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The relationship between vaccine acceptance and COVID-19 mortality in Europe: A Cross-Country analysis of public opinion and Epidemiological data

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ABSTRACT

Introduction: More than two years after SARS-CoV-2 emerged in Wuhan, China, COVID-19 has become one of the most severe pandemics in modern human history. Prior to the widespread availability of specific vaccines in 2021, public opinion surveys indicated significant vaccine hesitancy in 26 European countries.
Materials and methods: Epidemiological data on COVID-19 morbidity and mortality for 26 European countries were collected in November 2021 and compared with the proportions of people willing to receive the SARS-CoV-2 vaccine according to public opinion surveys analysed in 2020. Correlations between various variables were calculated using the Pearson correlation test and visualized with the R programming language.
Results: Paired Student's *t*-test revealed no significant differences between survey results and actual vaccination rates ($p = 0.9546$), suggesting that the polls were good predictors. The percentage of people willing to receive the SARS-CoV-2 vaccine was significantly positively correlated with actual vaccination rates ($R = 0.72$, $p = 0.00003$) and significantly negatively correlated with the number of cumulative deaths per million people ($R = -0.78$, $p = 0.0000024$). However, there was no significant correlation with the number of cumulative cases per million people ($R = -0.27$, $p = 0.18$). These findings indicate that vaccines used in Europe were particularly effective at preventing severe COVID-19 and disease-related deaths, but did not necessarily provide strong protection against SARS-CoV-2 infection itself.
Conclusion: Encouraging widespread immunization through vaccination was crucial for rapidly improving the epidemiological situation in Europe.

Introduction

More than two years after SARS-CoV-2 emerged in Wuhan, China, COVID-19 has become a global catastrophe, causing over 262 million confirmed cases and 5.2 million deaths worldwide by December 1st, 2021 [1]. This pandemic, one of the most severe in human history, has not only led to a global health crisis but also created significant negative psychological effects on individuals. The fear of contracting the disease, coupled with misinformation and major disruptions in social life, has added to the complexity of managing the pandemic [2].

The development and distribution of highly effective vaccines in early 2021 marked a turning point in the fight against COVID-19. However, this achievement was overshadowed by a growing concern about vaccine hesitancy, particularly in Europe. A decline in public trust in immunization and increasing rates of vaccine hesitancy have been observed over the past decades, posing a significant challenge to global vaccination efforts [3].

To understand the extent of vaccine hesitancy, Marcec et al. conducted a comprehensive study, collecting public opinion survey results on attitudes towards SARS-CoV-2 vaccination in 26 European countries in 2020 [4]. The findings raised critical questions about the relationship between public opinion and actual vaccination rates.

About a year later, after the first person in the world received a COVID-19 vaccine in the United Kingdom [5], the accuracy of these

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polls and their implications for the pandemic's dynamics in Europe remain subjects of interest and investigation. This study aimed to delve deeper into these questions, analyzing the correlation between vaccine hesitancy and actual vaccination rates, and assessing the impact on COVID-19 morbidity and mortality across Europe.

The main objectives of this study were to: 1. Analyze the correlation between public opinion on SARS-CoV-2 vaccination and actual vaccination rates in 26 European countries, 2. Assess the impact of vaccination hesitancy on COVID-19 morbidity and mortality and 3. Provide insights into the effectiveness of vaccines in preventing severe COVID-19 cases and related deaths.

By exploring these aspects, this research contributes to the broader understanding of vaccine acceptance and its role in shaping the course of the pandemic. The insights gained will be valuable for policymakers, healthcare professionals, and the general public, guiding efforts to enhance vaccine acceptance and ultimately control the spread of COVID-19.

Materials and methods

Epidemiological data on COVID-19 for 26 European countries were extracted in November 2021, covering the period from January 1st to November 1st, 2021, from the Our World in Data website [6]. The data were compared with the proportions of people willing to receive the SARS-CoV-2 vaccine according to public opinion surveys analyzed in 2020 [4]. A paired Student's *t*-test was used to evaluate the significance of the difference between survey results and actual vaccination rates. Correlations between different variables were determined using the Pearson correlation test and visualized with R programming language v.4.1.1. The correlation analysis, was conducted using the Pearson correlation test to determine the relationship between different variables, such as willingness to vaccinate and cumulative deaths per million. The expressed 'R' value represents the Pearson correlation coefficient, indicating the strength and direction of the linear relationship between the variables.

