Avataneo, V., Manca, A., Cusato, J., De Nicolò, A., Lucchini, R., et al. (2020). 25-Hydroxyvitamin D concentrations are lower in patients with positive PCR for SARS-CoV-2. *Nutrients*, 12(5): 1359. <https://doi.org/10.3390/nu12051359>.
- [11] Darling, A.L., Ahmadi, K.R., Ward, K.A., Harvey, N.C., Alves, A.C., Dunn-Walters, D.K., et al. (2021). Vitamin D concentration, body mass index, ethnicity and SARS-CoV-2/COVID-19: Initial analysis of the first-reported UK Biobank cohort positive cases (n 1474) compared with negative controls (n 4643). *Proceedings of the Nutrition Society*, 80(oc1): e17. <https://doi.org/10.1017/s0029665121000185>.
- [12] Hastie, C.E., Pell, J.P., & Sattar, N. (2021). Vitamin D and COVID-19 infection and mortality in UK Biobank. *European Journal of Nutrition*, 60(1): 545–548. <https://doi.org/10.1007/s00394-020-02372-4>.
- [13] Im, J.H., Je, Y.S., Baek, J., Chung, M.H., Kwon, H.Y., & Lee, J.S. (2020). Nutritional status of patients with COVID-19. *International Journal of Infectious Diseases*, 100: 390–393. <https://doi.org/10.1016/j.ijid.2020.08.018>.
- [14] Katz, J., Yue, S., & Xue, W. (2021). Increased risk for COVID-19 in patients with vitamin D deficiency. *Nutrition*, 84: 111106. <https://doi.org/10.1016/j.nut.2020.111106>.
- [15] Lips, P., Cashman, K.D., Lamberg-Allardt, C., Bischoff-Ferrari, H.A., Obermayer-Pietsch, B., Bianchi, M.L., et al. (2019). Current vitamin D status in European and Middle East countries and strategies to prevent vitamin D deficiency: A position statement of the European Calcified Tissue Society. *European Journal of Endocrinology*, 180(4): 23–54. <https://doi.org/10.1530/eje-18-0736>.
- [16] Abdollahi, A., Sarvestani, H.K., Rafat, Z., Ghaderkhani, S., Mahmoudi-Aliabadi, M., Jafarzadeh, B., et al. (2021). The association between the level of serum 25(OH) vitamin D, obesity, and underlying diseases with the risk of developing COVID-19 infection: A case-control study of hospitalized patients in Tehran, Iran. *Journal of Medical Virology*, 93(4): 2359–2364. <https://doi.org/10.1002/jmv.26726>.
- [17] Baktash, V., Hosack, T., Patel, N., Shah, S., Kandiah, P., Van den Abbeele, K., et al. (2021). Vitamin D status and outcomes for hospitalised older patients with COVID-19. *Postgraduate Medical Journal*, 97(1149): 442–447. <https://doi.org/10.1136/postgradmedj-2020-138712>.
- [18] Campi, I., Gennari, L., Merlotti, D., Mingiano, C., Frosali, A., Giovanelli, L., et al. (2021). Vitamin D and COVID-19 severity and related mortality: A prospective study in Italy. *BMC Infectious Diseases*, 21(1): 566.

<https://doi.org/10.1186/s12879-021-06281-7>.

[19] Cereda, E., Bogliolo, L., Klersy, C., Lobascio, F., Masi, S., Crotti, S., et al. (2021). Vitamin D 25OH deficiency in COVID-19 patients admitted to a tertiary referral hospital. *Clinical Nutrition*, 40(4): 2469–2472. <https://doi.org/10.1016/j.clnu.2020.10.055>.

[20] De Smet, D., De Smet, K., Herroelen, P., Gyspeerd, S., & Martens, G.A. (2020). Vitamin D deficiency as risk factor for severe COVID-19: A convergence of two pandemics. *MedRxiv [Preprint]*. <https://doi.org/10.1101/2020.05.01.20079376>.

[21] Hernández, J.L., Nan, D., Fernandez-Ayala, M., García-Unzueta, M., Hernández-Hernández, M.A., López-Hoyos, M., et al. (2021). Vitamin D status in hospitalized patients with SARS-CoV-2 infection. *Journal of Clinical Endocrinology & Metabolism*, 106(3): e1343–e1353. <https://doi.org/10.1210/clinem/dgaa733>.

