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Letter to the editor: Covid-19 And Vit-D: Disease Mortality Negatively Correlates With Sunlight Exposure

Florian Naudet¹, Clara Locher¹, Alain Braillon², André Gillibert³

1. Univ Rennes, CHU Rennes, Inserm, CIC 1414 [(Centre d'Investigation Clinique de Rennes)], F- 35000 Rennes, France
2. Previously senior consultant. Alcohol Treatment Unit, University Hospital, Amiens, France.
3. Department of Biostatistics, CHU Rouen, Rouen, Normandie, France.

Correspondence to:

Florian Naudet

University of Rennes 1, Rennes, France

Clinical Investigation Center (INSERM 1414) and Adult Psychiatry
Department, Rennes University Hospital, Rennes, France

Florian.NAUDET@chu-rennes.fr

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We declare no competing interests.

The manuscript “**Covid-19 And Vit-D: Disease Mortality Negatively Correlates with Sunlight Exposure**” [1] held our attention as we found fatal shortcomings that invalidates the analyses and conclusions.

General considerations

First, the title itself is misleading as the manuscript does not report any information on Vitamin D since it was not measured in the context of this study.

Second it relies on unfounded hypotheses as the authors refer to a website [2] without any scientific validity rather than to peer-reviewed articles.

Third, the reporting is poor. The manuscript does not conform to any reporting guidelines such as STROBE [3]. The public data sources citations (references 13 to 15) are hyperlinks to main pages of websites, insufficient to find the actual data, hampering any reproducibility effort. From authors’ words, it is not clear whether “mortality rate” refer to the number of confirmed COVID-19 deaths divided by the number of inhabitants of each region (i.e. incidence of lethal COVID-19) or to the number of confirmed COVID-19 deaths divided by the number of COVID-19 confirmed cases (i.e. lethality of confirmed COVID-19). The former would be related to the incidence of COVID-19 while the latter is related to the prognosis of COVID-19. Trying to reproduce the results from Table 1, we eventually found that the “mortality rate” refer to the latter and so, is related to the prognosis of COVID-19.

Major statistical flaws

The authors claimed that they have analyzed data of 64,553,275 French citizens to explore the correlation between Sunlight exposure and Mortality. The main finding is a correlation between mortality rate and Sunlight exposure (that is considered as a surrogate marker of Vit-D) with an impressive “p-value of 1.532×10^{-32} ” correlated to the COVID-19 mortality rate, with a Pearson coefficient of -0.636”.

To explore this correlation, authors used a “Pearson correlation” (that explores association between two quantitative variables), and refer to aggregate data reported by various health agencies and institutions, *i.e.* Santé Publique France, INSEE, Meteo France). Upon request, the primary author shared on social media [4] the scatterplot (not published in the manuscript) displaying the correlation they studied, suggesting an ecological analysis on data aggregated at regional level, confirmed by our further analysis (see below). Indeed, there are only 12 points in the figure, corresponding to the 12 regional areas reported in Table 1. Exploring such a correlation leads to weak evidence as it is prone to ecological fallacy, a bias that refers to inappropriate conclusions at an individual scale based on the analysis of aggregate data.

Moreover, a careful look at the manuscript, shows that the analysis done by the authors is totally flawed. From aggregate regional data provided in Table 1, we found that all correlation coefficients have been computed with 12 data points – one for each region – but that the statistical test has been performed as if there were as many data points as individuals ($n=64,553,275$). Indeed, the usual Student’s t statistic associated to a Pearson’s correlation coefficient is $t=r \times \sqrt{(n-2)/(1-r^2)}$. For $n=64,553,275$ and $r=0.663$, one can easily

compute that $t=7115.601$ as is displayed on the first line of table 3 for correlation between male sex and COVID-19 mortality rate.

Performing such an analysis violates the logic of Pearson's correlation. Indeed, Pearson's correlation is based on the empirical variance observed between the twelve data points that were given. The reduction of variance due to large regional sample sizes is already taken in account in this empirical variance and the Student's t statistic must be based on the sample size that has been used for the empirical variance calculation (i.e. $n=12$). This first error makes the estimation of statistical error highly biased. The actual error is at least $\sqrt{((64553275-2)/(12-2))}$ higher, i.e. 2540.7 times higher. After correction of this error, from Table 1 data, the significance level is $P=0.03$. Moreover, this statistic is based on two other dubious or erroneous assumptions. The first error is assumption of binormal distribution; to avoid this assumption, Spearman's correlation would be better than Pearson's correlation ($P=0.04$). The second assumption is that the 12 data points are independent. This second assumption is erroneous at least for sunlight exposure, since two neighboring regions have more similar climates than two distant regions. Consequently, even the P -value of Spearman's correlation is erroneous and the actual unbiased P -value would be higher if spatial correlation is taken in account!