The scatterplot graphs were produced using the ggplot2 package in R, visualizing the relationship between variables such as vaccine acceptance and mortality rates. A linear regression model was fitted to the data, and the value for 'R' represents the correlation coefficient. The maps were created using the ggmap package in R, displaying the geographical distribution of the analyzed countries. Generalized regression and transformations were not applied in this study.

The study design was a cross-sectional analysis, focusing on the correlation between public opinion on vaccination and actual vaccination rates, as well as the impact on COVID-19 morbidity and mortality.

Supplementary files (Appendix A) contain the R commands and packages used to produce the scatterplot graphs and maps as well as the data used for the analysis. The code includes detailed comments explaining each step of the process.

Results

The summary of information obtained from the Our World in Data website is provided in Table 1. The European countries with the highest proportions of fully vaccinated people were Portugal (87.39%), Denmark (75.92%), Ireland (75.30%), and Italy (71.50%). In contrast, countries with the lowest proportions of fully vaccinated people included Ukraine (17.34%), Bosnia and Herzegovina (20.99%), Russia (32.68%), and Romania (33.12%).

Cumulative deaths per million by country are visually represented in Fig. 1. Countries with the highest number of cumulative deaths per million people in 2021 were Bosnia and Herzegovina (n = 2305), Montenegro (n = 2266), Hungary (n = 2202), and Slovakia (n = 1977), while the countries with the lowest number of cumulative deaths per million people in 2021 were Norway (n = 85), Finland (n = 110), Denmark (n = 240), and the Netherlands (n = 421).

As shown in Fig. 2, there was a significant negative correlation between the proportion of fully vaccinated population members and the number of cumulative deaths per million people. In contrast, no significant correlation was found between the percentage of fully vaccinated individuals and the number of cumulative cases [7] per million people, as depicted in Fig. 3.

Fig. 4 illustrates a significant positive correlation between the percentage of people willing to receive the SARS-CoV-2 vaccine and the

Table 1
Epidemiological data regarding COVID-19 for 26 European countries combined with results of public opinion surveys on vaccination from 2020.

Country	Population at least partially vaccinated,in %	Population fully vaccinated,in %	Willingness to vaccinate from 2020 polls,in %	Case fatality rate	Cumulative cases per million	Cumulative deaths per million
Austria	65.33	62.22	47.5	1.36	52,260	565
Bosnia and Herzegovina	24.44	20.99	32	4.56	43,575	2305
Croatia	46.83	44.05	47.3	1.96	63,569	1296
Czech Republic	58.23	56.87	49	1.74	96,380	1778
Denmark	77.10	75.92	80	0.69	38,824	240
Finland	76.29	70.02	69	0.74	22,094	110
France	75.85	68.01	62	1.63	67,690	795
Germany	68.84	66.17	70	2.08	34,050	735
Greece	64.09	61.52	52.1	2.14	58,641	1071
Hungary	61.81	59.54	30	3.53	57,021	2202
Ireland	76.59	75.30	73	1.21	71,227	640
Italy	77.27	71.50	74	2.77	43,822	952
Latvia	62.58	54.72	46	1.49	95,502	1406
Lithuania	67.36	64.11	47	1.44	98,574	1515
Montenegro	41.00	38.76	34	1.46	153,018	2266
Netherlands	75.89	68.94	73	0.86	79,374	421
Norway	76,94	68.48	72	0.43	29,056	85
Poland	53.57	52.83	69	2.54	45,622	1271
Portugal	88.78	87.39	75	1.66	65,944	1101
Romania	36.85	33.12	44	2.90	53,264	1685
Russia	38.17	32.68	63	2.80	36,072	1223
Slovakia	45.97	42.25	40.9	2.69	55,143	1977
Sweden	71.35	67.85	67	1.28	72,256	620
Turkey	65.19	57.33	55.8	0.88	68,681	585
United Kingdom	73.34	67.05	79	1.54	96,628	980
Ukraine	24	17.34	37	2.36	45,466	1219