[22] Israel, A., Cicurel, A.A., Feldhamer, I., Dror, Y., Giveon, S.M., Gillis, D., et al. (2020). The link between vitamin D deficiency and COVID-19 in a large population. *MedRxiv [Preprint]*. <https://doi.org/10.1101/2020.09.04.20188268>.

[23] Karahan, S., & Katkat, F. (2021). Impact of serum 25(OH) vitamin D level on mortality in patients with COVID-19 in Turkey. *Journal of Nutrition, Health & Aging*, 25: 189–196.

[24] Li, S., Cao, Z., Yang, H., Zhang, Y., Xu, F., & Wang, Y. (2021). Metabolic healthy obesity, vitamin D status, and risk of COVID-19. *Aging and Disease*, 12(1): 61–71. <https://doi.org/10.14336/ad.2020.1108>.

[25] Livingston, M., Plant, A., Dunmore, S., Hartland, A., Jones, S., Laing, I., et al. (2021). Detectable respiratory SARS-CoV-2 RNA is associated with low vitamin D levels and high social deprivation. *International Journal of Clinical Practice*, 75(7): e14166. <https://doi.org/10.1111/ijcp.14166>.

[26] Luo, X., Liao, Q., Shen, Y., Li, H., & Cheng, L. (2021). Vitamin D deficiency is associated with COVID-19 incidence and disease severity in Chinese people. *Journal of Nutrition*, 151(1): 98–103. <https://doi.org/10.1093/jn/nxaa332>.

[27] Macaya, F., Espejo Paeres, C., Valls, A., Fernández-Ortiz, A., González Del Castillo, J., Martín-Sánchez, F.J., et al. (2020). Interaction between age and vitamin D deficiency in severe COVID-19 infection. *Nutrición Hospitalaria*, 37(5): 1039–1042. <https://doi.org/10.20960/nh.03193>.

[28] Maghbooli, Z., Ebrahimi, M., Shirvani, A., Nasiri, M., Pazoki, M., Kafan, S., et al. (2020). Vitamin D sufficiency reduced risk for morbidity and mortality in COVID-19 patients. *SSRN [Preprint]*. <https://doi.org/10.2139/ssrn.3616008>.

[29] Mardani, R., Alamdary, A., Mousavi Nasab, S.D., Gholami, R., Ahmadi, N., & Gholami, A. (2020). Association of vitamin D with the modulation of the disease severity in COVID-19. *Virus Research*, 289: 198148. <https://doi.org/10.1016/j.virusres.2020.198148>.

[30] Meltzer, D.O., Best, T.J., Zhang, H., Vokes, T., Arora, V., & Solway, J. (2020). Association of vitamin D status and other clinical characteristics with COVID-19 test results. *JAMA Network Open*, 3(9): e2019722. <https://doi.org/10.1001/jamanetworkopen.2020.19722>.

- [31] Mendy, A., Apewokin, S., Wells, A.A., & Morrow, A.L. (2020). Factors associated with hospitalization and disease severity in a racially and ethnically diverse population of COVID-19 patients. *MedRxiv [Preprint]*. <https://doi.org/10.1101/2020.06.25.20137323>.
- [32] Merzon, E., Tworowski, D., Gorohovski, A., Vinker, S., Golan Cohen, A., Green, I., et al. (2020). Low plasma 25(OH) vitamin D level is associated with increased risk of COVID-19 infection: An Israeli population-based study. *FEBS Journal*, 287(17): 3693–3702. <https://doi.org/10.1111/febs.15495>.
- [33] Panagiotou, G., Tee, S.A., Ihsan, Y., Athar, W., Marchitelli, G., Kelly, D., et al. (2020). Low serum 25-hydroxyvitamin D (25[OH]D) levels in patients hospitalized with COVID-19 are associated with greater disease severity. *Clinical Endocrinology*, 93(4): 508–511. <https://doi.org/10.1111/cen.14276>.
- [34] Radujkovic, A., Hippchen, T., Tiwari-Heckler, S., Dreher, S., Boxberger, M., & Merle, U. (2020). Vitamin D deficiency and outcome of COVID-19 patients. *Nutrients*, 12(9): 2757. <https://doi.org/10.3390/nu12092757>.