Furthermore, we are surprised that all regions of metropolitan France were included but Corsica (Corse in French). Authors state that they excluded Corsica "because of poorer access there than on the continent", a statement made without any reference. In contrast, the Insee statistics indicate that the density of healthcare providers per inhabitants is in the same range as on the continent [5]. As the authors point in the manuscript, they worked from a protocol. A time stamped protocol (e.g. registered on the Open Science Framework before any data extraction and analysis) is warranted to demonstrate that exclusion of Corsica was an *a priori* choice.

Indeed, an analysis based on Spearman correlation updated with data from Santé Publique France (Data from April 25th, 2020, extracted on July 24th, 2020 [6]) and Météo France extracted on July the 24th 2020 [7], show that the correlation observed between intra-hospital mortality (cumulative hospital deaths divided by cumulative hospital deaths plus cumulative discharged patients plus number of currently hospitalized patients) and Sunlight without Corsica is not significant anymore when Corsica is added. With our new data extraction, Spearman's $R=-0.47$ ($p=0.11$) with Corsica versus $R=-0.71$ ($p=0.01$) without Corsica (**Figure 1** and **Table 1** that includes data gathered from [6-8]). Note that our data extraction provided slightly different figures than author's ones, as we could not find the exact same data sources. Therefore, exclusion of Corsica may influence the results. If author cannot prove that this choice was made *a priori*, this is suspect of p-Hacking.

Authors' specify that they had assessed confounding factors. Indeed, with their erroneous analyses, they found that many potential confounding factors have significant effects (see Table 3) on the mortality rate, but no statistical adjustment is performed to cancel the effects of these factors. Moreover, climate confounding, such as temperature have not even been analyzed.

Let's now apply *reductio ad absurdum*. Applying the same methods as authors of this article, we can calculate the association between sunlight exposure and number of senior assisted living beds for 100 000 inhabitants of more than 75 years. With authors' raw data (table 1 of their article) we find a Pearson's $R=-0.693$ a Student's t statistic equal to -7720.827 and a P -value inferior to 10^{-30} . After fixing the Student's t calculation, we find a P -value equal to -3.039 and a P -value equal to 0.01. Using updated data, including Corsica, and Spearman's

correlation gives a $R=-0.69$ and a P-value equal to 0.009. Therefore, this method provides better evidence for the fact that sunlight exposure makes people build nursing homes (maybe via increased serological vitamin D in stakeholders building nursing homes, influencing their minds) than for the fact that vitamin D improves the prognosis of COVID-19; indeed, it is robust to the inclusion of Corsica. Another explanation would be the fact that the climate is influenced by nursing homes.

Conclusion

For all these reasons the manuscript has no informative value at all concerning any association between “Covid-19 And Vit-D”. Therefore, we think that the article methods and conclusions are too flawed to have any value.