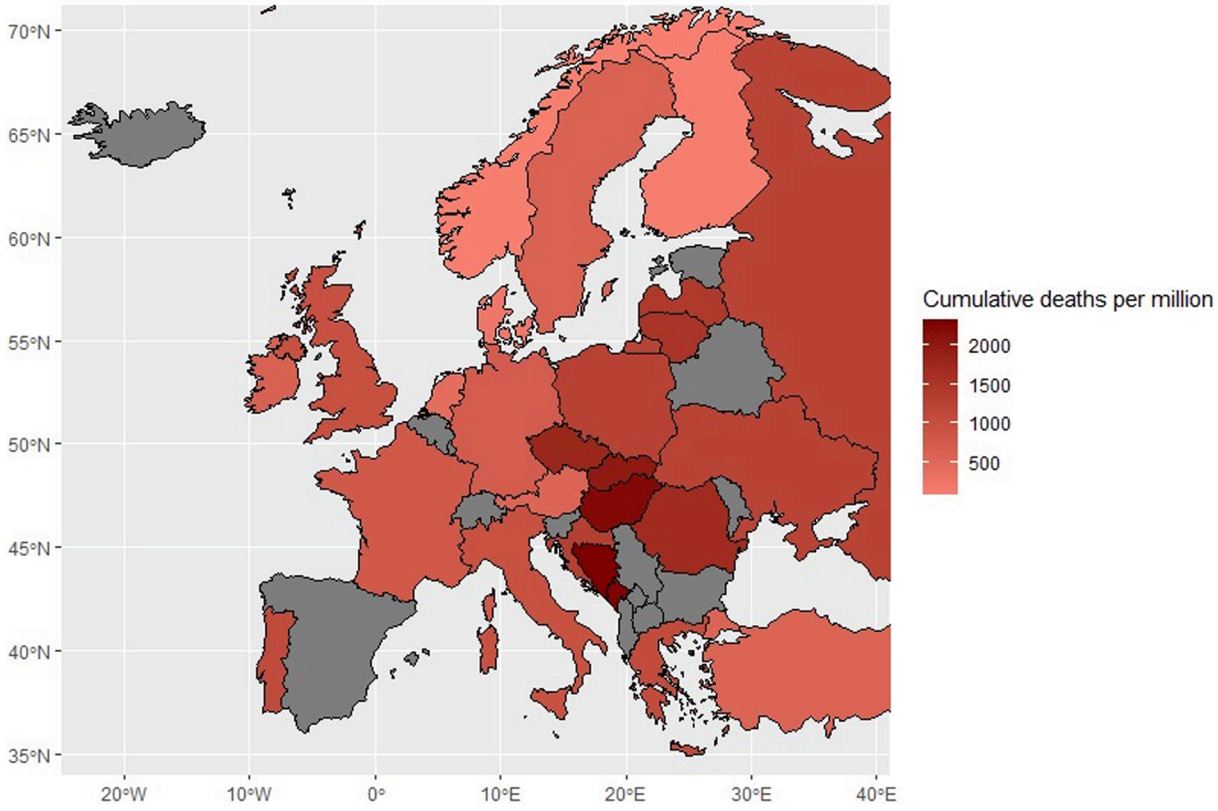

Fig. 1. Map of Europe showing cumulative deaths per million from COVID-19.

actual vaccination rate. Furthermore, the paired Student's *t*-test revealed no significant differences between these two variables ($p = 0.9546$). Additionally, a significant negative correlation was observed between the percentage of those willing to get vaccinated and the number of cumulative deaths per million people, as shown in Fig. 5. However, no significant correlation was found between the percentage of vaccinated individuals and the number of cumulative cases per million, as displayed in Fig. 6. These results suggest that the vaccines currently in use in Europe are particularly effective at preventing severe forms of COVID-19 and disease-related deaths, while they do not necessarily provide strong protection against SARS-CoV-2 infection itself.

Discussion

Countries with a higher proportion of fully vaccinated people registered significantly lower mortality rates, as seen in Fig. 2. This observation is in accord with CDC reports on the real-time impact of COVID-19 vaccines, suggesting that those who are not fully vaccinated have a > 10 times higher COVID-19 mortality risk [8]. Vaccines used in Europe were also effective against hospitalization/severe disease caused by the rapidly spreading Delta variant of the SARS-CoV-2 virus in 2021 [9], with protection rates varying from 67% to 87%[10], as reported by Nasreen et al.

Nevertheless, a few countries draw attention. The Czech Republic, Hungary, and Austria, three neighboring countries with comparable demographic characteristics and relatively similar proportions of fully vaccinated people (56.87%, 59.54%, and 62.22%, respectively), had large inequalities in terms of mortality. The Czech Republic recorded 3.15 (1778/565) times higher while Hungary had 3.9 (2202/565) times higher cumulative deaths per million people than Austria. One possible cause of such discrepancies could be the differences in the severity of government measures introduced to control the COVID-19 pandemic in these three countries. From January 1st to November 1st, 2021, Austria had considerably stricter anti-epidemic measures than the Czech Republic or Hungary for most of the time [11].

As shown in Fig. 4, there was a significant positive correlation ($R = 0.72$, $p = 0.00003$) between public survey opinion results from 2020 regarding COVID-19 vaccination and the actual data on proportions of those vaccinated in 2021, obtained from the Our World in Data website. The pooled survey results provided for some grim reading, as only 58% (n = 14,365/24,970) of the surveyed Europeans expressed willingness to get a SARS-CoV-2 vaccine once it became available, while 26% (n = 6607/24,970) said that they would refuse to get vaccinated altogether. Such public opinion survey results suggested that reaching herd immunity levels through vaccination against SARS-CoV-2 could be significantly impeded by high vaccination hesitancy rates. Since approximately 16% (n = 3998/24,970) of those surveyed in 2020 remained undecided, an immediate and widespread public campaign aimed at increasing awareness of the importance, safety, and efficacy of vaccines was considered worthwhile [4]. The success of such a public health intervention could be measured by reaching the estimated herd immunity threshold (67% or even 80% of the population vaccinated, considering the high transmissibility of Delta and Omicron SARS-CoV-2 variants).

However, as visible from our analysis, only a few countries actually succeeded in mobilizing the general public to vaccinate and thus approach the vaccination rates required for reaching the herd immunity level. The countries with the highest increases in vaccination percentage compared to the results of the 2020 survey were Hungary, Lithuania, and Austria, with the rise of 29.54%, 17.11%, and 14.72%, respectively. However, as Marcec et al. have already emphasized, the extremely small initial positive response rate in Hungary could have been influenced by the fact that the data for the survey were collected in February 2020, before the appearance of the first Hungarian COVID-19 case, which was confirmed on March 4, 2020. On the other hand, vaccination rates of 30.32% that were achieved in Russia, significantly less than the 63% projected by the 2020 surveys, appear particularly gloomy. According to