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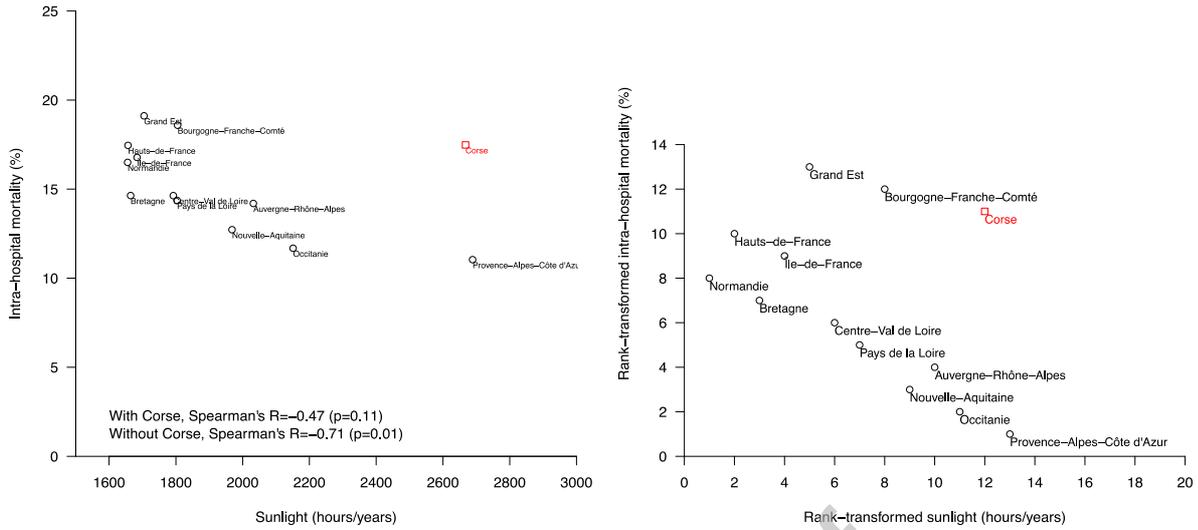


Figure 1: Scatterplot and Spearman's correlations of intra-hospital mortality (number of COVID-19 deaths in hospital divided by number of COVID-19 hospitalizations) and Sunlight exposure (with and without Corsica)

Region	Name	Sunlight (h/year) by station	Average sunlight (h/year)	Cumulative discharge on 04/25/2020	Cumulative in-hospital deaths on 04/25/2020	Hospitalized on 04/25/2020	In-hospital mortality rate	Physician density (/100 000)	N male inhabitants	M female inhabitants	Sex ratio M/F
11	Île-de-France	1637,3; 1661,6; 1752,5	1683,8	15754	5516	11609	0,168	396	5902798	6342009	0,931
24	Centre-Val de Loire	1758; 1767,3; 1833,3; 1743,6; 1811,4; 1840,6	1792,4	1056	348	974	0,146	265	1242428	1322830	0,939
27	Bourgogne-Franche-Comté	1774; 1767,7; 1848,8; 1836,4; 1799,3	1805,2	2227	786	1216	0,186	297	1358835	1434498	0,947
28	Normandie	1691,2; 1689,5; 1684,4; 1557,5	1655,7	974	314	615	0,165	288	1600250	1713090	0,934
32	Hauts-de-France	1617,5; 1679,7; 1659,9; 1669,4 1515,9; 1640,4; 1726,9; 1664,9; 1816,4; 1702,8; 1692,7; 1799; 1783	1656,6	3672	1281	2385	0,175	302	2897369	3080068	0,941
44	Grand Est	1771,8; 1798,5; 1791,3; 1852	1704,7	7232	2714	4253	0,191	321	2692457	2832834	0,950
52	Pays de la Loire	1771,8; 1798,5; 1791,3; 1852	1803,4	1113	307	717	0,144	289	1843001	1944399	0,948
53	Bretagne	1529,8; 1564,6; 1717,1; 1827,2; 1683,8	1664,5	766	202	412	0,146	321	1618845	1714875	0,944
75	Nouvelle-Aquitaine	1888,8; 1995,9; 1899,8; 2007,6; 2035,4; 1982,4 2078,9; 2066,1; 2662,9; 1928,6; 1951,2; 1936,3; 2119,3; 2464,9	1968,3	1276	289	707	0,127	337	2880996	3105322	0,928
76	Occitanie	1888,8; 1995,9; 1899,8; 2007,6; 2035,4; 1982,4 2078,9; 2066,1; 2662,9; 1928,6; 1951,2; 1936,3; 2119,3; 2464,9	2151,0	2006	361	724	0,117	356	2847749	3051460	0,933
84	Auvergne-Rhône-Alpes	1861,7+1913+1985,1+1909,6+2404,8+2117,5	2032,0	4643	1212	2682	0,142	340	3890241	4115641	0,945
93	Provence-Alpes-Côte d'Azur	2510,9; 2775,4; 2724,2; 2744,2	2688,7	3366	625	1671	0,110	408	2413218	2635187	0,916
94	Corse	2579,3; 2755,8	2667,6	172	50	64	0,175	306	165666	175888	0,942

Table1: Updated data gathered [6] for COVID-19 data, [7] (Yearly regional climate → Reporting of each station in each region), and [8] for number of male and female inhabitants in 2019.