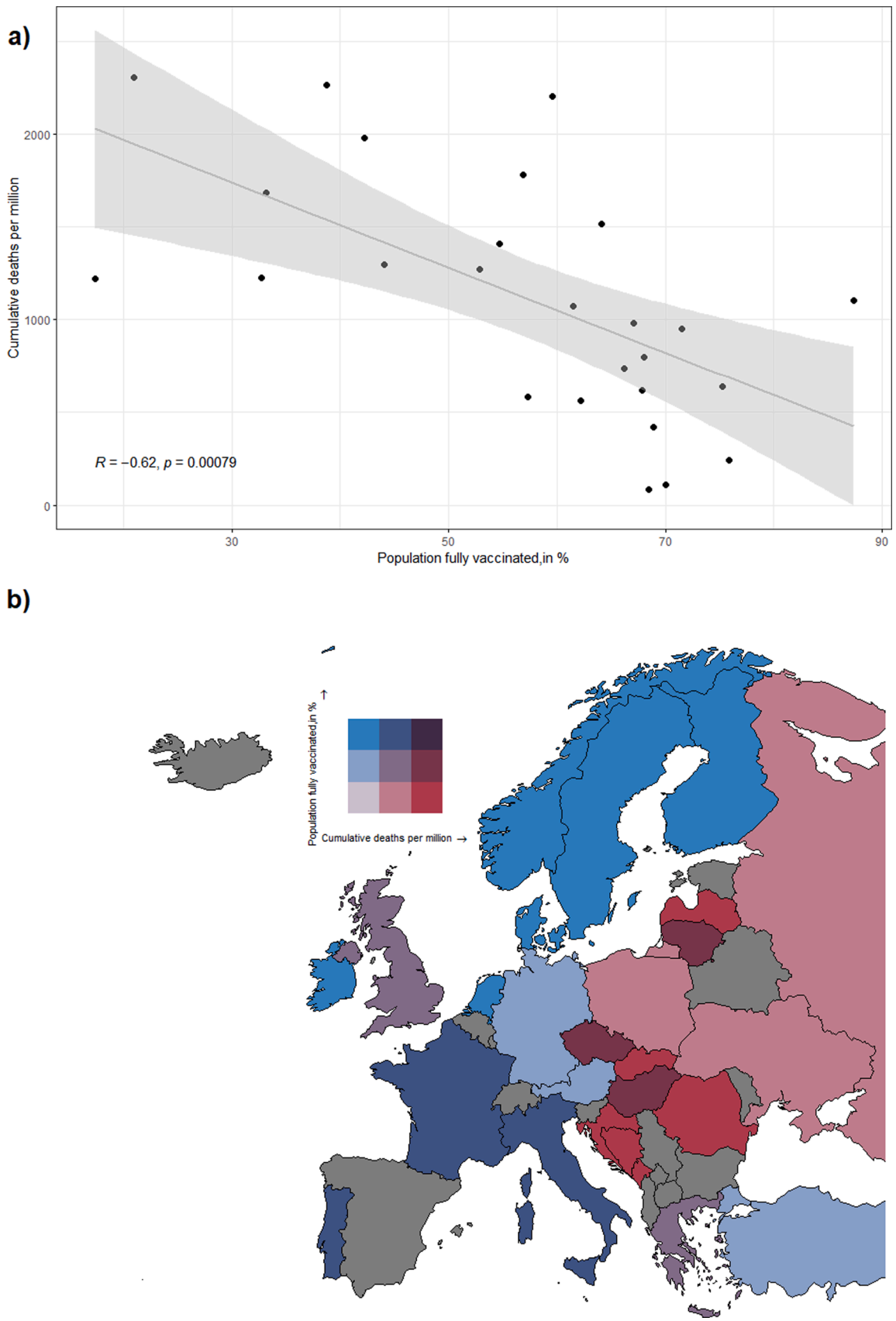

Fig. 2. Scatterplot graph(Fig. 2a) and a bivariant map(Fig. 2b) which show correlation between vaccination rates and cumulative deaths from COVID-19 in European countries.

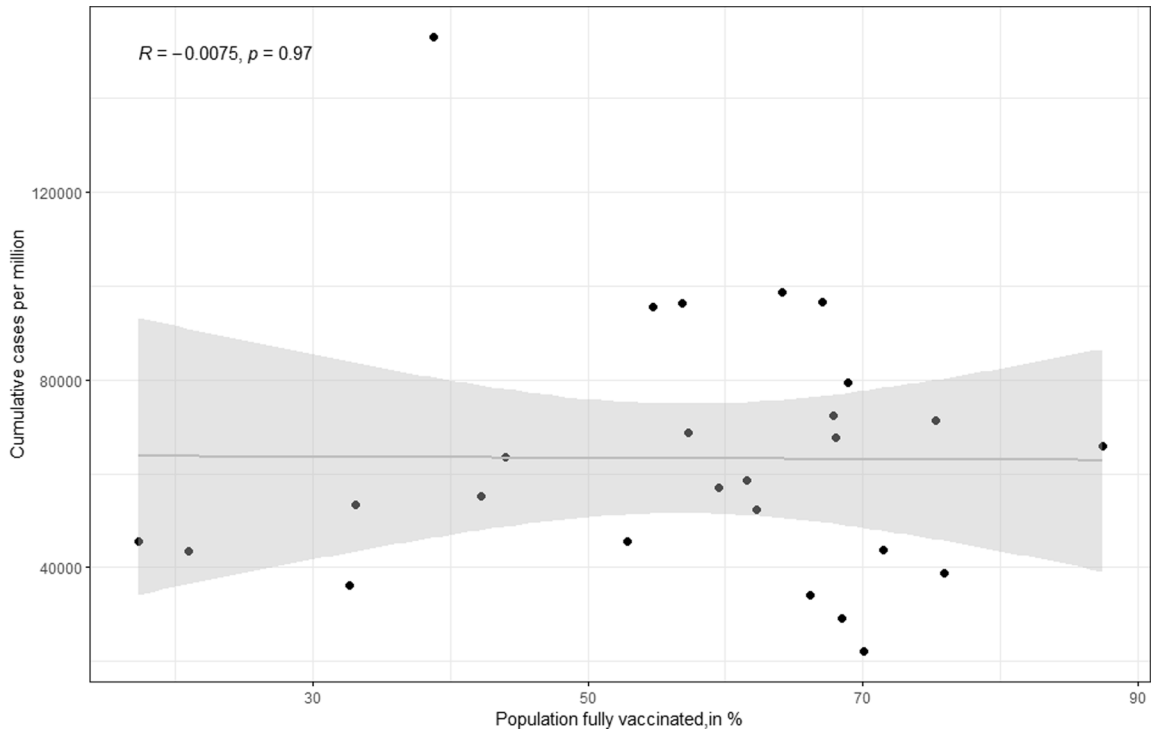

Fig. 3. Scatterplot graph which demonstrates correlation between vaccination rates and cumulative cases of COVID-19.

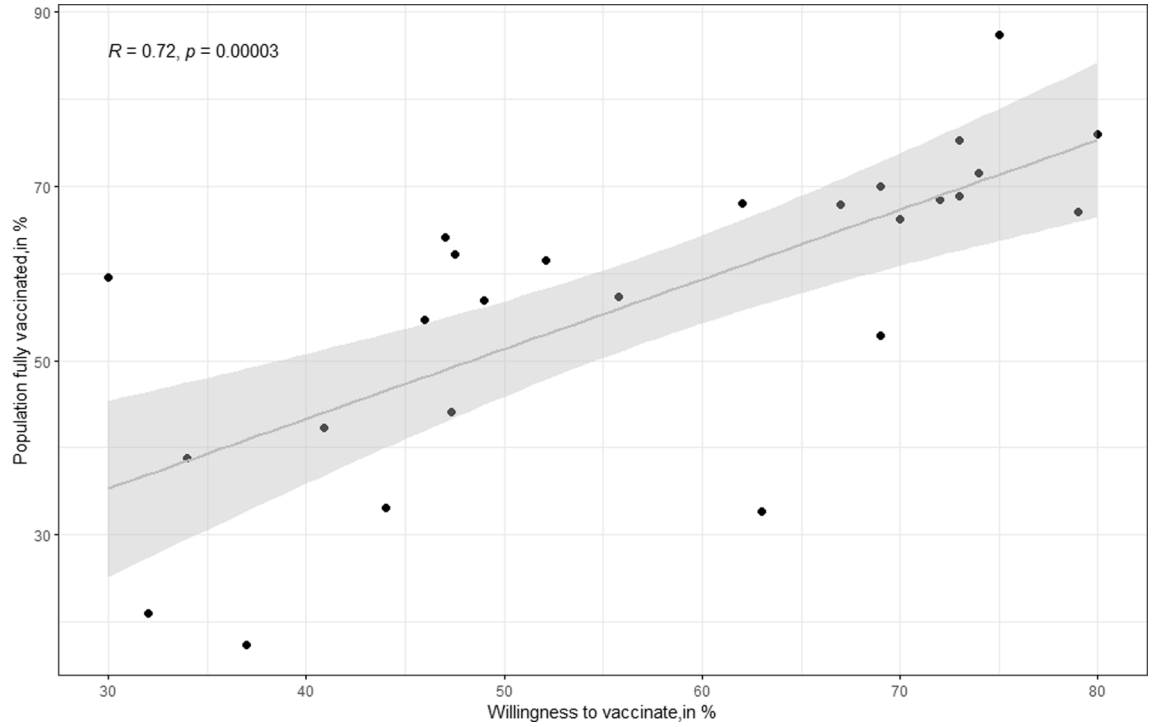

Fig. 4. Correlation between the percentage of people willing to vaccinate in the 2020 polls(4) and the actual vaccination rates obtained in November 1st 2021.

a survey among Russian doctors from the end of March 2021, the main reasons behind the low vaccination rates in the country were general vaccine hesitancy (52%) and distrust towards existing Russian vaccines (46%). Other listed causes were poor regional vaccine availability (38%), unawareness of the vaccination's importance (22%), ignorance of the severity of COVID-19 (19%), poor vaccination organization (16%), while 6% of interviewed doctors blamed other causes, and 1% stated that it was hard to say [12]. With all that in mind, it seems that the controversy around the Sputnik V vaccine [13] approval without a proper phase III trial [14] has eventually caused more harm than good.

Furthermore, it seems that countries with a higher GDP per capita achieved higher COVID-19 vaccination rates. Considering the 26 European countries included in our analysis, those with the highest GDP per capita, such as Ireland ($111,360), Norway ($69,860), and Denmark

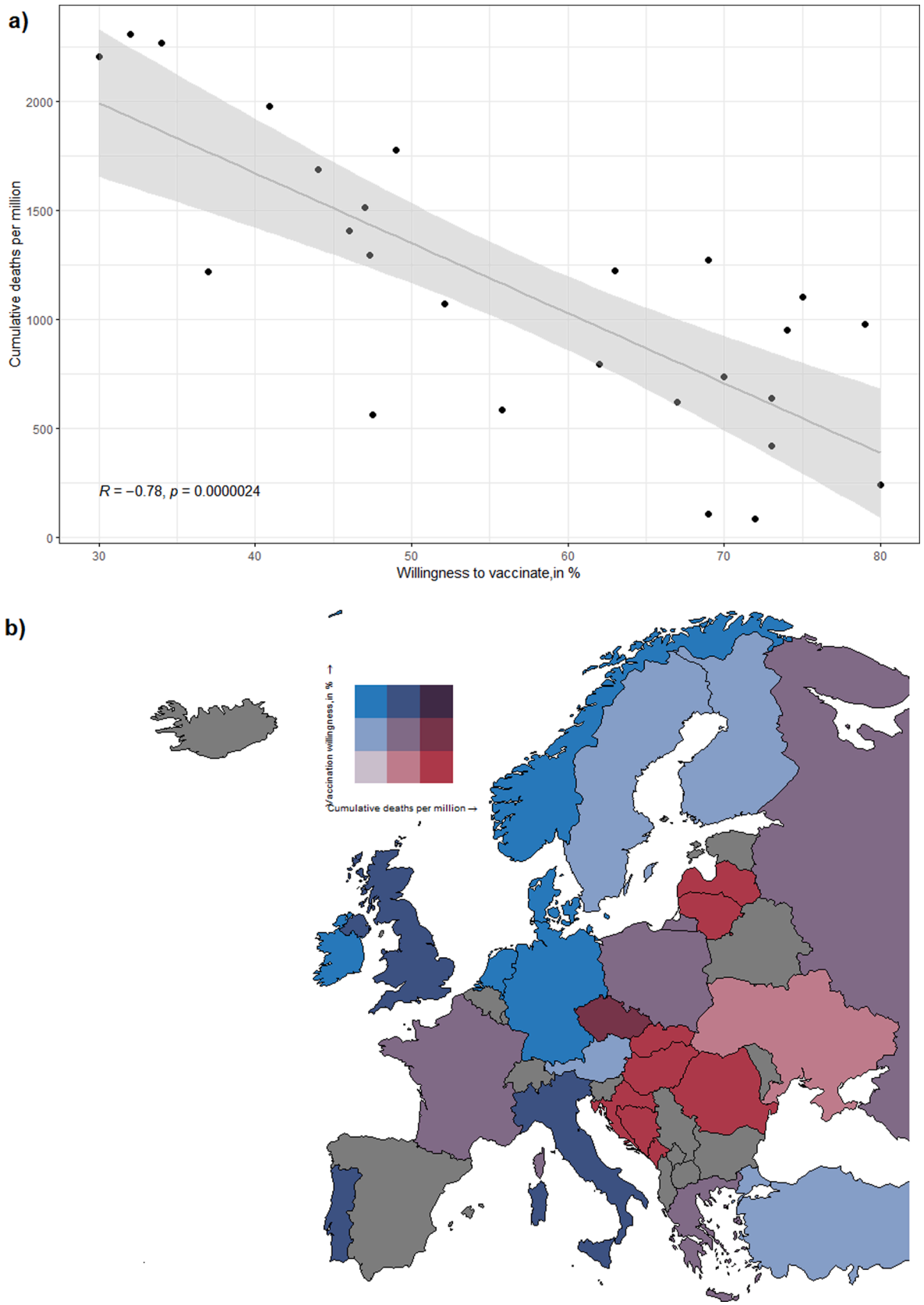

Fig. 5. Scatterplot graph(Fig. 5a) and bivariant map(Fig. 5b) which show correlation between willingness to vaccinate from 2020 polls and cumulative deaths from COVID-19 by November 1st,2021.

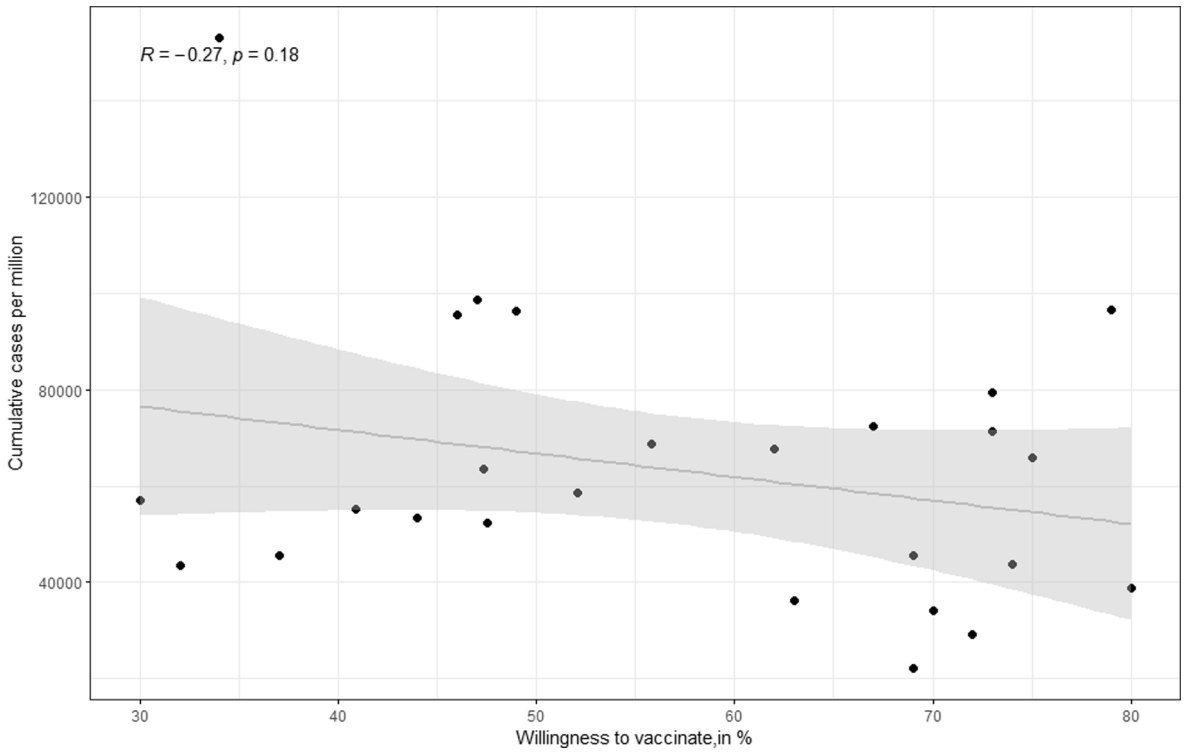

Fig. 6. Scatterplot graph which demonstrates correlation between willingness to vaccinate and cumulative cases of COVID-19.

($63,400)[15], accomplished vaccination rates ranging from 68.48% to 75.92%, thereby placing them in the 2nd, 3rd, and 7th spots on our list, respectively. This is in line with the WHO analysis from 2017 that reported high-income countries had the highest potential of achieving ≥ 90% national vaccination coverage [16]. Such trends could be explained by the fact that populations of higher-income countries received more social support, believed that vaccination is more beneficial for their health and that it can prevent diseases, and they were more likely to seek advice from individuals with vaccination experience, all likely a consequence of the availability of higher quality health systems [17].

One of the main limitations of this study is the fact that there is no accurate data showing vaccine availability throughout the months for each of the analyzed countries. It is possible that certain countries with lower vaccination rates have experienced vaccine supply issues, which consequently led to higher mortality rates regardless of the national vaccination hesitancy prevalence.

Conclusion

In 2019, the World Health Organization named vaccine hesitancy as one of the top 10 threats to global health. As it turns out, this insightful prediction is only exacerbated by fear and confusion in our new COVID-19 dominated world [18]. In spite of some encouraging results regarding drug repurposing and new drugs becoming available for COVID-19 treatment [19], widespread vaccination still remains the primary strategy employed to put an end to the pandemic. By reducing hospitalization rates and intensive care occupancy, healthcare costs would drop significantly, allowing for better resource allocation [20]. Therefore, it is crucial to continue encouraging widespread immunization through vaccination in order to more quickly achieve improvement in the epidemiological situation of this and potential future pandemics across Europe.

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Ethical statement

Not applicable.

CRediT authorship contribution statement

SB and BB took part in conceptualization, data curation and analysis. RM and RL revised the methodology, secured resources, software and provided supervision. All coauthors took part in writing of the original draft and data visualization, while RM and RL reviewed the final version of the manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data are available online and in publications which are cyted in the manuscript.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jvacx.2023.100391.

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